Early and Midterm Outcome of TEVAR for Thoracic Aortic Pseudoaneurysm

Hui Wang

Second Xiangya Hospital

Tun Wang

Second Xiangya Hospital

Hao He

Second Xiangya Hospital

Xin Li

Second Xiangya Hospital

Yuan Peng

Second Xiangya Hospital

Lunchang Wang

Second Xiangya Hospital

Likun Sun

Second Xiangya Hospital

Quanming Li

Second Xiangya Hospital

Chang Shu (✉ shuchang@csu.edu.cn)

Second Xiangya Hospital

Research

Keywords: aortic pseudoaneurysm, thoracic endovascular aortic repair, mortality, etiology, emergent TEVAR, aorto-esophageal fistula

Posted Date: June 30th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-659146/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Backgrounds: The prognosis of thoracic aortic pseudoaneurysm (TAP) after thoracic endovascular aortic repair (TEVAR) remains unclear. This study investigates the early and midterm clinical outcome as well as relevant risk factors of TAP patients following TEVAR therapy.

Methods: From July 2010 to July 2020, 37 eligible TAP patients who underwent TEVAR were selected into our research. We retrospectively explored their baseline, perioperative and follow-up data. Fisher exact test and Kaplan-Meier method were applied for comparing difference between groups. Risk factors of late survival were discerned using Cox regression analysis.

Results: There were 29 men and 12 women, with the mean age as 59.5 ± 13.0 years (range, 30-82). The mean follow-up time was 30.7 ± 28.3 months (range, 1-89). For early result, early mortality (≤ 30 days) happened in 3 (8.1%) zone 3 TAP patients versus 0 in zone 4 ($p = 0.028$); acute arterial embolism of lower extremity and type II endoleak respectively occurred in 1 (2.7%) case. For midterm result, survival at 3 months, 1 year and 5 years was $88.8 \pm 5.3\%$, $75.9 \pm 7.5\%$ and $68.3 \pm 9.9\%$, which showed significant difference between zone 2/3 versus zone 4 group ($56.3 \pm 14.8\%$ versus $72.9 \pm 13.2\%$, $p = 0.013$) and emergent versus elective TEVAR groups ($0.0 \pm 0.0\%$ versus $80.1 \pm 8.0\%$, $p = 0.049$). On multivariate Cox regression, lesions at zone 2/3 (HR 4.605, 95%CI 1.095-19.359), concomitant cardiac disease (HR 4.932, 95%CI 1.086-22.403) and emergent TEVAR (HR 4.196, 95%CI 1.042-16.891) were significant independent risk factors for worse late clinical outcome.

Conclusions: TEVAR therapy is effective and safe with satisfactory early and midterm clinical outcome for TAP patients. Lesions at zone 2/3, concomitant cardiac disease and emergent TEVAR were independent risk factors for midterm survival outcome.

Background

Considering the diversity of the natural history of TAP resulting from various etiologies (1–8), to date there is no consensus on the management of it. At present, available treatment options for TAP located at distal aortic arch and descending aorta mainly include optimal medical treatment, open surgery, and endovascular therapy. Gandhi et al found no statistically significant difference between optimal medical treatment and thoracic endovascular aortic repair (TEVAR) in traumatic TAP patients, but its primary end points were in-hospital mortality and complications without longer follow-up (9). The American Association for the surgery of trauma (AAST) trials (10) reported higher mortality and paraplegia rates for blunt aortic injury following open management than TEVAR, while recent research has shown favorable early and late outcome of open repair for acute blunt aortic injury, with 5- and 10-year survival as 86–98% and 68–92% (11).

Therefore, despite that endovascular treatment, as an alternative to surgical intervention, is increasingly more common for aortic pathologies owing to its less invasive nature, more evidence about the early and midterm follow-up results of TAP is needed to prove its security and efficacy (12, 13). The paper

retrospectively presents 37 patients diagnosed with TAP and treated by TEVAR therapy. We analyzed their clinical features, early and midterm results as well as prognostic factors.

Materials And Methods

This retrospective study is approved by the institutional research ethics committee of our hospital and waiver of informed consent form of individuals are granted.

Patients

We included patients if 1) they were diagnosed with TAP through contrast-enhanced computerized tomographic angiography (CTA), and digital subtraction angiography (DSA) result was also necessary when following endovascular therapy; 2) they received TEVAR for TAP. We excluded patients if thoracic aortic lesion was induced by cancer. From July 2010 to July 2020, 37 eligible patients were selected into the study. Mean age was 59.5 ± 13.0 years (range, 30–82). There were 29 males (78.4%) and 18 smokers (48.6%). The etiology was atherosclerosis in 13 (35.1%), blunt trauma in 7 (18.9%), tuberculosis in 7 (18.9%), esophageal foreign body in 4 (10.8%), systematic vasculitis in 3 (8.1%), previous stent grafting in 2 (5.4%) and unknown cause in 1 (2.7%). Based on Ishimaru classification(14), TAP lesions located at zone 2 in 1 (2.7%), zone 3 in 11 (29.7%), zone 4 in 15 (67.6%). 31 patients (83.8%) had obvious symptom while 6 patients (16.2%) were asymptomatic. More detailed information is listed in Table 1.

