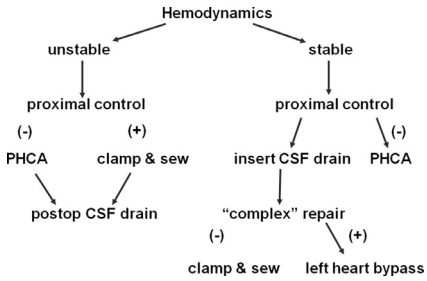
Surgery for Acute Presentation of Thoracoabdominal Aortic Disease

Christopher Lau, MD, Jeremy R. Leonard, MD, Erin Iannacone, MD, Mario Gaudino, MD, and Leonard N. Girardi, MD

Thoracoabdominal aortic aneurysms are most commonly asymptomatic until there is either an impending aortic catastrophe or one that has already occurred. While open surgery remains the gold-standard method for repair, modern technology has led to the development of less invasive endovascular devices and techniques. We provide an expert review of open and endovascular therapies for 3 highly lethal thoracoabdominal aortic emergencies in order to highlight expectations for both short- and long-term outcomes in an era of evolving technology and improvements in patient evaluation and postoperative care. Open repair of ruptured thoracoabdominal aortic aneurysms is associated with a dramatic increase in all postoperative complications, even in specialized aortic surgery centers. Mycotic thoracic aortic aneurysms are highly lethal if surgical treatment is not initiated quickly as they have a propensity toward rapid growth and fatal rupture. Thoracic endovascular aortic repair is well-suited for the treatment of acute complicated type B aortic dissection with outcomes superior to open repair in some centers. Acute aortic events associated with thoracoabdominal aneurysms represent technically challenging situations that require rapid diagnosis and treatment to avoid a fatal outcome. Endovascular techniques have evolved as a viable alternative therapy for acute complicated type B aortic dissection or as a bridge to more definitive repair in the setting of infection or rupture.

Semin Thoracic Surg 31:11–16 © 2018 Elsevier Inc. All rights reserved.

Keywords: Aortic aneurysm, Descending thoracic aortic aneurysm, Thoracoabdominal aortic aneurysm



Treatment algorithm for ruptured thoracoabdominal aortic aneurysms.

Central Message

Acute aortic events associated with thoracoabdominal aortic aneurysms require rapid diagnosis and treatment with open surgical repair or endovascular techniques to avoid a fatal outcome.

Perspective Statement

Thoracoabdominal aortic aneurysms presenting with acute emergencies such as rupture, infection, or complicated dissection require expedient surgical treatment for optimal outcomes. Medical therapy is associated with a dismal prognosis. Open surgical repair remains the gold standard treatment modality. Thoracic endovascular aneurysm repair is evolving as a viable alternative.

INTRODUCTION

Thoracoabdominal aortic aneurysms (TAAA) are most commonly asymptomatic[1,2] until there is either an impending aortic catastrophe or one that has already occurred. Of those who present for TAAA surgery, 64% present with symptoms, such as chest, back, or abdominal pain.[1] These are usually late findings signaling a need for immediate intervention to avoid a catastrophic outcome. Occasionally, TAAA may present emergently in the setting of aortic rupture, infection, or dissection. While infection is difficult to predict, aortic rupture, and dissection occur with greater frequency with larger aortic diameter. A heightened awareness for the presence of a TAAA in at-risk populations such as those with Marfan syndrome, along with a better understanding of the current guidelines for intervention,[3,4] should minimize the occurrence of these potentially fatal events and provide the patient the best opportunity for a successful elective repair.

As over 95% of thoracic aneurysms are asymptomatic, a majority are incidentally found during imaging performed for unrelated reasons or in patients for whom a high index of suspicion for aneurysm is present.[5] Once identified, TAAAs require regular monitoring. A majority of those followed with serial imaging ultimately are referred for elective surgical evaluation.[4] Those who qualify for and choose elective open TAAA

Abbreviations: ACTBAD, acute complicated type B aortic dissections; MTAA, mycotic thoracic aortic aneurysms; OM, operative mortality; TAAA, thoracoabdominal aortic aneurysm; TEVAR, thoracic endovascular aneurysm repair.

