General Thoracic and Cardiovascular Surgery (2019) 67:168–174
https://doi.org/10.1007/s11748-018-0978-y

SPECIAL EDITION

Controversies in Surgery for Thoracic Aorta

Reflection of pioneers: redo thoracoabdominal aortic aneurysm repair controversies in thoracic aortic aneurysm surgery

Joseph S. Coselli[1,2,3]

Received: 14 March 2018 / Accepted: 23 July 2018 / Published online: 1 August 2018

Abstract

Reoperative thoracoabdominal aortic aneurysm repair is frequently necessary and brings with it a unique set of challenges. Typically, most reoperative repairs are necessitated by aortic disease progressing into previously healthy aortic tissue from a replaced section of the aorta (an extension of the previous repair) or, to a lesser degree, because of a late complication of prior distal aortic repair (an open or endovascular repair failure). Characterizing the reason for the reoperation as well as the location of prior repair is the first step towards anticipating major outcomes following such repair. Since the introduction of endovascular repair for aortic aneurysms, indications for open repair have become more specific and limited; many centers have justified using endovascular approaches in patients with prior open aortic repair by deeming these patients "high risk" because of their previous incision. Our analysis found that reoperative repairs were not typically subject to worse early outcomes than patients without prior distal aortic repair, except for the more complicated types of reoperation, which involve infection.

Keywords Thoracoabdominal aortic aneurysm repair · Reoperation · Aortic aneurysm · Descending thoracic aorta · Abdominal aorta · Open surgical repair · Thoracic endovascular aortic repair

Introduction

Reoperative thoracoabdominal aortic aneurysm (TAAA) repair is often necessary and brings with it a unique set of challenges; such repair is performed after a previous distal aortic repair and involves a history of prior open or endovascular repair to correct a defect of the descending thoracic aorta (descending thoracic aneurysm; DTA), TAAA, or abdominal aorta (abdominal aortic aneurysm; AAA). There are two distinct scenarios when the operative field may be reopened: reoperations necessitated by aortic aneurysmal disease progressing into previously healthy aortic tissue and expanding from a previously replaced section of the aorta (an extension of the previous aortic repair), or, to a lesser degree, because of a late complication of prior aortic repair (an open or endovascular repair failure).

Pioneering aortic surgeon E. Stanley Crawford described his emerging experience with reoperative TAAA repair in a 1972 report [1]. Here, three patients with prior replacement of the DTA all went on to develop extensive aneurysms in the remaining distal aorta within 3–10 years after the initial DTA repair. All patients survived reoperation—with the replacement TAAA graft anastomosed to the prior DTA graft—but one patient developed paraparesis, which never resolved. This anecdotal experience kept thoughts of postoperative spinal cord deficit at the forefront of developments, amid speculation that the development of collateral circulation may play a protective role in some. Regarding Crawford's lifetime experience of 1509 TAAA repairs, nearly 25% had a prior distal aortic repair; these patients had similar rates of early death and paraplegia as compared to patients without prior repair [2].

✉ Joseph S. Coselli
jcoselli@bcm.edu

1 Division of Cardiothoracic Surgery, Michael E. DeBakey Department of Surgery, Baylor College of Medicine, One Baylor Plaza, BCM 390, Houston, TX 77030, USA

2 Section of Adult Cardiac Surgery, Department of Cardiovascular Surgery, Texas Heart Institute, Houston, TX, USA

3 CHI St. Luke's Health-Baylor St. Luke's Medical Center, Houston, TX, USA

Because late reoperation of prior aortic repair may occur months to years after the initial operation, it is difficult to assess the incidence of late events that necessitate reoperation. Reports from several experienced aortic institutions suggest that 10–30% of patients now requiring TAAA have had a prior distal open aortic repair [2–5]. In addition, although far less common, there is a growing experience of open TAAA repair after prior distal endovascular aortic repair (EAR) [6–10]. Information on whether reoperative repair yields poorer outcomes, specifically higher incidences of operative death and spinal cord deficit, appears to be contradictory [11, 12]. In light of these contradictory results, determination of whether reoperative repair should be undertaken after prior distal aortic repair is a complicated decision, especially in the most complex reoperative scenarios involving infection or fistula. To elucidate this decision, we have presented our experience [13] along with a review of other centers' reoperative results.

