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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Outcomes of endovascular treatment of thoracic aorta pathologies: 10-year single-center results

Mustafa Emre Akın
Koray Akkan
Abdullah Özer
Erhan Turgut Ilgıt
Baran Önal
Gürsel Levent Oktar

PURPOSE
Thoracic endovascular aortic repair (TEVAR) is a safe and effective treatment method for a variety of thoracic aortic pathologies. We aimed to investigate the mortality and complication outcomes and associated factors of TEVAR treatment in Turkey.

METHODS
In this single-centered retrospective study, patients with thoracic aorta pathologies treated with TEVAR at Gazi University School of Medicine, Department of Radiology, between January 2009 and January 2020 were included. Perioperative, early, and late mortality, complications, and technical success were the outcomes.

RESULTS
The sample comprised 58 patients with 68 TEVAR interventions. Eleven (16.2%) patients were female, the mean age was 60.1 ± 13.4 years. Emergent TEVAR was required in 20.7% of the patients. The main indications of TEVAR were intact descending aorta aneurysms in 37.9% of the sample, 31.0% Stanford type-B dissection, and 12.1% traumatic transections. The technical success rate of primary and secondary interventions was 98.3% and 100%, respectively. The mortality rate in the first 30 days was 8.6%. Seventeen (29.3%) cases had at least 1 complication related to TEVAR treatment. The most common complication was type-1A endoleak (10.3%). Having acute symptoms, stroke, and acute renal failure were significantly associated with mortality ($P = .020$, .049, and .009, respectively).

CONCLUSION
This study reported the outcomes of TEVAR treatment from a tertiary medical center in Turkey over a decade. Patients presenting with acute symptoms and who developed stroke and acute renal failure after the procedure should be carefully followed up as these factors were found to be associated with mortality.

Thoracic aorta pathologies are a spectrum of diseases composed of aneurysms, dissections, traumatic injuries, penetrating atherosclerotic ulcers (PAU), and intramural hematomas. Thoracic endovascular aortic repair (TEVAR) is a safe and effective treatment method described and used with increased frequency. Lower rates of complications like renal failure, paraplegia, stroke, lower blood transfusion requirement, and lower mortality rates, as well as shorter hospitalization time, make TEVAR a successful treatment alternative to open surgery regarding thoracic aortic pathologies.[1-3] TEVAR has become the treatment of choice for descending aortic aneurysm,[4-6] complicated type-B dissections,[7] and traumatic transections.[8]

While TEVAR has been used widely around the world, mortality and complications such as endoleak, stroke, renal failure, myocardial infarction, hemorrhage, thrombus, migration, and loss of graft integrity have been reported during follow-up.[4-6,9-14] This study aimed to investigate the mortality and complication outcomes in the first year after the TEVAR procedure and associated factors in patients with a variety of thoracic aorta pathologies.

Methods

Patients with thoracic aorta pathologies treated with TEVAR between January 2009 and January 2020 at Gazi University Department of Radiology were included in this

From the Department of Radiology (M.E.A. ✉ dremreakin@gmail.com, K.A., E.T.I., B.Ö.), Gazi University School of Medicine, Ankara, Turkey and Department of Cardiovascular Surgery (A.Ö., G.L.O.), Gazi University School of Medicine, Ankara, Turkey.

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single-centered retrospective study. Computed tomography angiography (CTA) and digital subtraction angiography (DSA) and images were obtained to evaluate the primary aortic pathology, vertebral artery dominancy, and cerebral circulation in all patients before the treatment and TEVAR indication is established with the consensus of Interventional Radiology and Cardiovascular Surgery after clinical and radiological evaluation.

Gazi University Ethics Committee approved the study (approval date: November 10, 2014, decision number:509). Informed consent was not obtained from participants as the study design was retrospective. The research was conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