Thoracic Endovascular Aortic Repair

Treatment with antihypertensive drugs and beta blockers to strictly maintain the systolic pressure at about 100 mm Hg and the heart rate at 60 to 70 beats/min was initiated on admission. Procedures were performed in the hybrid unit under general or local anesthesia. The right common femoral artery (CFA) was exposed through incision, approximately 5 cm, and then guidewire and catheters were inserted into CFA using puncture technique until reached appropriate sites. The left CFA was available when necessitating bilateral intervention. Digital subtraction angiography (DSA) of the thoracic aorta was performed to compare the lesion's dynamic characteristics with those seen on CTA. After intravenous administration of heparin sodium (0.5ml/kg), the stent graft with the diameter 10–20% oversized was advanced and prepositioned into the proper location. DSA was performed again to evaluate configuration of stent, endoleak and patency of branch vessels.

Physician-modified fenestration (PMF) technique was selected to preserve LSA when the distance from TAP to LSA was < 15 mm, the neck length of the TAP was < 15 mm and the diameter was > 5.5 cm or rapid aortic growth had occurred (> 1 cm/year). The detailed process of PMF technique was same as before (15). Generally, the outer sheath of the stent was moved 3-4cm backward to expose the stent, a scalpel and scissor were used to remove the member of pre-fenestration area, and then using a belt to constrain the stent to return the outer sheath to the original position. Adjust the stent-graft to fit LSA orifice under radioscopy. Balloon expandable stent for LSA was deployed when necessary. On the other hand, LSA was directly covered when lack of enough landing zone if the patient had dominant right

vertebral artery and no history of left internal mammary artery graft or the need of left arm access dialysis.

For patients meeting the diagnostic criteria for infection, adjunctive procedure also includes the inserting of a 5F sheath into the contralateral groin to enable the catheter to be preplaced in the aneurysmal sac for perfusion of anti-TB drugs or sensitive antibiotics after deploying the stent graft(16). TEVAR was performed under local anesthesia when including perfusing drugs to the sac, for early recognition of related complications. Additionally, in our experience, for traumatic patients with pleural effusion, perioperative antibiotic was necessary for preventing postoperative infection.

Follow-up

Patients were scheduled for CTA and physical examination 1 months, 3 months, 6 months and 12 months after discharge, and annually afterwards to evaluate general condition, patency and position of vascular graft as well as early and late complications. Telephone interview was conducted semiannually.

Statistics

Statistics analysis was performed with SPSS 18.0 (SPSS Inc, Chicago, IL) and R software (R Core Team, Vienna, Austria). Fisher exact test and Kaplan-Meier method were applied for comparing difference between groups. Potential risk factors were incorporated into multivariate Cox regression analysis based on univariate Cox regression results ($P < 0.1$). Difference between each group would be considered significant if P value < 0.05 .

Results

Early outcomes

TEVAR procedure was successfully performed in 37 patients including 7 (18.9%) emergent and 30 (81.1%) elective TEVAR. LSA was covered in 11 cases (29.7%). PMF for LSA was applied in one patient (2.7%, Fig. 1 (A-D)).

Early mortality happened in three zone 3 TAP patients versus 0 in zone 4 ($p = .028$), and 2 of them received emergent TEVAR (Table 2). One case died of acute arterial embolism of the lower extremity 7 days postoperatively, whose preoperative CTA showed extensive aortic calcification; one case with preoperative hydropericardium, hydrothorax and compressed main pulmonary artery died of pericardial tamponade and compressed main pulmonary artery the day after TEVAR, whose etiology was atherosclerosis. The death of third case happened after discharge who had stable physical condition when discharged. Type II endoleak was observed in one zone 4 TEVAR case, which was left untreated and expected to thrombose spontaneously. For other patients having received TEVAR within 30 days, there was no occurrence of ischemia of left upper extremity, stroke, paralysis, acute renal insufficiency, bowel ischemia or puncture complications, and the 30-days survival of them was $88.8 \pm 5.3\%$ (Table 2).