Department of Cardiothoracic Surgery, Weill Cornell Medicine, New York, New York

Funding: No funding was received for this work.

Conflict of Interest Statement: The authors have no conflicts of interest.

Presented at the 2018 AATS Aortic Symposium.

Address reprint requests to Leonard N. Girardi, MD, Department of Cardiothoracic Surgery, Weill Cornell Medicine, 525 East 68th St, M-404, New York, NY 10065. E-mail: lngirard@med.cornell.edu

repair in a high-volume aortic center can anticipate an excellent and durable result. Operative mortality is 5–8% depending mainly on aneurysm extent while the incidence of permanent neurologic deficit is less than 5%.[1,2,6]

While open surgery remains the gold-standard method for TAAA repair, modern technology has led to the development of less invasive endovascular devices and techniques. These methods may be appropriate for patients at particularly high-risk for open repair due to the presence of significant comorbid conditions or lack of access to an experienced open center. However, in the setting of acute aortic emergencies, the options are more limited for these critically ill patients. In the following sections, we provide a review of open and endovascular therapies for 3 highly lethal thoracoabdominal aortic emergencies in order to highlight expectations for both short- and long-term outcomes in an era of evolving technology and improvements in patient evaluation and postoperative care.

RUPTURED THORACOABDOMINAL AORTIC ANEURYSMS

The quintessential aortic emergency is a ruptured aneurysm. Without repair, the natural history of ruptured TAAA is dismal. Population-based studies of ruptured thoracic aneurysms have confirmed that less than half of the patients presenting with this condition will survive until hospital evaluation.[7] Those fortunate to survive the initial event most likely have had the ruptured aorta contained by the tissues of the mediastinum, pleura, lung, or esophagus, providing an opportunity for the circulation to stabilize to a degree. However, containment of the leak is nearly always temporary with a majority expiring within the first 6 hours and nearly 80% not surviving beyond 24 hours.[7] Five-year survival in the medically treated population ranges from only 7% for dissection patients to 20% in nondissection patients.[8]

Open repair of ruptured TAAA remains a formidable surgical challenge and the morbidity and mortality associated with it remains significantly higher than in elective situations. Rupture is associated with a dramatic increase in all postoperative complications, even in specialized aortic surgery centers.[9] Operative mortality (OM) ranges from 12% to 26% but can be significantly higher in less experienced hands.[9–14] Data obtained from the Nationwide Inpatient Sample from 1988 to 1998 showed that open repair of ruptured TAAA carried a mortality of 53%.[15] However, this sample included low-volume centers and surgeons, both well-established predictors of disappointing outcomes. Given the emergent nature of the clinical presentation and the near-certainty of death with nonsurgical therapy, many with limited familiarity with these types of repairs may still feel compelled to attempt repair. In these situations it is understandable that endovascular repair may be a more reasonable alternative to open repair.