TEVAR procedure was performed under general anesthesia in all cases with a multidisciplinary approach by a team composed of an interventional radiologist, cardiovascular surgeon, and anesthesiologist. Under general anesthesia, vascular access was provided by femoral arteriotomy for the delivery of the stent graft system over a stiff guidewire under fluoroscopy and 5000 IU heparin was given intravenously to the patient. The stent graft delivery system was positioned to cover the proximal part of the aortic lesion. The stent graft was released after a correct localization is obtained using the angiography images obtained via catheterization of the brachial artery. Angiographic images were obtained to verify the localization of the stent graft, reevaluate the aortic lesion after treatment, control the patency of adjacent branches, and check whether there was an endoleak. After the delivery system was removed, full expansion of the graft was achieved with a compliant balloon catheter if necessary. Arteriotomy access was closed with the proper surgical procedure. The average systolic blood pressure was kept in the range of 100 mmHg (70-120 mmHg) for 24 hours. After the procedure, all cases were followed in the intensive care unit and were heparinized (5000 IU/h for 24 hours). Antiaggregant treatment was given to all patients immediately after the procedure (clopidogrel 75 mg/day and acetylsalicylic acid 100 mg/day). Technical success was defined as the successful delivery of stent graft on the predefined correct segment of the aorta.

The angiography images of all cases during the procedure were evaluated. CTA examinations and clinical evaluation at 1, 6, and 12 months after the procedure were planned. For the planned follow-up evaluations, serum creatinine, blood urea–nitrogen, and estimated glomerular filtration rate values are obtained. The multislice CT angiography examinations of the cases were performed with Light Speed VCT (GE Medical Systems) and DSA examinations during the procedure were performed with Innova 3100 (GE Medical Systems). Images were evaluated on "Advantage Windows Volume Share 2 (AW 4.4)" (GE Medical Systems) workstation.

The follow-up of TEVAR patients after discharge was planned as the first month, the sixth month, the first year, and annual visits for 5 years as a part of the routine clinical practice with physical examination and CTA.

TEVARs within 24 hours of admission were defined as an emergency intervention. Symptoms were defined as acute if the onset was within 24 hours of admission. Information regarding mortality (perioperative mortality during the procedure, early mortality from the end of the procedure to 29 days after the procedure, and late mortality within 30-90 days after the procedure) and post-procedure complications (acute renal failure, neurological dysfunction, stent graft thrombosis, infection, wound healing complications, as well as stent graft misplacement, migration, buckling, endoleak, loss of graft integrity) were obtained from patient files and follow-up CT examination findings. Maximum intensity projection (MIP) images were used to evaluate the relationship between stent graft and aortic branches, integrity, migration of the stent graft, and endoleaks. Endoleaks were classified in this study into 5 types: type 1 endoleak, if occurred due to incomplete proximal seal; type 2, if due to sac centripetal reperfusion via side branches with inverted flow; type 3, if it was a result of dislodgement of the various graft components; type 4, if due to increased porosity of the graft material; and type 5 was used for endoleaks that do not fit any other classification.[9] Findings detected in multiplanar reconstruction (MPR), MIP, and virtual reconstruction images were confirmed with axial images in a single session by 2 radiologists. The secondary intervention was defined as additional endovascular intervention required during the follow-up.[15]

Main points

- Thoracic endovascular aortic repair (TEVAR) procedure is associated with increased mortality.
- This study showed the mortality and complication outcomes of TEVAR treatment for various aortic pathologies in a single tertiary center in Turkey over a 10-year period.
- Presenting with acute symptoms and developing stroke and acute renal failure after the TEVAR procedure were associated with mortality.

Statistical analysis

Statistical analyses were done using IBM Statistical Package for the Social Sciences 20.0 (SPSS Inc.) package program. The Shapiro–Wilk test and histograms were used to determine whether the data were normally distributed. Numerical variables were expressed as mean and standard deviation if distributed normally and median and interquartile range values if the distribution was not normal. Mortality and complication rates were given as numbers, frequencies, and percentages. Comparative analysis between 2 groups was performed with Student t-test for normally distributed continuous variables or Mann–Whitney *U* test for variables that are not distributed normally. Chi-square test and the Fisher exact test were used for the bivariate analysis of mortality and having at least 1 complication, namely, the patient's sex, symptom duration (acute and chronic), procedure type (elective and emergent), need for revascularization surgery, complications and diagnosis of descending aorta aneurysms, Stanford type-B dissections, and traumatic transections. Odds ratios with 95% confidence intervals (CIs) were provided. The results were considered statistically significant when $P < .05$.

Results

In the 11-year study period, 58 patients comprised the sample; 10 (17.2%) patients were female and 48 (82.8%) were male. The mean age of the sample was 60.1 ± 13.4 years.

