Long-Term Outcomes of TEVAR for Thoracic Aortic Diseases: A Retrospective Single-Center Study

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Abstract

Background: Long-term outcomes of TEVAR for different aortic pathologies are still debated for years. The procedural success and outcomes differ by comorbidities and thoracic aortic pathologies. Therefore, we present our ten-year experience, encountered rare complications, and long-term results.

Methods: Between 2006 to 2018, 97 patients underwent endovascular treatment for several indications. The primary endpoints are to explore the leading mortality causes, complications, and reinterventions, evaluate the effects of comorbidities on survival, and compare several indications with survival curves. The second is to investigate rare complications and graft durability in long-term follow-ups.

Results: The most indication was thoracic aortic aneurysm (n=52). Ten patients had aortic arch variations and anomalies, and the bovine arch was observed in 8 patients. Endoleaks were the main encountered complication, and 10 of 15 endoleaks were type 1 endoleak. Total reinvention was 18, and the most intervention was reTEVAR (n=5). Overall mortality was 20, and TEVAR-related death mortality was 12. Multivariant Cox regression revealed chronic renal diseases (OR=11.73; 95% CI:2.04-67.2; p=0.006), previous cardiac operation (OR:14.26; 95% CI: 1.59-127.36; p=0.01), chronic obstructive pulmonary diseases (OR:7.82; 95% CI: 1.43-42.78; p=0.001) to be an independent risk factor for 10-year-survival. There was no significant difference in the Kaplan-Maier survival curves of different aortic pathologies.

Conclusion: In long-term follow-ups, comorbid factors could independently be risk factors for mortality; however, there is no significant difference in endoleaks occurrence. TEVAR is a suitable solution for severe aortic pathologies with similar outcomes. Graft thrombosis in years should be a question on graft durability.

Introduction

Thoracic aortic diseases (TAD) represent a broad spectrum that includes thoracic aortic aneurism (TAA), aortic dissection (AD), penetrating aortic ulcer (PAU), intramural hematoma (IMH), traumatic aortic injury (TAI), aortic coarctation (AC)[1]. Since procedural simplicity and easy adaptability have become more favored in a short time widespread for all TAD [2, 3]. To assess the operational success in different aortic pathologies and the relationship with comorbidities, it is certain that long-term follow-up is required [3, 4]. Some complications such as endoleaks, graft breakage, graft defects, stent migration, and intracranial bleeding are detected in the early phase. However, the post-implantation syndromes, new onset of mural thrombosis inside the grafts, or graft thrombosis in years are vaxed questions for graft durabilities and it was only mentioned in case reports not in series[5, 6]. Therefore, the series become lacks assessments for rare complications. Indications are expanding, new graft brands are developing, and endovascular operational success is changing. Therefore, the studies including long-term results of TEVAR continue their importance in contributing to the literature.

We represent the 10-year follow-up results of TEVAR procedures, which we applied to 103 patients between 2006–2018. Our retrospective study aims to share our clinical TEVAR experience and long-term follow-up results.

Material And Methods

This study was reviewed and approved by the Ankara University Institutional Review Board, and the requirement for individual patient consent was waived (Approval no: 13-860-18.)

Data Source:

All patients enrolled at Ankara University from 2006 to 2018 were included. Our first patient was a 37-year-old male with TAI due to a traffic accident and it was the first TEVAR application in Turkey. The number of procedures almost increased year by year, and 103 patients had treated in 12 years (Fig. 1). We obtained demographic data, comorbid diseases, laboratory results, radiological images, and clinical and operational details from archive files or telephone clinical assessments. Telephonic and outpatient clinical assessments were reviewed. Complications and adjunctive procedures were determined. Imaging modalities such as aortic arch variants, anomalies, endoleak classification, measurements, graft landing zones, and graft landing length were investigated. Six patients were excluded since inadequate records, not to be achieved CT controls, or lost follow-up records. We investigated risk factors and survival analysis with the rest.

Procedures, Variables, Outcomes, and Statistics:

We performed TEVAR with a broad spectrum of aortic pathologies. TAA was the most treated aortic disease, and AD followed. Only one patient with type A aortic dissection was treated with TEVAR, and other patients with AoD were type B aortic dissections. For type B dissections, indications were an aortic enlargement above 5.5 mm, persistent chest pain, or complicated dissection, as previously described in the literature [7, 8].

The procedures were performed in a hybrid operating room, and TEVAR grafts were sealed thoracic aorta via the femoral artery under general or local anesthesia. We used Medtronic Valiant® grafts in 73 patients, Gore TAG® grafts in 20 patients, and Jotec E-Vita® grafts in 4 patients. In the TEVAR procedure, a single graft was used in 69 patients, two grafts in 23 patients, and three grafts in 5 patients. In total, 131 TEVAR grafts were used. The most used graft size is Medtronic Valiant® 46x46x200 (Table 1). In terms of graft properties, we investigated the relationship between graft brand, diameter, landing zone and length, the number of grafts used, and the success of TEVAR. While exploring the effect of graft diameter and sealing length on mortality and morbidity, we tried to identify a cut-off point. ROC (receiver operating characteristic) analysis determined the cut-off point, and graft characteristics were categorized.