Patients who arrive at or are stable enough to be transferred to a more experienced aortic center will have improved opportunity for a successful outcome. We recently examined our experience with open repair for ruptured descending and thoracoabdominal aneurysms.[9] In 100 consecutive patients the OM was 14%. The treatment algorithm we espouse for ruptured TAAAs is illustrated in Figure 1 and is primarily dependent upon the level of hemodynamic stability. For stable patients, we attempt to carry out our usual sequence of preparation including the use of a spinal drain. A rapid thoracoabdominal incision is created and proximal aortic control is immediately obtained in preparation for free rupture from either surgical manipulation or hemodynamic swings. With unstable hemodynamics, it is difficult to institute partial, left-heart bypass and repair is most commonly performed with a clamp-and-sew technique. Given the compelling evidence from a randomized trial showing benefit of spinal drains in extent I and II aneurysms,[16] we are committed to this adjunct for spinal cord protection and drains are placed at the end of the case before patients are transported from the operating room. Not unexpectedly, the incidence of postoperative complications was higher in the emergent setting when compared to those undergoing elective repair. Myocardial infarction (7.0% vs 0.8%, $P < 0.004$), respiratory failure (19% vs 5.7%, $P < 0.001$), and the need for postoperative dialysis (11% vs 4.2%, $P = 0.01$) were all more prevalent in those presenting with rupture. Fortunately, permanent spinal cord injury was not more common (5% vs 2.4%, $P = 0.16$). The 5-year survival was lower (47.5% vs 59.5%, $P < 0.001$) than for our nonruptured group but was substantially higher than that reported for ruptured thoracic aneurysm patients being treated with thoracic endovascular aneurysm repair (TEVAR) within the Medicare database.[17] The influence of higher open surgical experience is evident when examining the results of multiple manuscripts reporting on outcomes for ruptured TAAAs (Table 1).

TEVAR has evolved into a viable alternative to open repair of ruptured TAAAs. The obvious merits of an endovascular approach include the avoidance of a painful thoracoabdominal incision and the associated respiratory complications commonplace following these operations. The incidence of postoperative respiratory failure may be amplified by diaphragmatic dysfunction and recurrent nerve palsy, 2 complications not usually seen with an endovascular approach. However, despite

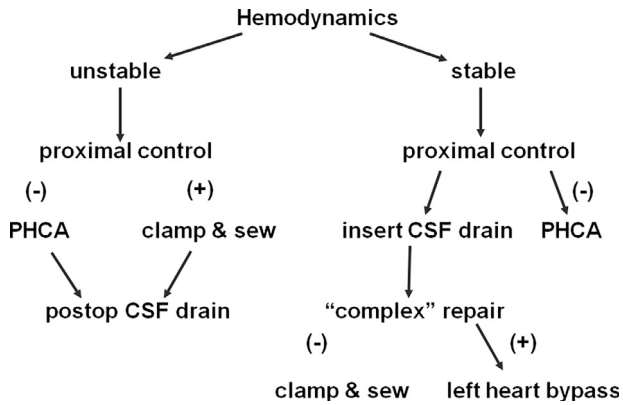


Figure 1. Treatment algorithm for ruptured thoracoabdominal aortic aneurysms.

Table 1. Open and Endovascular Repair of Ruptured Thoracoabdominal Aorta

Open series

Author, year	Number of patients	Mortality (%)	Paraplegia (%)	Stroke (%)	Myocardial infarction (%)	Tracheostomy (%)	Dialysis (%)
Lewis, 2002	17	12	5.8	0	–	29.4	11.7
Cowan, 2003	321	53.8	3.4	–	18.1	12.7	28
Barbato, 2007	40	26.8	15.6	2.5	–	35.5	15
Jonker, 2010	81	33	5.5	10.2	11.1	19	–
Jonker 2010	69	24.6	8.7	–	–	31.9	24.6
Girardi, 2015	100	14	5	1	7	19	11
Zanetti, 2015	51	43.1	13.9	4.6	2.3	11.6	11.6

Endovascular series

Author, year	Number of patients	Mortality (%)	Paraplegia (%)	Stroke (%)	MI (%)	Endoleak (%)	Reintervention (%)
Jonker, 2010	143	19	3.1	4.1	3.5	11.1	9.1
Jonker, 2010	92	17.4	7.6	7.6	5.4	17.4	12
Goodney, 2011	1307	28.4	–	–	–	–	–
Mitchell, 2011	7	43	0	14.2	28.5	–	–
Alsac, 2013	19	35.3	0	0	–	17.6	23.5
Minami, 2015	23	26	8.7	26.1	4.3	17.4	17.4