Midterm outcomes

The mean follow up was 30.7 ± 28.3 months (range, 1–89), and the overall survival at 3 months, 6 months, 1 year, 3 years and 5 years was $88.8 \pm 5.3\%$, $85.8 \pm 5.9\%$, $75.9 \pm 7.5\%$, $75.9 \pm 7.5\%$ and $68.3 \pm 9.9\%$, and no death occurred in zone 4 group within 6 months, which showed significant difference between zone 2/3 and zone 4 groups ($p = .013$) (Table 2, Fig. 2A). Six new adverse event happened during midterm follow up, 3 of which had known cause. One case developed aorto-esophageal fistula (AEF) due to esophageal foreign body, manifested as “hematochezia for 2 days, 79g/l hemoglobin”. He received emergent TEVAR and strict perioperative anti-infection treatment, but subsequently, he suffered from recurrent fever, was treated by exploratory thoracotomy and aorto-esophageal repair 5 months later, but finally died of sepsis because of stent infection after 57 months. The other case was also diagnosed with AEF caused by previous stent grafting due to aortic dissection three years ago. His massive hematemesis needed emergent TEVAR, but he died of bacteremia 11 months after TEVAR. The last case had satisfactory follow-up results but died of other disease 9 months later. There was no complication or reintervention in other patients. For special case, the patient following PMF remains alive after 45-months follow up. Representative midterm postoperative (5 years) CTA results of a trauma patient was showed in Fig. 1 (E-H).

Risk factor analysis of survival outcome

According to Kaplan-Meier analysis, locations of thoracic TAP lesions and surgery opportunity had significant different effects on patients’ midterm survival outcome. Patients with zone 4 TAP had more favorable survival than zone 2/3 TAP, especially in the early stage ($p = 0.013$) (Fig. 2A). The specific survival rate for zone 4 patients at 6 months, 1 year, 3 years and 5 years was $100.0 \pm 0.0\%$, $85.8 \pm 8.0\%$, $85.8 \pm 8.0\%$ and $72.9 \pm 13.2\%$, while that for zone 2/3 patients at 3 months and 6 months was $65.6 \pm 14.0\%$ and $56.3 \pm 14.8\%$, which maintained stable as $56.3 \pm 14.8\%$ in the subsequent follow up (Table 2). Patients received elective TEVAR had more satisfactory survival than emergent TEVAR cases, especially in the late stages ($p = 0.049$) (Fig. 2B). The detailed survival rate for elective TEVAR patients at 1 month, 3 months, 6 months, 1 year was $96.6 \pm 3.4\%$, $92.5 \pm 5.1\%$, $88.5 \pm 6.3\%$ and $80.1 \pm 8.0\%$, which maintained unchanged in the following 5 years. However, the survival for emergent TEVAR patients at 1 month, 1 year and 5 years was $75.0 \pm 15.3\%$, $60.0 \pm 18.2\%$ and $0.0 \pm 0.0\%$, respectively.

The trauma group had the most satisfactory result: no death happened and no complication was observed during 79-months follow up (Fig. 2C). The survival for 13 atherosclerosis cases at 1 month and 68 months was $84.6 \pm 10.0\%$ and $67.7 \pm 13.4\%$. The survival for tuberculosis patients at 1 month and 51 months was $85.7 \pm 13.2\%$ and $71.4 \pm 17.1\%$. The midterm survival of TAP patients caused by previous stent grafting, esophageal foreign bodies and systemic vasculitis was unsatisfactory, respectively as $0.0 \pm 0.0\%$, $50.0 \pm 35.4\%$ and $50.0 \pm 35.4\%$.

According to multivariate Cox regression results, certain factors posed increased risk to worse survival outcome including zone2/3 lesion (HR 4.605, 95%CI 1.095–19.359), concomitant cardiac disease (HR 4.932, 95%CI 1.086–22.403) and emergent TEVAR (HR 4.196, 95%CI 1.042–16.891) (Table 3).

Discussion

In this paper, we described early and midterm results of TAP patients following TEVAR therapy. As a procedure with less invasiveness, short procedure duration and less bleeding, TEVAR is an ideal alternative of open surgery for aortic pathologies at distal aortic arch and descending aorta, especially for emergent situation with combined traumatic injury, severe infection and aortic rupture. TEVAR should be considered for TAP considering its emergency and complexity.

Atherosclerotic thoracic TAP accounts for the largest proportion (13, 35.1%) in our series. Actually, atherosclerotic aortic pseudoaneurysm generally originates from penetrating aortic ulcer (PAU) (2). We usually make the judgment based on patients' advanced age, the gravity of aortic calcification by CTA and medical history of aortic ulcer or intramural haematoma by CTA results. A study showed that the survival of atherosclerotic TAP after TEVAR has a gradual yearly decreasing trend with 5-years survival lower than 40% due to extensive atherosclerosis of the aortic wall (17). The trend is unobvious in our results with 68-months survival as $67.7 \pm 13.4\%$. In addition, one atherosclerotic TAP case in our series with extensive aortic calcification died of acute embolism of lower extremity. Therefore, like well-studied periprocedural stroke due to the displacement and embolization of aortic debris after TEVAR, perioperative embolism of lower extremity also deserves more investigation.