Table 1
Demographic data, intervention zones, detected arch anomalies, and graft brands

Demographic, anatomic, and operative characteristics of TEVAR recipients			
Male			72
Etiology			
	Thoracic Aortic Aneurism		52
		Type 1	34
		Type 2	10
		Type 3	3
		Type 5	5
	Thoracic Aortic Dissection		
		Type A	1
		Type B	28
	Penetrated Aortic Ulcer		5
	Traumatic Aortic Injury		6
	Intramural Hematoma		4
	Aortic Coarctation		1
	Ruptured Aneurysm		9
		Due To Dissection	1
		Due To Aneurism	8
Intervention Zone			
	Zone 0		4
	Zone 2		32
	Zone 3		33
	Zone 4		28
Aortic Arch Anomalies and Variants			10
	Bovine Ark		8
	Commeral Diverticula		1
	Vertebral Artery Anomalies		1
Graft Brands			
	Gore Tag		20

Demographic, anatomic, and operative characteristics of TEVAR recipients		
	Medtronic	73
	Jotec Evita	4

The complications in patients are summarized. Some patients had more than one complication, and more than one intervention was performed. The procedural complications were assigned a severity score. Primary endoleaks detected in the operational room were tried to solve as needed. In postoperative periods, endoleak detection was performed using a contrast-enhanced CT scan. We aimed to investigate secondary type 1 and type 3 endoleaks after perioperative periods (> 30 days) and to assess the effects on long-term mortality. The secondary interventions, adjunctive procedures, and concomitant procedures were all documented (Table 2).

Table 2
TEVAR complications and re-interventions

Complications			**n**
Endoleak			15
	Type 1		10
		Type 1a	6
		Type 1b	4
	Type 2		5
	Type 3		3
	Type 5		3
Neurologic Complications			8
	Subdural Hematoma (SDH)		1
	Subarachnoid bleeding (SAB)		3
	Epidural hematoma		1
	Stroke		3
	Spinal Cord Ischemia (SCI)		3
Contrast Nephropathies			2
Groin Incision Complications			6
	Seroma		3
	Hematoma		2
	Peripheric Vascular Complications		1
Graft Infection			1
Upper Limp Ischemia			1
Bowel Ischemia			1
Retrograde Aortic dissection			1
Vertebrobasilar Insufficiency			1
Re-interventions			**n**
Total re-interventions			18
Re-TEVAR			5
Coil Embolization			3
EVAR			3

Complications	n
Bowel Resection	1
Iliac Artery-Mesentery Artery Bypass	1
Subdural Hematoma Drainage	2
Supraaortic Revascularization (SAR)	1
Carotis-subclavian Bypass (CSB)	1
Intra-aortic Balloon Contra pulsation (IABP)	2
Femoral-femoral Artery Crossover Bypass	1
Stent to Subclavian Artery Aneurysm	1
Groin Revision	3
Carotid-carotid Artery Bypass	1

In terms of proximal landing zones (PLZ) regarding Ishimaru’s classification, the cases were divided into groups. For sealing in zone 0, before the TEVAR operation, the supra-aortic branches were revascularized utilizing a sternotomy with complete arch de-branching surgery with Dacron tube grafts. For sealing Zone 2, the left carotid-subclavian bypass (CSB) was performed even if the left subclavian artery was fully covered as previously described [9]. Aortic de-branching surgery was performed for 4 patients to maintain the optimal PLZ, and TEVAR with zone 0 sealing was performed. Zone 2 sessions were made for 32 patients, zone 3 for 33 patients, and zone 4 and below graft landing for 28 patients.

Our initial strategy for the prevention of SCI was to employ CSB and cerebrospinal fluid drainage (CFD). CSB was performed in 22 of 33 patients with Zone 2 landing. Upper extremity ischemia occurred for one emergency patient who could not perform CSB, solved by immediately performing CSB. Selectively prophylactic cerebrospinal fluid drainage (CFD) was performed at the high risk of spinal cord ischemia (SCI) as previously described [10]. Prophylactic CFD was selectively applied to 20 patients who had a risk for SCI. According to the surgical procedure, patients were divided into having made CFD, carotid-subclavian bypass (CSB), and including the T8 segment coverage, or not.

Comorbid diseases and factors; hypertension (HT), hyperlipidemia (HL), chronic obstructive pulmonary disease (COPD), peripheral artery disease (PAD), cancer, diabetes mellitus (DM), atrial fibrillation (AF), heart failure (HF), anticoagulant use, previous cardiac intervention, chronic renal failure (CRF) was included. Seventy-six patients had hypertension, 43 patients had dyslipidemia, 25 patients had COPD, 25 patients had peripheral artery disease, 14 patients had cancer, 11 patients had type 2 DM, eight patients had atrial fibrillation, and eight patients had heart failure. In diabetic patients, 11 patients were taking oral anticoagulants, and there was no patient using insulin. Sixteen patients had a cardiac operation history; 9 of these operations were CABG. Fifteen patients had creatinine values above 1.6, and 3 patients received dialysis.