the obvious advantages of TEVAR, OM and other major adverse events continue to occur at rates similar to open repair (Table 1). In single-center, retrospective observational studies, OM ranges from 18% to 43% (Alsac, Goodney, Jonker, Minami, and Mitchell).[12,13,17–20] The incidence of permanent spinal cord injury is nearly 8% while the risk of a stroke may be as high as 26%.[20] The specter of complex reinterventions in nearly 20% of those surviving the initial procedure remains disappointing and negates the early mortality benefit of TEVAR in ruptured TAAAs in large data sets. Goodney et al examined a large cohort of patients in the Medicare database having both open and endovascular repair of ruptured thoracic aneurysms. There was significantly lower OM with TEVAR when compared to open repair in these critically ill patients (28.4% vs 45%, $P < 0.001$). However, this survival advantage disappeared by 1.5 years after the procedure and no survival benefit could be gleaned after 5 years of follow-up (23% vs 25%, $P = 0.37$).[17] Furthermore, late endoleaks have been reported out beyond 5 years after TEVAR leading to late, fatal aortic rupture, an event rarely encountered following open repair.

In the emergent setting of a ruptured TAAA, the selection between an open or endovascular procedure is largely dictated by the available local expertise and presence of robust systems for perioperative care. TEVAR is supplanting open repair in most centers with experience in endovascular surgery and clearly provides a less invasive alternative with fewer postoperative respiratory complications. However, the incidence of major postoperative adverse events and OM are similar to those reported with open repair in experienced centers. Furthermore, the avoidance of endoleaks and reinterventions may lead to improved long-term survival. Longer follow-up will be necessary to sort out this ongoing debate.

MYCOTIC THORACOABDOMINAL AORTIC ANEURYSMS

Mycotic thoracic aortic aneurysms (MTAA) are an uncommon subset comprising less than 1% of aortic aneurysms in Western countries. MTAA are highly lethal if surgical treatment is not initiated quickly as they have a propensity toward rapid growth and fatal rupture. The incidence of MTAA is higher in Asian countries where the bacteriology of the aneurysms is different and Salmonella infection is more prevalent.[21] A majority of MTAA outside of Asia are secondary to gram-positive cocci. Thirty-day mortality with medical therapy alone, regardless of bacteriology, is in excess of 45%.[22]

Traditional treatment involves directed intravenous antibiotics and aggressive, open debridement of the infected space followed by in situ prosthetic aortic replacement. Despite a greater than 90% freedom from graft-related complications or reinfections,[23] operative mortality remains quite high. Weis-Muller et al reported their experience with 36 patients with thoracic and abdominal mycotic aneurysms and OM was 36%.[24] Others have reported OM between 11% and 21%, depending on the extent of aortic replacement and the bacteriology responsible for the infection.[21,23]

In our experience, patients with MTAA benefit from a multimodal treatment algorithm. Once an infected aneurysm is suspected, empiric antibiotics are administered until culture sensitivities permit narrowing of the antibiotic coverage. Imaging is critical to confirm the location and extent of aorta involved. Computed tomography scans are quite sensitive in identifying suspected areas of infection. Periaortic inflammation, fluid or even a contained rupture in the setting of bacteremia should alert one to the presence of a mycotic aneurysm. Positron-emission tomography

scan is also sensitive for mycotic aneurysm and can assist in determining the extent of surgical resection.[25] Immediate debridement and in situ dacron graft replacement quickly restore aortic continuity and reduce the infectious burden. When possible, we favor the addition of either muscle flap (serratus or latissimus) or omental flap coverage of the graft (Fig. 2). We recently reported on 14 patients presenting to our institution with mycotic descending or TAAA.[22] The OM was 7.1% and no patient experienced a permanent neurologic deficit. Survivors received 6 weeks of intravenous antibiotics followed by lifelong oral antibiotic suppression based on culture sensitivities. Five-year actuarial survival was 71% with no episodes of recurrent infection or late aortic events.[22]