Blunt trauma is a mostly reported pathogenesis, and it has been a trend to use TEVAR to treat trauma related aortic pathologies. 7 (18.9%) trauma TAP cases in our series all received TEVAR therapy, and no complication and death was observed during the follow up (Fig. 2C). The result is understandable due to healthier and younger vessel nature based on trauma patients' relative younger ages (52.9 ± 9.6 years, 44 to 68) than atherosclerotic patients (66.9 ± 8.1 years, 56 to 82). According to the literatures, the line between nonoperative management (NOM) and operative treatment for grade III (pseudoaneurysm) blunt traumatic aortic injury (BTAI) remains blurred. Some studies suggested that BTAI with pseudoaneurysm could be managed by NOM instead of instant operative treatment (9, 18). However, there was 10% risk of TAP requiring surgical therapy after NOM (18), and postdischarge follow-up was restricted to < 1 year in most studies (19). Based on our series, we suggest that instant TEVAR for traumatic TAP is reasonable.

Infected TAP is a tough condition with high mortality (20–23). This microorganisms reach the vessel wall through various ways including direct invasion and spread, feeding vessels, lymphatic vessels and iatrogenic factors. Despite the controversy of treatment with artificial graft exposed to infected tissue, many studies have shown that endovascular repair is a palliative treatment in acute phase, a temporary bridge to secondary open surgery (20, 24–26). For patients only undergoing endovascular treatment, life-long appropriate antibiotic therapy, or regular and full-course anti-tuberculous chemotherapy is recommended (27). 4 (10.8%) infectious cases originated from AEF, which was caused by esophageal foreign bodies in 2 and previous stent grafting in 2. Blood culture was positive for staphylococcus aureus in one case. Moreover, there were 7 (18.9%) tuberculosis TAP patients having received TEVAR in our series, and satisfactory early and midterm outcome had been obtained: patients gained weight during follow up, with 1 month and 51 months survival as $85.7 \pm 13.2\%$ and $71.4 \pm 17.1\%$.

For patients with infected TAP, innovative adjunctive procedure in addition to TEVAR was adopted in our center, which might contribute to the satisfactory outcome and has been published recently for the first time (16). After the deployment of aortic stent sealing the aneurysm sac, directly delivering the antibiotic agent to the aneurysmal sac via pre-placed catheter would ensure that the drugs would permeate into nearby tissues continued and slowly instead of being swept away by blood stream. Moreover, in situ administration might improve drug bioavailability compared to oral or intravenous administration.

Systemic vasculitis is another intractable pathogenesis of TAP, and the outcome of them was unsatisfactory albeit following immunotherapy (Fig. 2C). Some experience on TEVAR for systemic vasculitis has been reported, which is superior to open surgery on preventing immediate complications and aortic anatomical pseudoaneurysm. However, recurrent TAP remains to be a continuing problem because of aortic wall injury or mechanical force at the edge of the stent triggering vascular inflammation (28). It is suggested that adjunctive perioperative and postoperative immunosuppressive treatment is essential (29, 30).

Two cases having received TEVAR due to previous aortic dissection developed distal TAP with secondary AEF, and the time to the development of AEF after TEVAR respectively was 39 months and 8 years. A multicenter study showed that the occurrence of AEF after TEVAR was 1.5% and the median time was three months (31). The incidence of distal TAP is a joint result of the unsolved underlying aortic inflammation at the time of TEVAR or mismatched oversize proportion of the stent, plus the mechanical force at the edge of the stent. The mechanical compression and secondary invasion from TAP might be the cause of AEF considering 2-years dysphagia history of our patient.

Symptomatic cases accounts for 83.8% (31/37) percent of overall TAP patients. The most common symptom was chest/back pain or tightness (56.8%, 21/37). It was back pain and distress in another study (17). Actually, hemoptysis, hematemesis, hematochezia and melena are strikingly noticeable as quite common symptoms of respiratory and digestive diseases. They occurred due to aortopulmonary fistula (APF) or AEF even with a visible intrabronchial or intraesophageal mass (24, 32–37). In such situations, endoscopic clamping biopsy poses a risk of massive bleeding. There was no detectable APF in our patients manifested as hemoptysis, albeit in one patient who complained of persistent hemoptysis for even seven years after TEVAR. Under this circumstances, respiratory disorder is more likely to be considered.

Our results suggest that patients with zone 4 TAP have a significantly more favorable midterm outcome than zone 3 TAP. A similar study also indicated the existence of better death/survival ratio among patients with middle thoracic aneurysms than among patients with aneurysms situated at proximal aorta (38). On one hand, when the orifice of LSA that was only partially covered by the stent, local fluid dynamics showed remarkable disturbance (39). On the other hand, zone 4 aneurysms, with sufficient proximal landing zone, could receive a straightforward endovascular surgery without secondary endovascular intervention and thus avoid relevant complications, having greater chance of satisfactory survival (38). However, a single-center research on TEVAR for thoracic TAP, with 24.0 ± 18.5 months (range,

1.5 to 67.3) follow-up, showed no evidence about this (17). It might be because that they only focused on univariate effect and ignored the interaction between covariates. In univariate analysis, they found that surgery opportunity, emergent or elective, had significantly distinctive effect on the survival, which is consistent with our finding.