All patients enrolled were documented according to their indications and aortic pathologies. The relationship between graft landing zones and mortality was another topic of the study.

The categorized data were analyzed with the chi-square test, Fisher exact test, and Cox regression test. Potential risk factors on 10-year survival and endoleak occurrence were investigated with Cox regression analysis. According to aortic pathologies, the Kaplan Maier analyses were performed.

All statistical analyses were performed using SPSS 20.0 for Windows (SPSS Inc, Chicago, IL). Significance was accepted below $p < 0.05$ in all groups. Confidence intervals (CI) were accepted with over 95%.

Results

We investigated 97 patients who underwent TEVAR operations from 2006 to 2018. According to the aortic pathology, 52 patients had TAA, 29 patients had AD, six patients had TAI, 4 patients had IMH, 5 patients had PAU, and one patient had AC. When the TAI group was examined, five patients had blunt thoracic injuries after a traffic accident, and one patient had an iatrogenic aortic injury due to endovascular intervention. Nine patients with preoperatively ruptured TAA were operated on in an emergency.

Aortic arch anomalies or variants were detected in ten recipients. The most common arch variation was a bovine arch, and it was found in 8 patients and included the right-left brachiocephalic artery in one. One patient had an aberrant right subclavian artery and kommerell diverticulum, and one patient had a vertebral artery anomaly.

The most common complication was endoleaks. In the 10-year follow-up, 15 patients had endoleaks and type 1a in 6 patients, type 1b in 4 patients, type 2 in 5 patients, type 3 in 3 patients, and type 5 in 3 patients, respectively. Some patients had multiple endoleaks, and we did not encounter type 4 endoleaks. Our treatment for type 1 endoleaks was re-TEVAR or balloon dilatation for an excellent fixation and seal. We used glue or coil embolization on the left subclavian artery for the treatment of type 2 endoleaks. Two Type 3 endoleaks were seen after multiple graft applications and were treated with balloon dilatation. The rest disappeared in follow-up without any intervention. All aneurysm expansions (type 5 endoleaks) vanished in outpatient follow-up.

Intracranial hemorrhage occurred in 4 patients, including one subdural hematoma (SDH) and three subarachnoid hemorrhages (SAH). One of these occurred due to a coumadin overdose in the postoperative second month and was successfully treated with decompression surgery. Except for this, all patients with intracranial bleeding after TEVAR applications died. CFD was performed for these three patients previous to the operation. Spinal cord ischemia (SCI) and paraplegia in three patients (3%), and cerebrovascular event (CVE) in two patients (2%) occurred. Temporary paraplegia developed in 1 patient with epidural hematoma, and permanent paraplegia in 2 patients occurred. Epidural hematoma related to the CFD catheter was detected in one patient (Fig. 2a). Laminectomy was recommended, but the procedure was canceled by the resolution of paraplegia in two days.

The contrast nephropathy was observed in 10 patients. All patients except one returned to pre-procedure creatinine and average values after conservative medical treatment. Access site complications were seen in 5 patients. One patient was a peripheric embolism, and an embolectomy was performed. Short-segment dissection in femoral access occurred and the femoral artery was repaired in one patient.

Bowel ischemia occurred in one patient due to the progression of the aortic dissection to the superior mesenteric artery (SMA). There was also extremity ischemia. Therefore, the femoral-femoral artery bypass was applied first and then the femoral-SMA bypass was accomplished. Despite all efforts, the patient died on the postoperative 5th day.

Symptomatic vertebrobasilar insufficiency occurred in one patient after the TEVAR procedure and the left carotid-subclavian bypass was performed. However, the flow measurements were insufficient, then a carotid-carotid bypass was accomplished.

Retrograde dissection was seen in one patient. After TEVAR sealing Zone 3 for type B aortic dissection, type 1a endoleak occurred in the follow-ups. Re-TEVAR was performed by sealing Zone 2 and coil embolization was performed for the type 2 endoleak from the left subclavian artery. However, a new type 1a endoleak occurred due to retrograde dissection. At last, the patient was successfully treated with a re-TEVAR sealing zone 0 following the aortic debranching surgery.

TEVAR graft infection, another rare complication, occurred in 1 patient. There were infection symptoms like fever, weight loss, sedimentation, and high CRP levels. Although the blood cultures were negative, F-FDG PET provided a conclusive diagnosis with round FDG uptake (Fig. 2b). Fever and infection parameters decreased by using antibiotics during the outpatient controls.