Characteristics of reoperative patients

Because patients require reoperation for different reasons, there are distinctions between patients experiencing progressive distal aortic disease and those with late repair failure. In our own recently published results regarding prior open distal aortic repair [13], patients with progressive aortic disease tended to have higher rates of smoking and were slightly older than non-reoperative patients; those with late repair failure tended to have higher rates of connective tissue disorder and aortic dissection than did non-reoperative patients. Regarding reoperative patients with prior endovascular aortic repair, trends are more difficult to identify because of more varied reasons for reoperation and the relatively small numbers of patients needing further repair. In general, reoperative repairs are heterogeneous, and complicate the evaluation of risk of these patients.

Extension of repair for progressive aortic disease

Conceptually, we have defined this type of repair as an extension of repair necessitated by the progression of disease into aortic segments that are adjacent to and contiguous with the previously repaired segment; in most cases, the previously placed graft was left in place (Fig. 1). Afifi et al. described this group as reoperation within the same operative field because of the formation of an aneurysm in a new aortic segment not previously operated on [14]. Reoperation because of progressive aortic disease necessitating an extension of prior aortic repair is the most common reason for performing reoperative surgery [13–15]. In our experience, the majority of the previous distal open aortic repairs were infrarenal AAA repairs, and most of these were performed outside of our center [13]. Observations from Afifi

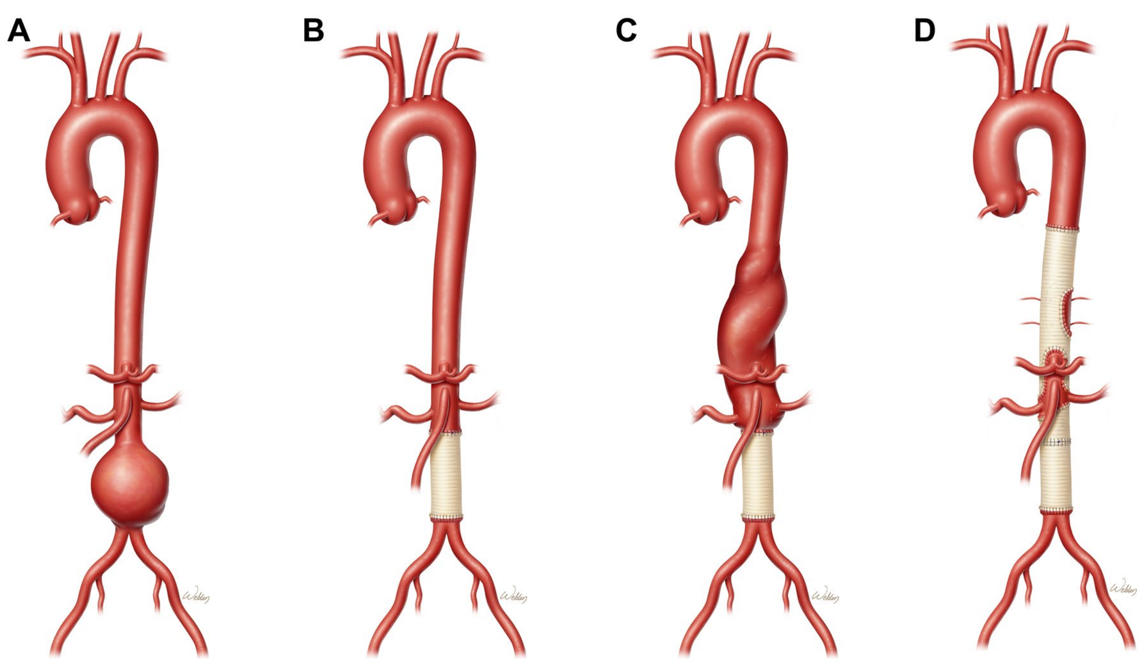

Fig. 1 Illustration depicting the progression of aortic disease. **a** Abdominal aortic aneurysm is shown. **b** Open replacement of the abdominal aorta is shown. **c** Over time, a nearby section of the thoracoabdominal aorta becomes aneurysmal and is adjacent to the previously replaced abdominal aortic graft. **d** Aortic repair is extended by performing an extent III thoracoabdominal aortic aneurysm repair; the two grafts are anastomosed together. Used with permission of Baylor College of Medicine

et al. similarly indicate that the majority of prior repairs are to treat AAA [14].