TEVAR is gaining interest as initial therapy for preventing fatal rupture in the setting of a MTAA. Stellmes et al treated 6 MTAA patients with TEVAR. One expired secondary to ongoing sepsis. Two proceeded to open repair after they were stabilized. Long-term follow-up was not available.[26] Patel et al reported their experience with TEVAR for MTAA in 27 high-risk patients deemed poor candidates for open repair. OM was a respectable 11.5%. However, 4 late deaths were due to aortic reinfection and significant endoleaks were seen in 18.5% of patients.[27] These experiences support TEVAR as a viable, initial option for treating MTAA in certain high-risk patients, particularly when experience with open repair is limited. However, there remains a high rate of ongoing sepsis and fatal, late reinfection. Perhaps the optimal role for TEVAR in the setting of MTAA is as a bridge to stabilize patients before transfer to a high-volume open aortic surgery center.

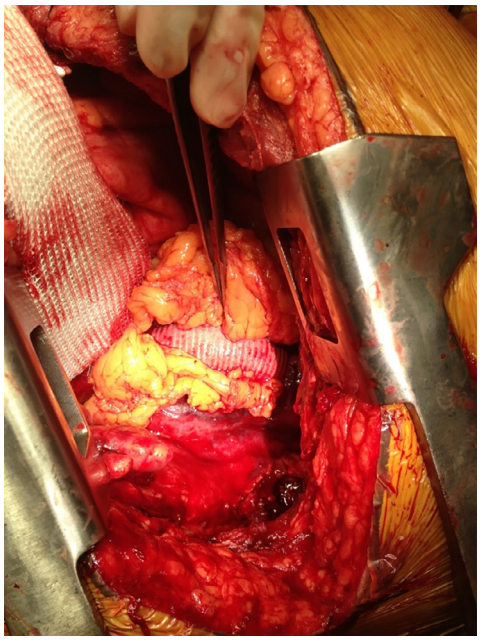


Figure 2. Repair of mycotic thoracoabdominal aortic aneurysm with a dacron graft and omental flap.

ACUTE COMPLICATED TYPE B AORTIC DISSECTION

A majority of Type B aortic dissections are uncomplicated and do not require urgent surgical management.[28] Debates regarding the optimal treatment of uncomplicated Type B dissections are ongoing but there remains no clear indication for surgical intervention.[29] Acute complicated Type B aortic dissections (ACTBAD), however, do require urgent surgical intervention to avoid rupture or a fatal complication related to end organ malperfusion. Dissections included in the definition of "complicated" include frank or impending rupture, malperfusion, rapid expansion, ongoing symptoms despite optimal medical therapy, or refractory hypertension. Intervention is necessary to prevent rupture, improve true lumen flow and reduce perfusion of the false lumen.

TEVAR is well-suited for the treatment of ACTBAD and has been given a class I, level of evidence A recommendation as primary therapy in this high-risk cohort of patients. The Medtronic DISSECTION trial enrolled 50 patients with ACTBAD, 20% with rupture and 86% with malperfusion and demonstrated 30-day mortality of 8% and 1-year mortality of 15%. Two patients had retrograde Type A dissection, 6% had spinal cord injury and 91% had partial or complete thrombosis of the false lumen.[30] Others have reported similar results, confirming the utility of this endovascular approach. Wiedemann et al performed TEVAR in 110 patients with ACTBAD. Operative mortality, similar to the Valiant trial, was 12%. Significant complications, however, continue to occur despite increasing experience with this less invasive modality. Retrograde Type A dissection was seen in 5.4% of patients while permanent stroke occurred in 4.5%. An additional 8% developed either a Type Ia or Ib endoleak.[31] Others report similar early results.[32] The need for late reintervention remains a conundrum. Hanna, et al, reported 26% of 50 patients having TEVAR for ACTBAD required late aortic reinterventions. An additional 30% ultimately crossed over to needing open surgical repair.[33] Clearly, careful follow-up imaging is mandatory following this life-saving therapy. However, despite historical reports of extremely high OM with open repair of ACTBAD,[34,35] select patients may have a contraindication to TEVAR (poor landing zones, connective tissue disorders, extensive abdominal aortic involvement, and extreme hemodynamic instability) and open repair should be considered.