As a rare complication, intragraft thrombosis was observed in 2 of our patients in years. Asymptomatic stenosis in the graft lumen was diagnosed in two patients in the fourth and seventh years postoperatively. For both, we decided on medical treatment and follow-up (Fig. 2c)

During the 10-year follow-up, 20 patients died. We aimed to focus on the investigation of TEVAR-related mortalities. Eight deaths were not related to the procedure, as three patients died due to cancer, one died due to multiple organ traumas, spleen rupture, hemothorax, and crush syndrome, one died due to sepsis, one died due to kidney failure after subsequent EVAR procedure, one died due to pneumonia, one died due to advanced age and other comorbid diseases. One patient died after two years following a successful TEVAR operation due to a complication of EVAR for an abdominal aortic aneurysm. These patients were excluded; the number of TEVAR-related mortality was 12. Eight of these patients died in the first postoperative month. The causes of short-term mortality were ruptures in 3 patients, SAH in 2 patients, SDH in 1 patient, and cardiac arrest in 1 patient, respectively. One patient died due to an aortic-bronchial fistula and a newly developed rupture after the TEVAR operation (Table 3).

Table 3
Overall causes of all mortality

Causes of All Mortality After TEVAR	**20**
Causes of Procedure-Related Mortality	12
Rupture	3
Rupture after implantation	1
Cerebrovascular events	3
Cardiac arrest during the procedure	1
Sepsis	1
Bowel Ischemia	1
Peripheral embolism	1
Aortobronchial fistula	1
Other Causes	8
Cancer	3
Crush Syndrome	1
Sepsis	1
CRI	1
Pneumonia	1
EVAR related	1

A 10-year follow-up investigated comorbidities, mortalities, and endoleak. COPD increased TEVAR-related mortality (p = 0.018, 95% CI: 1.43–42.78). Having a cardiac operation increased the mortality (p = 0.01, 95% CI: 1.59-127.36). The mortality rate was higher in the chronic renal failure group (p = 0.006, %95 CI: 2.04–67.2). ROC curves were analyzed for the relationship of TEVAR-related death according to the grafts' proximal diameters, and session lengths, 38 mm for diameter and 25 cm for length, were obtained as the cut-off values. Mortality increases as the length of graft sealing increases to 25 cm or more (p = 0.08, %95 CI: 1.59–22.56). There was no relationship between the use of 38 cm or more grafts' diameter and mortality. As the number of grafts used increased, mortality increased. Using three grafts or more had significantly worse survival (p = 0,035). 42 patients were operated on as ASA 2, 35 as ASA 3, and 20 as ASA 4. ASA classification correlated with TEVAR-related mortality. Especially patients with ASA 4 had significantly higher mortality (p = 0,006) (Table 4).

Table 4
Cox regression analysis of comorbidities on ten years-TEVAR related mortality and risk estimation of comorbidities in terms of endoleak occurrence

	n	Mortality	CI	OR	p	Endoleak	CI	OR	p
Demographical Characteristics									
Age (mean = 61)		12	0.94–1.03	0.98	0.62	12	0.95–1.03	0.99	0.86
Sex (Male)	72	11	0.02–1.79	0.216	0.62	13	0.12–2.82	0.58	0.5
Comorbidities									
Hypertension (HT)	76	9	0.12–7.23	0.94	0.95	14	0.50-33.36	4.11	0.18
Dyslipidemia (DL)	43	3	0.02–0.92	0.15	0.04	9	0.26–3.79	0.99	0.99
COPD	25	8	1.43–42.78	7.82	0.01	5	0.73–9.21	2.6	0.13
Peripheric Vascular Diseases	21	3	0.09–3.38	0.55	0.52	3	0.22–6.79	1.23	0.81
Malignity	14	3	0.19–7.70	1.23	0.82	2	0.61–20.45	3.54	3.54
DM	11	2	0.44–64.69	5.37	0.18	1	0,16-17.95	1.71	0.52
AF	8	2	0.33–48.97	4.06	0.27	1	0.35-116.67	6.44	0.2
Chronic Heart Failure (CHF)	8	1	0.06–23.93	1.21	0.89	0	0-.	0	0.98
Anticoagulant Usage	11	1	0.01–1.59	0.11	0.1	3	0.23–13.4	1.78	0.57
Previous Cardiac Operation	16	4	1.59–127.3	14.26	0.01	5	0.2–9.55	1.38	0.74
Chronic Renal Disease (CRD)	18	5	2.04–67.20	11.73	0.006	1	0.03–2.82	0.3	0.65
ASA score									
2	42	3	-	-	0.01	5	-	-	0.79
3	35	3	0.24–6.09	1.23	0.8	9	0.58–5.24	1.75	0.31

	n	Mortality	CI	OR	p	Endoleak	CI	OR	p
4	20	6	1.89–48.16	9.55	0.006	1	0.17–13.31	1.52	0.7
Operational comorbidity									
T8 cover	48	8	0,53 – 6,69	1,8	0,32	11	0,88 – 1,01	3,35	0,052
CSB	22	4	0,36 – 4,05	1,2	0,75	6	0,18 – 2,12	1,61	0,44
CSFD	20	4	0,45 – 5,81	1,6	0,45	4	0,19 – 1,51	1,8	0,26
Comorbidities related to Endograft Features									
38 mm and above	38	7	0,28 – 4,03	1,08	0,18	7	0,36-,4,29	1,25	0,72
25 cm and above	20	7	1,59 – 22,56	5,99	0,08	6	0,92 – 11,46	3,24	0,06
The number of endograft									
1	74	5	-	-	0,59	11	-	-	0,39
2	18	4	0,85 – 10,72	3,02	0,87	2	0,20 – 4,23	0,92	0,92
3	5	3	1,13–27,93	5,62	0,035	2	0,61 – 12,62	2,78	0,18