In our experience, reoperative patients with progressive aortic disease tend to be older than non-reoperative patients. The extension of repair group also had a higher prevalence of coronary artery disease, cerebrovascular disease, and peripheral vascular disease. In addition, this group was more likely to be male, to have an aneurysm without dissection, and to be current or former smokers—these preoperative characteristics and older age may indicate that these patients face a greater atherosclerotic, chronic disease burden than other patients. Consistent with this hypothesis, we found increased rates of visceral or renal endarterectomy in this group of patients [13].

Repair failure: prior open repair

In the case of reoperative repairs undertaken for repair failure, the failure exists in only the region that was first repaired. The repair failure does not extend to any region, where the index graft replacement was not originally present. Within our group, we defined repair failure as a complication of prior open distal aortic repair that necessitated aortic reoperation; largely due to the following causes—pseudoaneurysm, patch aneurysm, and graft infection, rupture, or related fistula. Reoperation because of repair failure is relatively uncommon, in our series, this was nearly 3% of 3379 TAAA repairs [13]. In a series of 1900 DTA or TAAA repairs, repair failures accounted for roughly 15% of repairs performed—visceral patch aneurysm was most common (11%) followed by anastomotic pseudoaneurysm (8%), intercostal patch aneurysm (7%), and infection (5%) [14].

Patients with repair failure patients tend to be younger. This finding seems reflective of higher rates of connective tissue disorders and chronic aortic dissection [13, 15]. There is a sense that long-term postoperative surveillance protocols need better development in these younger patients with aortic dissection. We observed trends in having large aneurysms (> 7.5 mm) at the time of reoperation and also increased rates of rupture. Due to this, it is unsurprising that reoperative repairs for the repair failure group were more likely to be urgent or emergent repairs than non-reoperative repair [13, 14].

Repair failure: prior endovascular repair

Patients with completed endovascular aortic repair face continued challenges, because there is an incomplete understanding of how and why such repair fails. Part of the overall sense of these failures appears related to early off-label use; since then, the use of EAR has been greatly expanded, and the term "off-label" has lost meaning. There are several different types of late complications after EAR—only the most serious of these complications will necessitate open repair. In general, any continued aortic expansion that is resistant to secondary endovascular repair will necessitate open repair, as will endograft infection or related fistula or any rare events such as endograft-related device failure (e.g, fracture). In general, EAR in patients with heritable thoracic aortic disease, such as Marfan syndrome, is not supported by current practice guidelines [16]. Overall, the experience in reoperation because of EAR is relatively small and extremely heterogeneous—it is difficult to identify trends. However, that being said, evidence suggests that EAR for aortic dissection, particularly that for chronic aortic dissection, tends to have a higher rate of failure necessitating further aortic EAR repair as does repair in persons with heritable thoracic aortic disease [7, 17, 18].

Surgical techniques

Operative details for reoperative repairs often follow repair techniques for standard TAAA repairs, although each institution may vary the details of performing the procedure. For reoperative surgeries, our surgical approach broadly follows that of standard thoracoabdominal surgeries, with routine use of moderate systemic heparinization (1.0 mg/kg), mild passive hypothermia (32C–34C), and cold renal perfusion (4C) whenever the renal ostia are sufficiently exposed. For extensive aortic repair (extents I and II), we typically use left heart bypass and selective visceral perfusion. Because there is a sense of heightened risk of postoperative paraplegia in patients undergoing reoperative repair, we tend to use cerebrospinal fluid drainage more frequently than in patients undergoing non-reoperative repair; similarly, while we commonly strive to reattach intercostal and lumber arteries whenever possible, we tend to reattach additional pairs of these arteries in reoperative aortic repair.