Table 2. Outcomes for Open Repair of Acute Complicated Type B Dissection

Variable	Acute (n = 56)	Other (n = 592)	P
Operative death	4 (7.1)	32 (5.4)	0.539
Myocardial infarction	1 (1.8)	3 (0.5)	0.228
Stroke	0 (0.0)	4 (0.7)	0.545
Spinal cord lesion	1 (1.8)	19 (3.2)	0.556
Respiratory failure	4 (7.1)	42 (7.1)	0.989
Renal failure requiring dialysis	2 (3.6)	32 (5.4)	0.556
Revision for bleeding	2 (3.6)	13 (2.2)	0.513

In our experience with 56 patients undergoing ACTBAD (Table 2), a majority of the patients had TAAAs with 96% being either an extent I or II aneurysm. The patients were significantly younger than a comparative cohort of nonacute patients and they more commonly presented in shock in an emergent setting. Partial, left-heart bypass was the primary surgical strategy but slightly more than 10% did require circulatory arrest because proximal aortic clamping was felt to be too hazardous. Significantly fewer patent intercostal arteries were reimplanted because of tissue fragility. Using this conservative surgical strategy, the OM was 7.1%. There were no perioperative strokes, a 1.8% incidence of permanent spinal cord injury while 2 patients (3.6%) required temporary renal replacement therapy. Long-term follow-up will be necessary to determine the durability of this complicated open surgical strategy.

CONCLUSION

Acute aortic events associated with TAAA represent technically challenging situations that require rapid diagnosis and treatment to avoid a fatal outcome. Open surgical repair remains the gold standard method of repair in many of these situations. Results have improved significantly over time. TEVAR has evolved as a viable alternative therapy or as a bridge to more definitive repair. Additional follow-up will be necessary to determine whether this less invasive therapy will supplant open repair in the future.