Secondary type 1 and type 3 endoleaks were investigated and risk factors were assessed. No factors affect endoleak occurrence. In terms of the operational details; 25 cm and above graft sealing and T8 coverage had increased endoleak risk, however, it was not significant (OR:3.35; 95% CI: 0.88–1.01, p = 0.052 and OR:3.24; 95% CI: 0.92–11.46; p = 0.06, respectively).
Acute aortic syndromes including AoD, PAU, IMH, TAI, and ruptured TAA were examined, and there were 53 patients (54%). In terms of TEVAR-related mortality, there was no significant difference in Kaplan Maier survival analysis according to aortic pathologies (p = 0.35).

According to cumulative TEVAR-related mortality, 1-month mortality was 8%, 6-month mortality was 9%, 1-year mortality was 10%, 5-year mortality was 12%, and 10-year mortality was 12%. The most reason for TEVAR-related mortality was rupture (n = 4). There were three ICHs as other serious complications. The most common reason for mortality unrelated to TEVAR was lung cancer and respiratory failure (n = 3).

According to aortic pathologies, the highest mortality rate was observed in ruptured aortic aneurysms in survival analysis. Mortality and secondary type 1 and type 3 endoleak were not detected in TAY, PAU, and AC. Survival analysis between groups was performed by Kaplan Maier analysis, and there was no significant difference. Survival curves AD and TAA were so similar. There was no mortality at Zone 0 TEVAR landing following the aortic debranching surgery. The highest mortality rate was observed in Zone 2 landing. Although zone 4 interventions had relatively more minor mortality, there was no statistically significant ($p = 0.27$) (Fig. 3).

Discussion

Thoracic aortic diseases are one of the main interests of cardiovascular surgeons due to their severe mortality and morbidity rates. With the widespread use of diagnostic tests and the ability to perform BT angiography in many centers, the number of patients diagnosed TAD has increased. Therefore, the yearly cost of aortic diseases in the health economy increases. TEVAR is being applied more and more every day because of its low cost, easy application, and easy adaptability [3]. We see a similar increase in the number of patients who underwent TEVAR over the years (Fig. 1). Additionally, zone 0 hybrid interventions increase our experience with complicated aortic diseases. Debraching surgery previous to TEVAR helps maintain the adequate sealing zone [11]. Aortic debranching surgery has been performed in 4 patients with zone 0 landings in our series as a hybrid operation. However, there was no zone 1 landing TEVAR limited our series.

According to the demographics, 74% of the patients who undergo TEVAR were male, and 26% were female. The ratio of men to women was 3:1 in our series. Especially in aortic aneurysms, the female-male balance favors men [12]. The sex difference does not affect the outcomes, as some papers claimed [13]. Our finding was correlated with the literature. The median age of patients treated with TEVAR is 64, and the women are ten years younger than the men. The youngest patient is a 23-year-old AK female patient, and the oldest patient is an 87-year-old male patient with AoD. Age was not associated with higher odds of mortality and endoleak. Despite the lack of long-term follow-up results for young patients, some centers preferred TEVAR in adolescents [14]. Especially, a 23-year-old patient with TEVAR, the youngest patient in our series, is an example of a successful mid-term result.

After retrospectively examining the images of the patients, arch anomalies and variants were detected in ten patients. The most common arch variant was a bovine arch. Our series had similar incidence rates to the literature[15]. Variants are more prevalent in patients with AD due to flow hemodynamics [16], however having arch anomalies did not affect our surgical or endovascular treatment preferences, which did not differ the outcomes. TEVAR treatment is safe and effective in arch anomalies and variants.

Despite continued innovation in endograft engineering, TEVAR-related complications remain the biggest problem in long-term follow-up. Recipients should be followed closely in terms of complications, especially for endoleaks because of a high incidence (4–24%) [17]. Endoleaks were seen at a rate of 15% in our series. Five patients had more than one endoleak type. Type 1 endoleaks are the most common type of endoleak in our series and the most intervention-required type, too. The balloon dilatation was the first solution for type 1 endoleaks, however, re-TEVAR was applied in some cases. Type 2 endoleaks were the second most common. It mainly occurred due to the left subclavian artery with zone 2 landing TEVAR and causing re-intervention. Coil embolization could be a good solution for solving type 2 endoleaks. Type 3 endoleak was observed in multiple graft usage, and we solved it with balloon dilatation. Type 5 endoleaks were in three of our patients who had an aneurysm sac enlargement without any detected leakage. We followed and watched all of them, and the resolution of all type 5 endoleaks was maintained without any intervention. There was no type 4 endoleak. The absence of type 4 endoleaks is probably associated with developed graft technologies in use.

Retrograde aortic dissection is another severe complication after TEVAR, and its incidence and mortality are 2.5% and 37%, respectively [15]. Our series occurred in one patient, and we performed two times reTEVAR interventions. No endoleak or dissection was detected in the follow-up after the last intervention.