Further care is taken regarding adhesions, as lysing adhesions remaining from the previous operations both lengthens and adds complexity to the current procedure. Exposure may be hampered by adhesions—sharp dissection or electrocautery at low-power settings may free adhesions. In addition, for open TAAA reoperative surgery, we attempt an off-set incision through a different intercostal space, which limits bleeding and unintentional injury of nearby structures when adhesions are dissected. During reoperative TAAA repair, we minimize lung retraction during anticoagulation—if separating the lung from the chest wall does result in parenchymal injury, before closing the chest, we apply a sealant to the affected area of the lung. In case of progressive aortic disease with a stable endograft, it is often possible to fully salvage the prior repair and incorporate it into the new suture line using full thickness bites of both the endograft and residual aortic wall. To treat visceral patch aneurysms, we commonly use a branched graft; in addition, in patients with known heritable thoracic aortic disease, we also use a branched graft to minimize residual native aortic tissue as visceral arteries are managed.

Because adhesions involving the spleen are common, we carefully inspect the spleen before closure. If a small capsular tear or other damage to the spleen is found, it may be possible to repair it using cautery and Surgicel; however, if the tear cannot be repaired, a splenectomy is performed. In our experience, where there are very dense adhesions, there is an increased risk to the spleen and removal is not uncommon. Patients undergoing splenectomy typically receive additional vaccination in the early recovery period. Reoperative aortic repair may warrant an aggressive use of blood products to minimize bleeding complications and fresh frozen plasma and platelets are particularly helpful in ameliorating postoperative bleeding.

Techniques for treating infection

When graft or endograft infection is suspected, repair is inherently complicated and greatly so in the presence of fistula—removal of the graft or endograft is commonly necessitated. In 1961, Blaisdell et al. described the first use of an extra-anatomic bypass approach to treat persistent graft infection in a patient who had undergone infrarenal abdominal aortic replacement with a Teflon graft [19]. Following postoperative treatment for low-grade fever, the elderly patient was discharged home; within a month, he returned to the hospital because of sudden pain and a pulsatile mass in his abdomen. Upon exploration, a small portion of proximal anastomosis of the graft was noted to have dehisced due to infection, which was subsequently replaced. Several weeks later, symptoms returned and upon exploration, the entire proximal anastomosis of the graft was dehisced due to gross infection. The graft was removed and the residual aortic stumps were oversewn. A bypass graft was anastomosed end-to-side at the midlevel of the descending thoracic aorta and routed well away from the infected field to the femoral arteries. Although the patient survived for several weeks, ultimately, he died of infection—however, the bypass graft was noted to remain patent and free of infection. For the next few decades, extra-anatomic bypass approaches were the preferred technique in cases of extensive or highly virulent graft infection. In 1987, Walker, Cooley, and others in Houston [20] described a series of 23 patients with prior abdominal aortic replacement grafts that became infected and with the development of fistula; remarkably, many of these patients survived after in-situ graft replacement.

Although surgery related to infection was uncommon in our experience, reoperative surgery due to the indication of infection requires the use of additional techniques. These may include replacing the entire graft, extensive debridement, using pedicled omentum or a muscle flap to cover the replacement graft [20–22], delivering antibiotics via irrigation catheters, or using a synthetic graft soaked in antibiotics (i.e., prepared tableside by soaking a polyester graft in rifampin) [23]. Although extra-anatomic bypass was the gold-standard approach in decades past, it is less commonly used today—drawbacks include catastrophic blowout of the remaining aortic stumps. Although we rarely use a homograft as a distal aortic replacement because of some observed early degeneration and rupture, others have reported the successful use of homografts to treat graft infection in the distal aorta [24].

Techniques for heritable thoracic aortic disease

Even after successful aortic repair, patients with heritable thoracic aortic disease such as Marfan syndrome commonly face long-term surveillance for the development of late aortic complications or de novo aneurysm. Previously, we have reported our experience regarding 300 patients with Marfan syndrome; two-thirds of these patients underwent 2 or more aortic repairs, and many of these involved reoperation of the distal aorta [25]. Notably, endovascular aortic repair in such patients necessitates more stringent surveillance as the need for further reintervention in not uncommon [26]. However, there are situations where endovascular repair may be useful in such patients—when endovascular repair may be used to treat a late complication of prior open repair, namely, for pseudoaneurysm or patch aneurysms of the intercostal aorta, in which the endograft can be landed in previously replaced sections of the aorta that are now composed of synthetic graft [27].