REFERENCES

1. Coselli JS, LeMaire SA, Preventza O, et al: Outcomes of 3309 thoracoabdominal aortic aneurysm repairs. J Thorac Cardiovasc Surg 151:1323–1337, 2016. https://doi.org/10.1016/j.jtcvs.2015.12.050
2. Girardi LN, Lau C, Ohmes LB, et al: Open repair of descending and thoracoabdominal aortic aneurysms in octogenarians. J Vasc Surg 2018. https://doi.org/10.1016/j.jvs.2017.12.083
3. Erbel R, Aboyans V, Boileau C, et al: 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). Eur Heart J 35:2873–2926, 2014. https://doi.org/10.1093/eurheartj/ehu281
4. Hiratzka LF, Bakris GL, Beckman JA, 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 121. https://doi.org/10.1161/CIR.0b013e3181d4739e. e266-369
5. Kuzmik GA, Sang AX, Elefteriades JA: Natural history of thoracic aortic aneurysms. J Vasc Surg 56:565–571, 2012. https://doi.org/10.1016/j.jvs.2012.04.053
6. Estrera AL, Jan A, Sandhu H, et al: Outcomes of open repair for chronic descending thoracic aortic dissection. Ann Thorac Surg 99:786–793, 2015. https://doi.org/10.1016/j.athoracsur.2014.08.077. discussion 794
7. Johansson G, Markström U, Swedenborg J: Ruptured thoracic aortic aneurysms: A study of incidence and mortality rates. J Vasc Surg 21:985–988, 1995
8. Crawford ES, Hess KR, Cohen ES, Coselli JS, Safi HJ: Ruptured aneurysm of the descending thoracic and thoracoabdominal aorta. Analysis according to size and treatment. Ann Surg 213:417–425, 1991. discussion 425
9. Gaudino M, Lau C, Munjal M, Girardi LN: Open repair of ruptured descending thoracic and thoracoabdominal aortic aneurysms. J Thorac Cardiovasc Surg 150:814–821, 2015. https://doi.org/10.1016/j.jtcvs.2015.06.077
10. Lewis ME, Ranasinghe AM, Revell MP, Bonser RS: Surgical repair of ruptured thoracic and thoracoabdominal aortic aneurysms. Br J Surg 89:442–445, 2002. https://doi.org/10.1046/j.0007-1323.2001.02049.x
11. Barbato JE, Kim JY, Zenati M, et al: Contemporary results of open repair of ruptured descending thoracic and thoracoabdominal aortic aneurysms. J Vasc Surg 45:667–676, 2007. https://doi.org/10.1016/j.jvs.2006.12.049
12. Jonker FHW, Verhagen HJM, Lin PH, et al: Open surgery versus endovascular repair of ruptured thoracic aortic aneurysms. J Vasc Surg 53:1210–1216, 2011. https://doi.org/10.1016/j.jvs.2010.10.135
13. Jonker FHW, Trimarchi S, Verhagen HJM, Moll FL, Sumpio BE, Muhs BE: Meta-analysis of open versus endovascular repair for ruptured descending thoracic aortic aneurysm. J Vasc Surg 51:1026–1032, 2010. https://doi.org/10.1016/j.jvs.2009.10.103. 1032.e1
14. Zanetti PP, Krasoń M, Walas R, et al: Open" repair of ruptured thoracoabdominal aortic aneurysm (experience of 51 cases). Kardiochir Torakochirurgia Pol 12:119–125, 2015. https://doi.org/10.5114/kitp.2015.52852
15. Cowan JA, Dimick JB, Wainess RM, Henke PK, Stanley JC, Upchurch GR: Ruptured thoracoabdominal aortic aneurysm treatment in the United States: 1988 to 1998. J Vasc Surg 38:319–322, 2003. https://doi.org/10.1016/S0741-5214(03)00227-1
16. Coselli JS, LeMaire SA, Köksoy C, Schmittling ZC, Curling PE: Cerebrospinal fluid drainage reduces paraplegia after thoracoabdominal aortic aneurysm repair: Results of a randomized clinical trial. J Vasc Surg 35:631–639, 2002. https://doi.org/10.1067/mva.2002.122024
17. Goodney PP, Travis L, Lucas FL, et al: Survival after open versus endovascular thoracic aortic aneurysm repair in an observational study of the medicare population. Circulation 124:2661–2669, 2011. https://doi.org/10.1161/CIRCULATIONAHA.111.033944
18. Alsac J-M, Pierard T, El Batti S, Achouh P, Julia P, Fabiani J-N: Applicability and mid-term results of endovascular treatment for descending thoracic acute aortic syndromes. Ann Vasc Surg 27:1029–1035, 2013. https://doi.org/10.1016/j.avsg.2012.10.033
19. Mitchell ME, Rushton FW, Boland AB, Byrd TC, Baldwin ZK: Emergency procedures on the descending thoracic aorta in the endovascular era. J Vasc Surg 54:1298–1302, 2011. https://doi.org/10.1016/j.jvs.2011.05.010. discussion 1302
20. Minami T, Imoto K, Uchida K, et al: Thoracic endovascular aortic repair for ruptured descending thoracic aortic aneurysm. J Card Surg 30:163–169, 2015. https://doi.org/10.1111/jocs.12499
21. Hsu R-B, Chen RJ, Wang S-S, Chu S-H: Infected aortic aneurysms: clinical outcome and risk factor analysis. J Vasc Surg 40:30–35, 2004. https://doi.org/10.1016/j.jvs.2004.03.020
22. Lau C, Gaudino M, de Biasi AR, Munjal M, Girardi LN: Outcomes of open repair of mycotic descending thoracic and thoracoabdominal aortic aneurysms. Ann Thorac Surg 100:1712–1717, 2015. https://doi.org/10.1016/j.athoracsur.2015.05.067
23. Oderich GS, Panneton JM, Bower TC, et al: Infected aortic aneurysms: Aggressive presentation, complicated early outcome, but durable results. J Vasc Surg 34:900–908, 2001. https://doi.org/10.1067/mva.2001.118084
24. Weis-Müller BT, Rascanu C, Sagban A, Grabitz K, Godehardt E, Sandmann W: Single-center experience with open surgical treatment of 36 infected aneurysms of the thoracic, thoracoabdominal, and abdominal aorta. Ann Vasc Surg 25:1020–1025, 2011. https://doi.org/10.1016/j.avsg.2011.03.009
25. Murakami M, Morikage N, Samura M, Yamashita O, Suehiro K, Hamano K: Fluorine-18-fluorodeoxyglucose positron emission tomography-computed tomography for diagnosis of infected aortic aneurysms. Ann Vasc Surg 28:575–578, 2014. https://doi.org/10.1016/j.avsg.2013.04.013