Clinical indications for emergent/urgent TEVAR includes ruptured descending thoracic aortic aneurysms, acute BTAI and complicated acute type B aortic dissections (40). In our series, TAP patient with AEF manifested as massive haematemesis or hematochezia was also indications. Although TEVAR therapy could prevent death by exsanguination, the survival outcome is not desirable due to high risk of infectious complications and failure to solve fundamental cause. AEF patients following open management also had poor outcome including implantation of vascular prosthesis and patch repair (41). The latest research indicated that in situ aortic replacement by cryopreserved aortic homograft and concomitant primary closure of the esophagus is a feasible and promising therapy for primary and secondary AEF (42).

TAP patients with cardiac disease (16.2% of the series) as an independent risk factor were proved to pose a 4.9-fold increased risk to worse late survival outcome. Patients with coronary disease also developed aortic calcification, particularly the occurrence of atherosclerotic aortic aneurysm reached 46.3%. A research suggested that cardiac catheterization before TEVAR is necessary for evaluating coronary arteries' condition and predicting the degree of aortic calcification (43).

In this series of TAP, the mortality at 1 and 5 years was 75.9 ± 7.5 and 68.3 ± 9.9 , which was a satisfactory result comparing to open surgery(44). The mortality of over 10% at 3 months might links to patients' complex condition or early complication of TEVAR. As a research showed that once emergent cases survived TEVAR procedure, the survival of them become stable after 6 months(17).

Although there are several results in this report, there are also limitations. Actually, the effectiveness of endovascular therapy is underestimated because we only calculated all-cause mortality and concomitant cardiac disease was proved significantly associated with TAP patients' survival. It is a retrospective observational study based on single center experience with a long time span and limited cases. Cohort study and randomized controlled trial are needed to further demonstrate our results.

Conclusion

In conclusion, TEVAR therapy is effective and safe with satisfactory early and midterm clinical outcome for TAP patients. Lesions at zone 2/3, concomitant cardiac disease and emergent TEVAR might be independent risk factors for their midterm survival outcome.

Abbreviations

TAP Thoracic Aortic Pseudoaneurysm

TEVAR Thoracic Endovascular Aortic Repair

CTA Computerized Tomographic Angiography

DSA Digital Subtraction Angiography

CFA Common Femoral Artery

PMF Physician-modified Fenestration

LSA Left Subclavian Artery

AEF Aortoesophageal Fistula

PAU Penetrating Aortic Ulcer

NOM Nonoperative Management

BTAI Blunt Traumatic Aortic Injury

APF Aortopulmonary Fistula

Declarations

Ethics approval and consent to participate

This retrospective study is approved by the institutional research ethics committee of the Second Xiangya Hospital and waiver of informed consent form of individuals are granted.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by Beijing Municipal Science & Technology Commission (No. D171100002917004); National Natural Science Foundation of China (No. 81870345); the Grant of CAMS

Initiative for Innovative Medicine, China (No. 2016-I2M-1-016) and Central South University Innovation Foundation For Postgraduate (No. 2021zzts0399).

Authors' contributions

CS, HW and TW designed the study. HW, YP, LW, LS and QL enrolled patients and collected data. HW performed the analysis and made the Figs. HW, TW, HH, XL and CS drafted and revised the manuscript. LW and LS helped revise the manuscript. All authors critically reviewed the manuscript. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Neschis DG, Scalea TM, Flinn WR, Griffith BP. Blunt aortic injury. The New England journal of medicine. 2008;359(16):1708-16.
2. Belkin RN, Kalapatapu SK, Lafaro RJ, Ramaswamy G, McClung JA, Cohen MB. Atherosclerotic pseudoaneurysm of the ascending aorta. Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography. 2003;16(4):367-9.
3. Zhang C, Chen B, Gu Y, Luo T, Yang S, Liang W, et al. Tuberculous abdominal aortic pseudoaneurysm with renal and vertebral tuberculosis: a case and literature review. Journal of infection in developing countries. 2014;8(9):1216-21.
4. van den Akker PJ, Brand R, van Schilfgaarde R, van Bockel JH, Terpstra JL. False aneurysms after prosthetic reconstructions for aortoiliac obstructive disease. Annals of surgery. 1989;210(5):658-66.
5. Stefanczyk L, Elgalal MT, Chrzastek J, Szubert W, Czeczotka J, Papiewski A, et al. Pancreatitis-related abdominal aortic pseudoaneurysms treated with stent-grafts. Annals of vascular surgery. 2012;26(5):730 e7-11.
6. Queiroz AB, Silva ES, Aun R, Benitti DA, Bertoldi V, Puech-Leao P. Abdominal aortic pseudoaneurysm diagnosed 42 years after abdominal gunshot wound. Clinics. 2011;66(6):1113-4.
7. Wang A, Zhou Y, Huang Q. A fish bone induced aortic arch pseudoaneurysm in a male patient: A case report. Medicine. 2019;98(29):e16486.
8. Kim SW, Lee DY, Kim MD, Won JY, Park SI, Yoon YN, et al. Outcomes of endovascular treatment for aortic pseudoaneurysm in Behcet's disease. Journal of vascular surgery. 2014;59(3):608-14.
9. Gandhi SS, Blas JV, Lee S, Eidt JF, Carsten CG, 3rd. Nonoperative management of grade III blunt thoracic aortic injuries. Journal of vascular surgery. 2016;64(6):1580-6.
10. Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American