Here, we have included figures of a complex aortic reoperation in a young patient with Marfan syndrome, to illustrate surgical decisions in a patient who required multiple reoperations (Fig. 2). This female patient first presented at 29 years old at an outside center with an acute type B dissection, for which a stent graft was placed in the descending thoracic aorta along with a bypass graft to maintain blood flow to the left subclavian artery, whose origin was obstructed by the endograft. One month later, due to a persistent endoleak and continued aortic expansion, the patient was sent to our service, at which point the stent graft was removed and replaced with a graft. Three years later, at age 32, the patient experienced an acute type A aortic dissection and had an emergent resection and replacement of the aortic root with a composite valve graft and concomitant ascending and proximal transverse arch aortic replacement as well as endovascular coverage of the remaining native aortic arch. Two years later, at age 34, the patient received an extent IV TAAA repair using a branched graft to reattach the visceral arteries and minimize the amount of residual native aortic

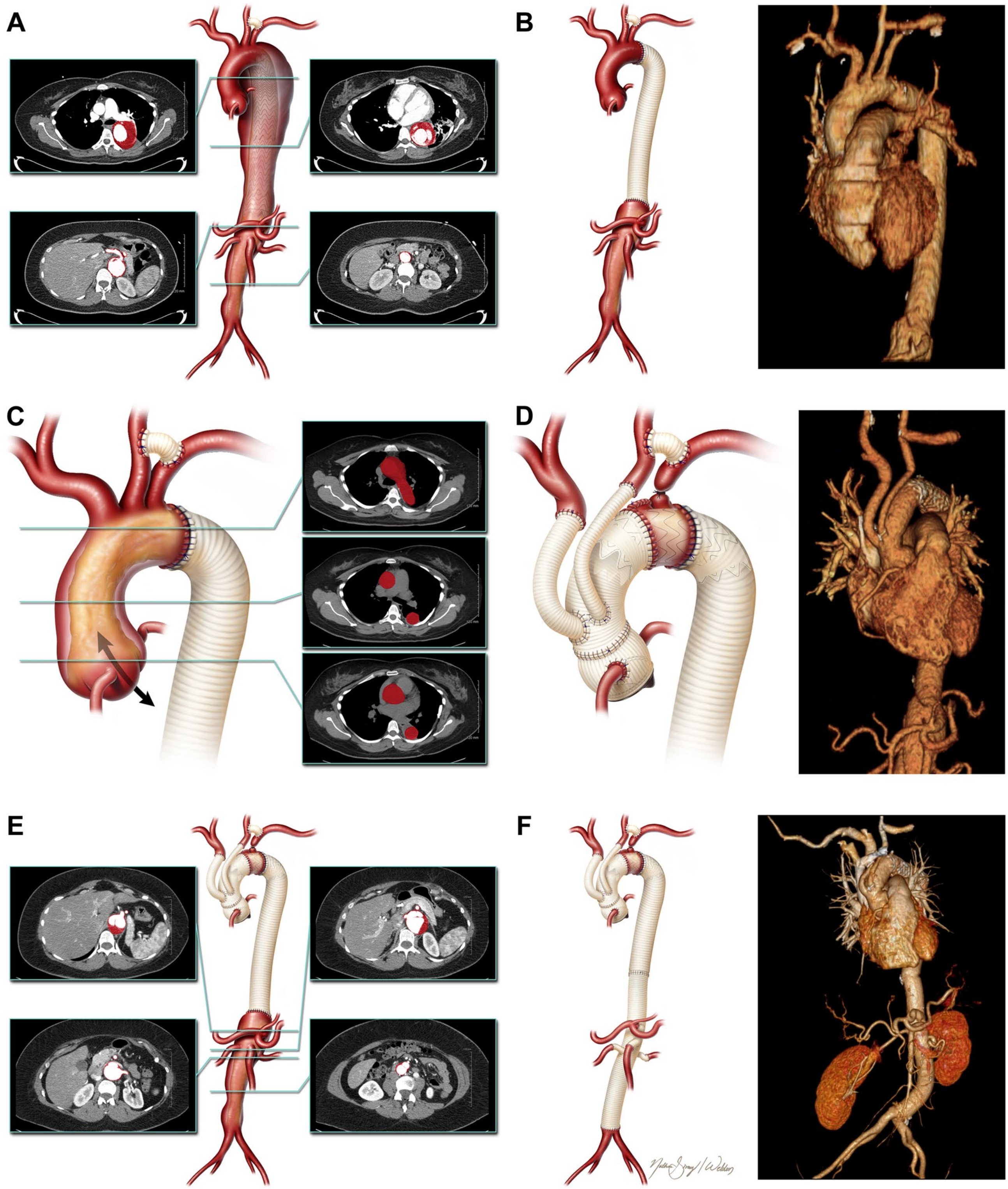

Fig. 2 Illustration depicting the case of a young woman with Marfan syndrome who underwent multiple open aortic repairs after initial stent-graft placement to treat acute DeBakey type III aortic dissection at age 29. At this time, a bypass graft was performed, because the origin of the left subclavian artery was obstructed by the stent graft. **a** One month later, because of persistent endoleak and expansion, the stent graft was removed and the descending thoracic aorta was replaced with a synthetic graft (**b**). Three years later, she experienced an acute DeBakey type I aortic dissection (**c**); the proximal aorta was repaired with an aortic root and hybrid total arch replacement (**d**). After an additional 2 years, the patient underwent extent IV thoracoabdominal aortic aneurysm repair using a four-branched replacement graft to treat progressive dilatation of the remaining native aorta. Nearly 5 years after her last procedure, she continues to do well. Used with permission of Baylor College of Medicine