Neurological complications related to TEVAR are the most dreaded complications even though they are rare. The incidence of paraplegia after TEVAR is between 0 and 12.5%, with a wide range of incidence, but it is between 3% and 6% [18]. With the proven that CFD dropped the SCI rates at conventional thoracic aortic surgery by increasing spinal cord perfusion pressure, it has also become a favorite for SCI protection at TEVAR. However, controversy over CFD usage at TEVAR continues [19]. Some surgeons perform prophylactic CFD in all patients undergoing TEVAR, while others perform selective CFD using salvage CFD only when necessary. It is reported in a historical paper that 8% of paraplegia is seen in TEVARs performed without CFD. A systematic review showed that the pooled SCI rate without routine prophylactic drainage was around %1.98–5.37, despite the SCI rate with regular prophylactic drainage being %1.7–5.1 [20]. In addition, CFD causes some complications, and they are closely related to CFD [21]. Even though we performed preoperatively selective CFD, paraplegia occurred in three patients. Intracranial hemorrhage was another severe cause of death related to CFD. ICH occurred in 4 patients and could be associated with CFD. SAH occurred in two patients, and SDH occurred due to extensive drainage for SCI in one patient. Three patients died due to ICH. Epidural hematoma is a rare complication of CFD [22]. In one case, after unilateral paralysis developed on the second postoperative day, the patient was diagnosed epidural hematoma (Fig. 2). The paraplegia regressed in the follow-up, and healed without any sequelae. Stroke is a serious neurological complication associated with high mortality after TEVAR. In the literature, stroke rate is between 2% and 8% [23]. In our study, the stroke occurred in three patients.

The rate of bowel ischemia is around 0.6%-2.8 in EVAR; however, it is highly mortal [24]. In one patient with complicated type B dissection, the false lumen closed, and mesenteric ischemia developed with the expansion of the true lumen. Abdominal pain and elevated lactate value indicated bowel ischemia with an inadequate collateral network. The diagnosis was confirmed with emergency laparotomy. Although the patient underwent an iliac artery mesenteric superior bypass, the complication was mortal due to reperfusion injury.

Intragraft thrombosis has been reported in minimal case studies as a late device-related complication [25]. In our series, intragraft thrombosis was detected incidentally in two patients with less than 50% stenosis (Fig. 2c). There was no need for additional intervention because of the asymptomatic prognosis. We continued treatment with antilipemic and antiplatelet therapy.

The relationship between comorbid factors and TEVAR mortality, procedural success, and endoleak has been investigated in many studies [1, 26–28]. We found that COPD and CRD increased mortality as in the literature [29]. Interestingly, there was no endoleak in patients with chronic heart failure (CHF) [30]. Although there was no data on drug use in our study, CHF medical therapy (such as maximally tolerated B blocker therapy, and antihypertension medications) could protect cardiac remodeling and help aortic remodeling and aortic stability by reducing shear stress and downregulation of matrix metalloproteinases on the aortic wall. DM is a significant risk factor for mortality in cardiovascular diseases; however, recent studies provide evidence of a lower aortic aneurysm rate in patients with DM. Despite the unknown mechanism, hyperglycemia was reported to reduce experimental AAA diameter [31]. In our study, there was no significant effect on outcomes.

We evaluated all patients with ASA classification preoperatively, which is the most helpful in predicting perioperative risks. We found that, as the ASA score increased, mortality significantly increased likely in the literature [32]. Risk factors in terms of graft characteristics were determined with Roc analysis, and mortality increased with aortic coverage length larger than 25 cm. Similarly, although endoleak and mortality were seen more in grafts larger than 38 mm diameter, it was not statistically significant. As the number of grafts increased, the success of the procedure decreased.

In the 10-year survival analysis, more deaths occurred during the first perioperative 30-day follow-up. Cumulative TEVAR-related mortality was 8% for one month, 9% for six months, 10% for one year, 13% for five years, and 13% for ten years, respectively. The most common cause of TEVAR-related mortality was a rupture. 10-year total mortality was twenty, and its rate was 21%. The highest number of deaths was due to lung cancer. The rupture was the most common cause of TEVAR-related mortality. After a relatively high rate of procedural mortality, the mortality rate decreased over the years. In this respect, the survival curve resembles more likely long-term results of conventional surgery in aortic diseases [33, 34]. Patients were separated according to their etiology, and survival analyses were compared. There was no difference between the groups in terms of survival. However, no mortality and endoleak was seen in PAU, AC, and TAI. TEVAR procedural success in these aortic diseases is also high in other series [29, 35]. Significantly, the long-term durability of TEVAR for TAI was considerably superior [35, 36]. The survival curves of the patients according to their landing zones were investigated. Although there was no significant difference, zone 2 and zone 3 sealing associated with the left subclavian artery landing zone had higher endoleak and mortality. More successful results in the zone 0 landings encourage us about hybrid endovascular interventions and postoperative outcomes were excellent [37].