- Association for the Surgery of Trauma Multicenter Study. *The Journal of trauma*. 2008;64(3):561-70; discussion 70-1.
11. Choi MS, Cho YH, Kim WS, Lee YT, Jeong DS, Park PW, et al. Favorable Outcomes of Open Surgical Repair for Blunt Aortic Injury in the Era of Endovascular Repair. *The Thoracic and cardiovascular surgeon*. 2017;65(2):105-11.
 12. Piffaretti G, Benedetto F, Menegolo M, Antonello M, Tarallo A, Grego F, et al. Outcomes of endovascular repair for blunt thoracic aortic injury. *Journal of vascular surgery*. 2013;58(6):1483-9.
 13. Garcia Reyes ME, Goncalves Martins G, Fernandez Valenzuela V, Dominguez Gonzalez JM, Maeso Lebrun J, Bellmunt Montoya S. Long-Term Outcomes of Thoracic Endovascular Aortic Repair Focused on Bird Beak and Oversizing in Blunt Traumatic Thoracic Aortic Injury. *Annals of vascular surgery*. 2018;50:140-7.
 14. Mitchell RS, Ishimaru S, Ehrlich MP, Iwase T, Lauterjung L, Shimono T, et al. First International Summit on Thoracic Aortic Endografting: roundtable on thoracic aortic dissection as an indication for endografting. *Journal of endovascular therapy : an official journal of the International Society of Endovascular Specialists*. 2002;9 Suppl 2:II98-105.
 15. Li X, Li Q, Zhang W, Li M, He H, Luo M, et al. Early experience and technical aspects of physician-modified fenestration in thoracic endovascular aortic repair for aortic arch pathologies. *The Journal of international medical research*. 2020;48(2):300060519870903.
 16. He H, Li Q, Wang J, Li X, Li J, Shu C. Early and Midterm Outcomes of Endovascular Repair of Tuberculous Infected Native (Mycotic) Aortic Aneurysms. *European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery*. 2021.
 17. Xue YG, Ma WG, Wu WH, Charilaou P, Huang XY, Liu W, et al. Endovascular Repair for Thoracic Aortic False Aneurysms: Single-Center Experience in 102 Patients. *The Annals of thoracic surgery*. 2016;101(4):1410-7.
 18. Tanizaki S, Maeda S, Matano H, Sera M, Nagai H, Nakanishi T, et al. Blunt thoracic aortic injury with small pseudoaneurysm may be managed by nonoperative treatment. *Journal of vascular surgery*. 2016;63(2):341-4.
 19. Harris DG, Rabin J, Bhardwaj A, June AS, Oates CP, Garrido D, et al. Nonoperative Management of Traumatic Aortic Pseudoaneurysms. *Annals of vascular surgery*. 2016;35:75-81.
 20. Della Schiava N, Arsicot M, Montvener M, Millon A. Successful total endovascular repair of a giant salmonella-infected painful thoraco-abdominal aortic pseudoaneurysm. *Interactive cardiovascular and thoracic surgery*. 2018;27(5):792-3.
 21. Wang S, Wang Q, Liu H, Sun S, Sun X, Zhang Y, et al. Endovascular treatment of thoracic aortic pseudoaneurysm due to brucellosis: a rare case report. *BMC infectious diseases*. 2017;17(1):387.
 22. Mazzalai F, Ragazzi R, Iurilli V, Toniato A, Da Giau G, Ballotta E. Pseudomonas aeruginosa-infected infrarenal abdominal aorta pseudoaneurysm secondary to laparoscopic colorectal surgery: failure of endovascular stent graft treatment after primary open repair failed. *Canadian journal of surgery Journal canadien de chirurgie*. 2009;52(5):E193-4.