Table 1 Review of literature for reoperative repairs involving a prior open distal aortic repair

Author, Year	Type(s) of repair	Overall *n*	Type of prior open repair	Reoperative repairs *n* (%)	Early mortality for reoperative repairs	Reoperative[a] verdict?
Coselli, 1997 [29]	TAAA	726	Ascending, DTA, or TAAA repair	179 (24.7%)	8 (4.5%)	Not significantly different
Lombardi, 2003 [4]	TAAA	279	TAAA or AAA	76 (27.2%)	8 (10.5%)	Not significantly different
Kawaharada, 2004 [30]	TAAA	100	DTA	30 (30.0%)	4 (13.3%)	Not significantly different
Etz, 2009 [31]	DTA or TAAA	60	DTA or TAAA	N/A	8 (13.3%)	N/A
Afifi, 2017 [14]	DTA or TAAA	1900	DTA or TAAA	266 (14.0%)	61 (22.9%)	Reoperative repair worse
Lau, 2017 [15]	DTA or TAAA	678	DTA or TAAA	69 (10.2%)	6 (8.7%)	Not significantly different
Coselli, 2018 [13]	TAAA	3379	DTA, TAAA or AAA	726 (21.5%)	78 (8.7%)	Not significantly different

TAAA thoracoabdominal aortic aneurysm, *DTA* descending thoracic aneurysm, *AAA* abdominal aortic aneurysm, *N/A* not available

[a]Reoperative verdict: Was the early mortality significantly worse or not significantly different compared to non-reoperative repair?

tissue. Five years following her last procedure, the patient continues to do well.

Outcomes

Consensus on outcomes after reoperative surgery of the thoracoabdominal aorta is lacking. Whether the operative mortality rate is better or worse compared to non-reoperative TAAA repairs is a matter of some debate, as different institutions have arrived at different conclusions. Afifi et al. [14] recently reported a higher incidence of operative death in reoperative repairs (22.9%), which has been supported by a prior report [28]. However, others have reported that reoperative repairs are not subject to worse outcomes [4, 15, 29, 30] this includes our own recent report on reoperation of the thoracoabdominal aorta [13]. A summary of key data for reoperative TAAA repairs, following previous descending thoracic, thoracoabdominal, or abdominal repairs, is shown above (Table 1); operative mortality ranges from 8.7 to 22.9% [4, 13–15, 29–31].