26. Stellmes A, Von Allmen R, Derungs U, et al: Thoracic endovascular aortic repair as emergency therapy despite suspected aortic infection. Interact Cardiovasc Thorac Surg 16:459–464, 2013. https://doi.org/10.1093/icvts/ivs539
27. Patel HJ, Williams DM, Upchurch GR, Dasika NL, Eliason JL, Deeb GM: Thoracic aortic endovascular repair for mycotic aneurysms and fistulas. J Vasc Surg 52(4 suppl):37S–40S, 2010. https://doi.org/10.1016/j.jvs.2010.06.139
28. Fattori R, Cao P, De Rango P, et al: Interdisciplinary expert consensus document on management of type B aortic dissection. J Am Coll Cardiol 61:1661–1678, 2013. https://doi.org/10.1016/j.jacc.2012.11.072
29. Nienaber CA, Kische S, Rousseau H, et al: Endovascular repair of type B aortic dissection: long-term results of the randomized investigation of stent grafts in aortic dissection trial. Circ Cardiovasc Interv 6:407–416, 2013. https://doi.org/10.1161/CIRCINTERVENTIONS.113.000463
30. Bavaria JE, Brinkman WT, Hughes GC, et al: Outcomes of thoracic endovascular aortic repair in acute type B aortic dissection: Results from the valiant united states investigational device exemption study. Ann Thorac Surg 100:802–828, 2015. https://doi.org/10.1016/j.athoracsur.2015.03.108. discussion 808
31. Wiedemann D, Ehrlich M, Amabile P, et al: Emergency endovascular stent grafting in acute complicated type B dissection. J Vasc Surg 60:1204–1208, 2014. https://doi.org/10.1016/j.jvs.2014.06.001
32. Wilkinson DA, Patel HJ, Williams DM, et al: Early open and endovascular thoracic aortic repair for complicated type B aortic dissection. Ann Thorac Surg 96:23–30, 2013. https://doi.org/10.1016/j.athoracsur.2013.01.041. discussion 230
33. Hanna JM, Andersen ND, Ganapathi AM, et al: Five-year results for endovascular repair of acute complicated type B aortic dissection. J Vasc Surg 59:96–106, 2014. https://doi.org/10.1016/j.jvs.2013.07.001
34. Moulakakis KG, Mylonas SN, Dalainas I, et al: Management of complicated and uncomplicated acute type B dissection. A systematic review and meta-analysis. Ann Cardiothorac Surg 3:234–246, 2014. https://doi.org/10.3978/j.issn.2225-319X.2014.05.08
35. Murashita T, Ogino H, Matsuda H, et al: Clinical outcome of emergency surgery for complicated acute type B aortic dissection. Circ J 76:650–654, 2012. https://doi.org/10.1253/circj.CJ-11-0982