23. Atiyah M, Mohsin S, Al Faraidi L, Al-Hawri K, Al Otay A, Al Najashi K. Surgical management of ascending aortic pseudoaneurysm in a 2-year-old boy: a case report. *Journal of medical case reports*. 2018;12(1):98.
24. Zeng L, Shu W, Ma H, Hu J. Aortic injury caused by esophageal foreign body-case reports of 3 patients and literature review. *Medicine*. 2020;99(26):e20849.
25. Xue J, Yao Y, Liu L. Treatment of tuberculous aortic pseudoaneurysm associated with vertebral tuberculosis: A case series and a literature review. *Medicine*. 2018;97(15):e0382.
26. Haidar GM, Hicks TD, Strosberg DS, El-Sayed HF, Davies MG. "In situ" endografting in the treatment of arterial and graft infections. *Journal of vascular surgery*. 2017;65(6):1824-9.
27. Chakfe N, Diener H, Lejay A, Assadian O, Berard X, Caillon J, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2020 Clinical Practice Guidelines on the Management of Vascular Graft and Endograft Infections. *European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery*. 2020;59(3):339-84.
28. Yamamoto Y, Inoue Y, Ichinose T, Nishizawa M, Igari K, Toyofuku T, et al. Multiple Recurrent Pseudoaneurysms after Endovascular Repair of Abdominal Aortic Aneurysm in a Patient with Behcet's Disease. *Annals of thoracic and cardiovascular surgery : official journal of the Association of Thoracic and Cardiovascular Surgeons of Asia*. 2018;24(6):315-9.
29. Liu Q, Ye W, Liu C, Li Y, Zeng R, Ni L. Outcomes of vascular intervention and use of perioperative medications for nonpulmonary aneurysms in Behcet disease. *Surgery*. 2016;159(5):1422-9.
30. Balcioglu O, Ertugay S, Bozkaya H, Parildar M, Posacioglu H. Endovascular Repair and Adjunctive Immunosuppressive Therapy of Aortic Involvement in Behcet's Disease. *European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery*. 2015;50(5):593-8.
31. Czerny M, Eggebrecht H, Sodeck G, Weigang E, Livi U, Verzini F, et al. New insights regarding the incidence, presentation and treatment options of aorto-oesophageal fistulation after thoracic endovascular aortic repair: the European Registry of Endovascular Aortic Repair Complications. *European journal of cardio-thoracic surgery : official journal of the European Association for Cardio-thoracic Surgery*. 2014;45(3):452-7.
32. Lu YQ, Yao F, Shang AD, Pan J. Pseudoaneurysm of the aortic arch: A rare case report of pulmonary cancer complication. *Medicine*. 2016;95(31):e4457.
33. Yang TS, Reddy S, Choi P, Hsia DW. A Challenging Diagnosis of Endobronchial Aortic Pseudoaneurysm. *Annals of the American Thoracic Society*. 2017;14(10):1595-7.
34. Lam L, Kumar A, Hoffman S, Almeida FA. Pseudoaneurysm of Aorta Presenting as Endobronchial Mass. *Journal of bronchology & interventional pulmonology*. 2017;24(2):144-7.
35. Tousek P, Kocka V, Petr R, Ulman J, Hlavicka J, Kolesar M. Use of Amplatzer occluders for treatment of aorto-pulmonary fistulas - case and review of the literature. *Expert review of medical devices*. 2017;14(11):845-7.

36. Shen JY, Zhang HW, Fan KJ, Liao H, Zhang EY, Hu J. Aortoesophageal fistula and arch pseudoaneurysm after removing of a swallowed chicken bone: a case report of one-stage hybrid treatment. *BMC surgery*. 2018;18(1):3.
37. Lock G, Daniels T, Kock L. A patient with lower gastrointestinal bleeding: common history, very uncommon cause, minimally invasive treatment. *Zeitschrift fur Gastroenterologie*. 2018;56(2):133-8.
38. Sedivy P, Spacek M, El Samman K, Belohlavek O, Mach T, Jindrak V, et al. Endovascular treatment of infected aortic aneurysms. *European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery*. 2012;44(4):385-94.
39. van Bogerijen GH, Auricchio F, Conti M, Lefieux A, Reali A, Veneziani A, et al. Aortic hemodynamics after thoracic endovascular aortic repair, with particular attention to the bird-beak configuration. *Journal of endovascular therapy : an official journal of the International Society of Endovascular Specialists*. 2014;21(6):791-802.
40. Lopez Espada C, Linares Palomino JP, Dominguez Gonzalez JM, Iborra Ortega E, Lozano Vilardell P, Solanich Valldaura T, et al. A multicenter study of emergency endovascular repair of the thoracic aorta: indications and outcomes. *Medicina intensiva*. 2019.
41. Mosquera VX, Marini M, Pombo-Felipe F, Gomez-Martinez P, Velasco C, Herrera-Norena JM, et al. Predictors of outcome and different management of aortobronchial and aortoesophageal fistulas. *The Journal of thoracic and cardiovascular surgery*. 2014;148(6):3020-6 e1-2.
42. Jeon YJ, Kim HK, Kim WS, Cho JH, Sung K. Repair of aortoesophageal fistula with homograft aortic replacement and primary esophageal closure. *The Journal of thoracic and cardiovascular surgery*. 2020.
43. Luehr M, Etz CD, Berezowski M, Nozdrzykowski M, Jerkku T, Peterss S, et al. Outcomes After Thoracic Endovascular Aortic Repair With Overstenting of the Left Subclavian Artery. *The Annals of thoracic surgery*. 2019;107(5):1372-9.
44. Malvindi PG, Cappai A, Raffa GM, Barbone A, Basciu A, Citterio E, et al. Analysis of postsurgical aortic false aneurysm in 27 patients. *Texas Heart Institute journal*. 2013;40(3):274-80.