Conclusion

Recent reports by aortic centers seem to corroborate that reoperative repairs are possible with good outcomes. It is impossible to determine the extent to which the fear of poor outcomes may play a role in inhibiting surgeons from performing reoperative repair [29]. However, this fear must then be weighed against the risks of inaction and the potential of a worse outcome, such aortic rupture. In addition, the role that endovascular technology may play in reoperative surgery has yet to be fully actualized, since these techniques remain largely experimental as applied to the thoracoabdominal aorta. Today, the use of a variety of techniques may be necessitated in the most complex reoperative thoracoabdominal aortic repairs—those involving infection or in patients with heritable thoracic aortic disease.

Acknowledgements Dr. Coselli thanks Susan Y. Green, MPH, and Hiruni S. Amarasekara, MS, for editorial support, and Scott A. Weldon, MA, CMI, and Nathan Gray, BFA for creating the illustrations.

Funding None.

Compliance with ethical standards

Conflict of interest The author declares that they have no competing interest.

References

1. Lefrak EA, Crawford ES. Thoracoabdominal aneurysm after resection and dacron graft replacement of the descending thoracic aorta. Ann Surg. 1972;176:765–8.
2. Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operations. J Vasc Surg. 1993;17:357–68 **(discussion 68–70)**.
3. Estrera AL, Sandhu HK, Charlton-Ouw KM, Afifi RO, Azizzadeh A, Miller CC 3rd, et al. A quarter century of organ protection in open thoracoabdominal repair. Ann Surg. 2015;262:660–8.
4. Lombardi JV, Carpenter JP, Pochettino A, Sonnad SS, Bavaria JE. Thoracoabdominal aortic aneurysm repair after prior aortic surgery. J Vasc Surg. 2003;38:1185–90.
5. Schlosser FJ, Mojibian H, Verhagen HJ, Moll FL, Muhs BE. Open thoracic or thoracoabdominal aortic aneurysm repair after previous abdominal aortic aneurysm surgery. J Vasc Surg. 2008;48:761–8.