Conclusion

Multicenter trials confirmed that TEVAR could be used safely to treat TAD. However, long-term complications limited the outcomes. Establishing an endovascular team is vital to determine the appropriate treatment for the suitable patient and detect complications, to provide the solution. Hybrid interventions and flexibility in treatment increase operational success.

We found no significant difference in types of aortic diseases. With long term results in TAI treatment, the durability of the endograft is high and provides successful treatment for suitable young patients. Even though we encountered rare complications, it is important to mention them in the long-term series. Being a single-center retrospective study and having a small size amount limit our results.

Declarations

Declarations of interests:

None

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Figures

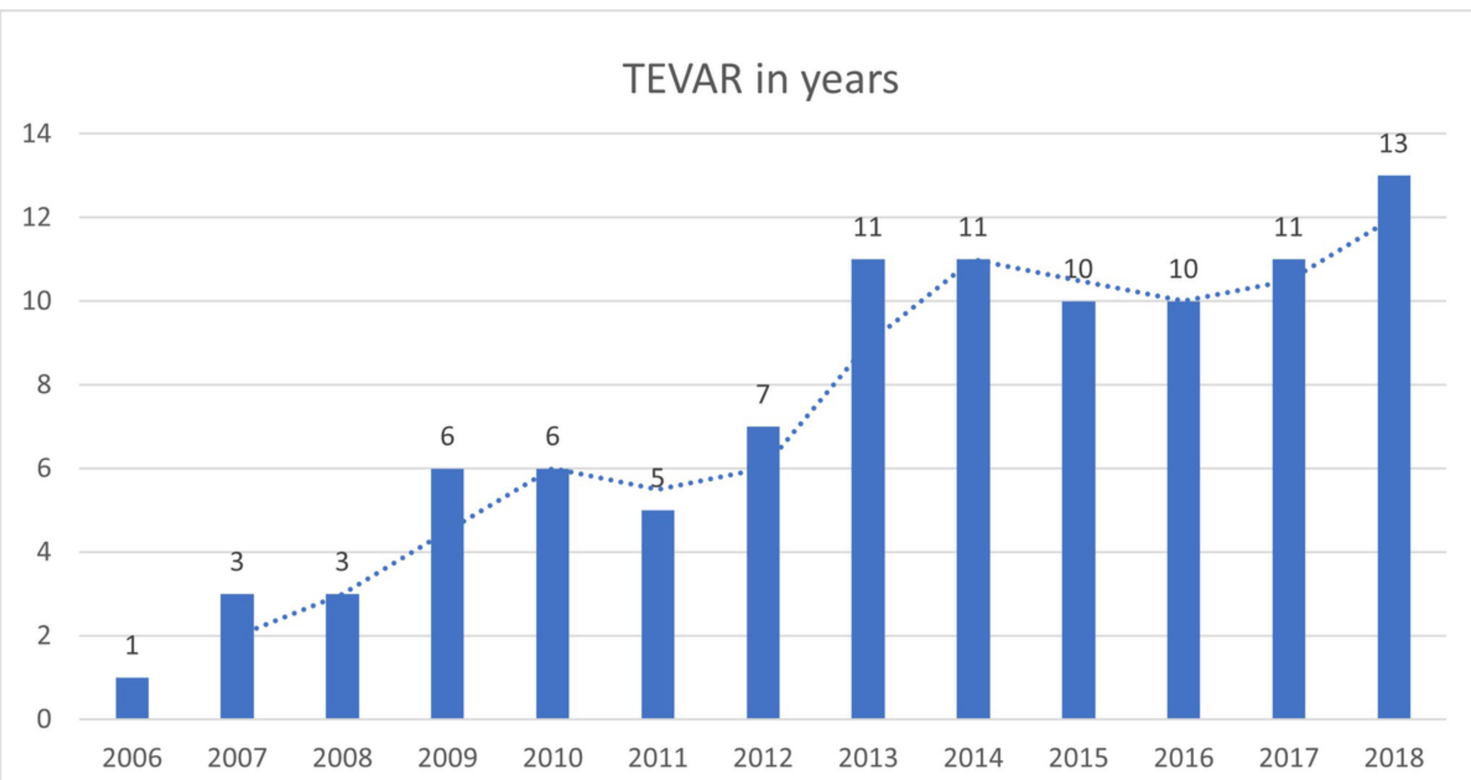

Figure 1

Numbers of TEVAR procedures over the years

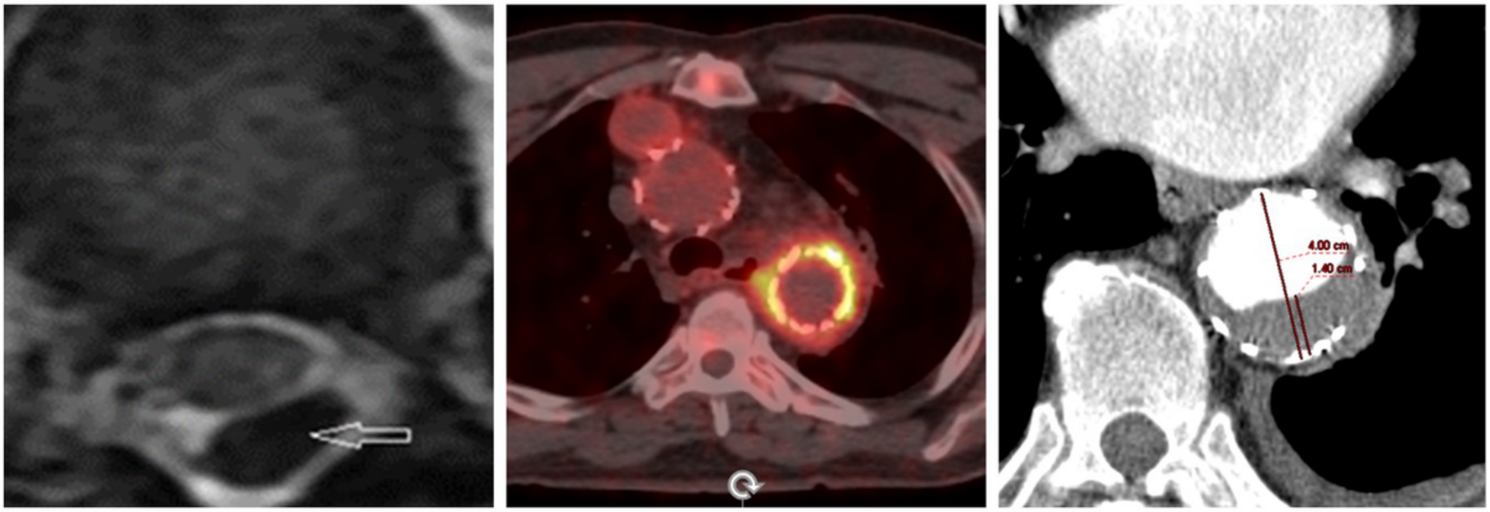

Figure 2

2a (at the left): Epidural hematoma after CSF drainage in postoperative 5th day, Figure 2b (in the middle): Infected graft detected with PET CT, Figure 2c (at the right): 14 mm diameter intragraft thrombosis

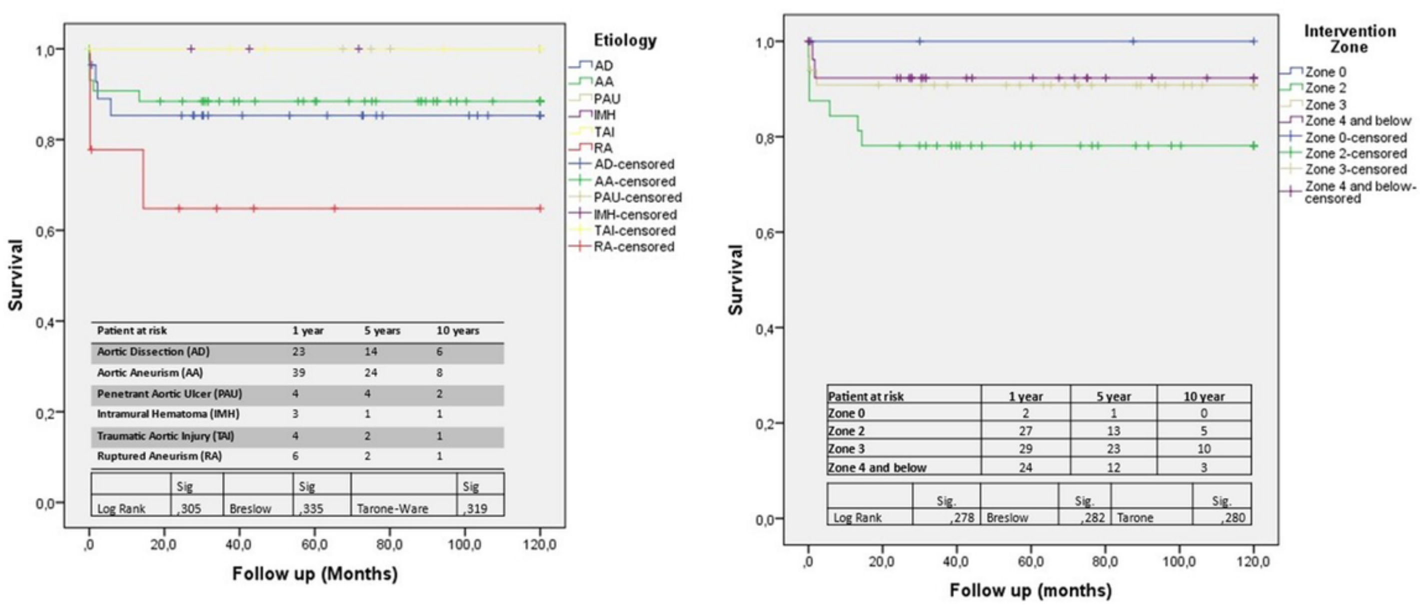

Figure 3

Kaplan-Meier long-term survival curve comparing etiology and intervention zone