Tables

Table 1: Baseline characteristics of patients (n = 37)

Variables	Values or n(%)
Age(years)	59.5±13.0(30-82)
Male	29(78.4)
Smoking	18(48.6)
Etiology	
Atherosclerosis	13(35.1)
Trauma	7(18.9)
Tuberculosis	7(18.9)
Esophageal foreign bodies	4(10.8)
Systemic vasculitis	3(8.1)
Previous stent grafting	2(5.4)
Unknown	1(2.7)
Location of pseudoaneurysm	
Zone 2	1(2.7)
Zone 3	11(29.7)
Zone 4	25(67.6)
Clinical manifestation	
Chest/back pain or tightness	21(56.8)
Haematemesis, hematochezia or melena	8(21.6)
Trachyphonia	4(10.8)
Hemoptysis	2(5.4)
Fever	2(5.4)
Cough and Sputum	1(2.7)
Asymptomatic	6(16.2)
Comorbidities	
Hypertension	18(48.6)
Coronary artery disease	4(10.8)
Diabetes	3(8.1)
Cardiac valvular disease	1(2.7)
Cardiac arrhythmia	1(2.7)
Renal insufficiency	1(2.7)

Table2. Surgery related details and clinical outcome in zone2/3 and zone4 TAP patients. (n (%))

Variable	Zone2/3 TAP (n=12)	Zone4 TAP (n=25)	Total (%) (n=37)	p
Surgery opportunity				.406
Emergent TEVAR	3 ^a	4	7(18.9)	
Elective TEVAR	9 ^b	21	30(81.1)	
Stent type				
Ankura, Lifetech	5	14	19(51.4)	
Valiant, Medtronic	3	6	9(24.3)	
Hercules, Microport	3	3	6(16.2)	
Zenith TX2, Cook	1	1	2(5.4)	
Relay, Bolton	0	1	1(2.7)	
Early mortality	3	0	3(8.1)	.028
Early morbidity				.642
Acute arterial embolism of lower extremity	1	0	1(2.7)	
Type II endoleak	0	1	1(2.7)	
Secondary intervention	0	1 ^c	1(2.7)	.676
Midterm survival				.013 ^d
3 months	65.6±14.0	100.0±0.0	88.8±5.3	
6 months	56.3±14.8	100.0±0.0	85.8±5.9	
1 year	56.3±14.8	85.0±8.0	75.9±7.5	
3 years	56.3±14.8	85.0±8.0	75.9±7.5	
5 years	56.3±14.8	72.9±13.2	68.3±9.9	

a. Postoperative in-hospital death happened in one case.

b. One zone 2 case received PMF to preserve LSA.

c. Exploratory thoracotomy and aorto-esophageal repair 5 months after TEVAR.

d. Kaplan-Meier method with Breslow test.

Table3. Risk factor analysis of survival outcome for TAP patients after TEVAR.

Baseline	HR	95%CI	<i>P</i>	
Age (y)	1.659	0.414-6.644	.474	
Male sex	1.054	0.219-5.082	.948	
Smoking	1.131	0.303-4.214	.855	
Infection/vasculitis	2.532	0.653-9.814	.179	
Zone2/3	3.279	0.875-12.281	.078	
Comorbidities				
Hypertention	1.951	0.487-7.823	.345	
Cardiac disease	3.899	0.929-16.356	.063	
Peri-operative				
Emergent TEVAR	3.451	0.917-12.994	.067	
Multivariate analysis				
Zone2/3	4.605	1.095-19.359	.037	
Cardiac disease	4.932	1.086-22.403	.039	
Emergent TEVAR	4.196	1.042-16.891	.044	

Figures

Figure 1

(A-D) Preoperative and 1-week postoperative CTA images of a thoracic TAP patient receiving TEVAR and in vitro fenestration of LSA. (E-H) Preoperative and 5-year postoperative CTA images of a thoracic TAP patient undergoing TEVAR.

Figure 2

Kaplan-Meier survival curve based on different locations of TAP lesions (A), different surgery opportunities (B) and different etiologies (C).