6. Girdauskas E, Falk V, Kuntze T, Borger MA, Schmidt A, Scheinert D, et al. Secondary surgical procedures after endovascular stent grafting of the thoracic aorta: successful approaches to a challenging clinical problem. J Thorac Cardiovasc Surg. 2008;136:1289–94.
7. Spiliotopoulos K, Preventza O, Green SY, Price MD, Amarasekara HS, Davis BM, et al. Open descending thoracic or thoracoabdominal aortic approaches for complications of endovascular aortic procedures: 19-year experience. J Thorac Cardiovasc Surg. 2018;155:10–8.
8. Nozdrzykowski M, Luehr M, Garbade J, Schmidt A, Leontyev S, Misfeld M, et al. Outcomes of secondary procedures after primary thoracic endovascular aortic repair. Eur J Cardiothorac Surg. 2016;49:770–7.
9. Roselli EE, Abdel-Halim M, Johnston DR, Soltesz EG, Greenberg RK, Svensson LG, et al. Open aortic repair after prior thoracic endovascular aortic repair. Ann Thorac Surg. 2014;97:750–6.
10. Szeto WY, Desai ND, Moeller P, Moser GW, Woo EY, Fairman RM, et al. Reintervention for endograft failures after thoracic endovascular aortic repair. J Thorac Cardiovasc Surg. 2013;145:165–70.
11. Etz CD, Zoli S, Mueller CS, Bodian CA, Di Luozzo G, Lazala R, et al. Staged repair significantly reduces paraplegia rate after extensive thoracoabdominal aortic aneurysm repair. J Thorac Cardiovasc Surg. 2010;139:1464–72.
12. Schepens MA, Heijmen RH, Ranschaert W, Sonker U, Morshuis WJ. Thoracoabdominal aortic aneurysm repair: results of conventional open surgery. Eur J Vasc Endovasc Surg. 2009;37:640–5.
13. Coselli JS, Rosu C, Amarasekara HS, Green SY, Zhang Q, Price MD, et al. Reoperative surgery on the thoracoabdominal aorta. J Thorac Cardiovasc Surg. 2018;155:474–85 e1.
14. Afifi RO, Sandhu HK, Trott AE, Nguyen TC, Miller CC, Estrera AL, et al. Redo thoracoabdominal aortic aneurysm repair: a single-center experience over 25 years. Ann Thorac Surg. 2017;103:1421–8.
15. Lau C, Gaudino M, Gambardella I, Mills E, Munjal M, Elsayed M, et al. Reoperative repair of descending thoracic and thoracoabdominal aneurysms. Eur J Cardiothorac Surg. 2017;52:501–7.
16. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation. 2010;121:e266–369.
17. Boufi M, Patterson BO, Grima MJ, Karthikesalingam A, Hudda MT, Holt PJ, et al. Systematic review of reintervention after thoracic endovascular repair for chronic type B dissection. Ann Thorac Surg. 2017;103:1992–2004.
18. Pacini D, Parolari A, Berretta P, Di Bartolomeo R, Alamanni F, Bavaria J. Endovascular treatment for type B dissection in Marfan syndrome: is it worthwhile? Ann Thorac Surg. 2013;95:737–49.
19. Blaisdell FW, Demattei GA, Gauder PJ. Extraperitoneal thoracic aorta to femoral bypass graft as replacement for an infected aortic bifurcation prosthesis. Am J Surg. 1961;102:583–5.
20. Walker WE, Cooley DA, Duncan JM, Hallman GL Jr, Ott DA, Reul GJ. The management of aortoduodenal fistula by in situ replacement of the infected abdominal aortic graft. Ann Surg. 1987;205:727–32.
21. Coselli JS, Crawford ES. Primary aortoesophageal fistula from aortic aneurysm: successful surgical treatment by use of omental pedicle graft. J Vasc Surg. 1990;12:269–77.
22. Frautschi RS, Bassiri Gharb B, Duong MM, Gurunluoglu R, Papay F, Zins JE, et al. The cardioplastic approach to the treatment of infected aortic grafts. Ann Plast Surg. 2017;79:221–5.
23. Coselli JS, Green SY, LeMaire SA. When stent-grafts fail: extraction and open surgical repair of the thoracic aorta. Tex Heart Inst J. 2011;38:658–60.
24. McCready RA, Bryant MA, Fehrenbacher JW, Beckman DJ, Coffey AC, Corvera JS, et al. Long-term results with cryopreserved arterial allografts (CPAs) in the treatment of graft or primary arterial infections. J Surg Res. 2011;168:e149–53.
25. LeMaire SA, Carter SA, Volguina IV, Laux AT, Milewicz DM, Borsato GW, et al. Spectrum of aortic operations in 300 patients with confirmed or suspected Marfan syndrome. Ann Thorac Surg. 2006;81:2063–78 (**discussion 78**).
26. Kouchoukos NT. Endovascular surgery in Marfan syndrome: CON. Ann Cardiothorac Surg. 2017;6:677–81.
27. Schwill S, LeMaire SA, Green SY, Bakaeen FG, Coselli JS. Endovascular repair of thoracic aortic pseudoaneurysms and patch aneurysms. J Vasc Surg. 2010;52:1034–7.
28. Gloviczki P, Pairolero P, Welch T, Cherry K, Hallett J, Toomey B, et al. Multiple aortic aneurysms: the results of surgical management. J Vasc Surg. 1990;11:19–27 (**discussion-8**).
29. Coselli JS, Poli de Figueiredo LF, LeMaire SA. Impact of previous thoracic aneurysm repair on thoracoabdominal aortic aneurysm management. Ann Thorac Surg. 1997;64:639–50.
30. Kawaharada N, Morishita K, Fukada J, Hachiro Y, Takahashi K, Abe T. Thoracoabdominal aortic aneurysm repair through redo left-sided thoracotomy. Ann Thorac Surg. 2004;77:1304–8.
31. Etz CD, Zoli S, Kari FA, Mueller CS, Bodian CA, Di Luozzo G, et al. Redo lateral thoracotomy for reoperative descending and thoracoabdominal aortic repair: a consecutive series of 60 patients. Ann Thorac Surg. 2009;88:758–66 (**discussion 67**).