In this period, 21 patients (36.2%) were presented with acute symptoms and 12 (20.7%) required emergent TEVAR intervention, while the rest were treated electively. Indications of TEVAR are

summarized in Table 1. Of the 10 secondary intervention cases, 4 were initially treated for Stanford type-B dissections; 2 of these patients had type-1A endoleak on the follow-up CT examinations and 1 of these patients who was treated for type-1A endoleak required the third intervention for patent false lumen compression and narrowing of the true lumen. Other 2 patients required re-intervention for patent false lumen compression and narrowing of the true lumen. Two patients who were initially treated for descending aorta aneurysm required re-intervention in the follow-up due to type-1B endoleak in one case and an increase in aneurysm diameter without evident endoleak in other case. The last case was initially treated for PAU and associated descending aorta aneurysm and needed reintervention for increase in aneurysm diameter without evident endoleak. Totally 11 patients (19.0%) required revascularization or surgical debranching before TEVAR, while 1 patient with the diagnosis of Stanford type-B dissection underwent left carotid-subclavian bypass surgery after TEVAR due to the requirement of occlusion of left subclavian artery secondary to retrograde aneurysmal filling after implantation of the stent graft during the procedure. Before TEVAR treatment, 8 patients required left carotid-subclavian bypass, and 3 patients required aortic surgical debranching. Of these 11 patients who needed operation (19.0% of the total sample), the diagnosis was aortic transections in 5 patients, Stanford type-B dissections in 4 patients, traumatic pseudoaneurysm in 1 patient, and fistula between descending aorta and esophagus in 1 patient.

The outcomes of TEVAR are summarized in Table 2. Technical success of primary and secondary TEVAR treatments was found to be, 98.3% (57/58) and 100% (10/10), respectively. During one procedure of a patient presenting with acute symptoms and ruptured descending aorta aneurysm, iliac vein was ruptured while performing femoral arteriotomy which resulted in perioperative mortality.

The perioperative mortality rate was 3.4% (2 cases). The first case was described as a technical failure and the second mortality resulted from aortic rupture during TEVAR for Stanford type-B dissection after surgical debranching. The early mortality rate was 5.2% (3 cases). Myocardial infarction during hospitalization resulted in early mortality in 2 other cases treated for Stanford type-B dissection and intact descending aorta aneurysm. The third early mortality case, treated for traumatic transection, resulted from ischemic stroke during hospitalization. When perioperative and early mortality are considered together, the 1-month mortality rate was 8.6%. The late mortality rate (1-3 months) was 1.7% (1 case). The case treated with TEVAR for Stanford type-B dissection revealed a persistent increase of false lumen diameter on follow-up CT and was referred to open surgery. During

Table 1. Indications of thoracic endovascular aortic repair procedures

Indications	n	%
Aneurysms		
Intact descending aorta	22	37.9
Intact ascending aorta	1	1.7
Ruptured	3	5.2
Dissections		
Stanford type-B	18	31.0
Stanford type-A	2	3.4
Traumatic lesions		
Transections	7	12.1
Focal traumatic dissection	1	1.7
Penetrating atherosclerotic ulcers	3	5.2
Aorto-esophageal fistulae	1	1.7
Total (n)	58	100.0
Indications for secondary intervention		
Patent false lumen compression	4	40.0
Endoleak	3	30.0
Increase in aneurysm diameter	2	20.0
Hemotoma around treated aneurysm	1	10.0
Total (n)	10	100.0

Table 2. Outcomes of thoracic endovascular aortic repair procedures (n = 58)

	Overall (n = 58)		DAA (n = 22)		SBD (n = 18)		TT (n = 7)		RAA (n = 3)	
Outcome variables	n	%	n	%	n	%	n	%	n	%
Mortality										
Perioperative mortality	2	3.4	0	0	0	0	0	0	1	33.3
Early mortality	3	5.2	1	4.5	1	5.6	1	14.3	0	0
Late mortality	1	1.7	0	0	1	5.6	0	0	0	0
Total mortality	6	10.3	1	4.5	2	11.1	1	14.3	1	33.3
Complications										
Having any complication	17	29.3	8	36.4	3	16.7	2	28.6	0	0
Endoleak (type 1A)	6	10.3	4	18.1	1	5.6	0	0	0	0
Stroke	4	6.9	1	4.5	1	5.6	2	28.6	0	0
Wound healing complications	4	6.9	1	4.5	1	5.6	0	0	0	0
Acute renal failure	2	3.4	0	0	1	5.6	1	14.3	0	0
Hospital infection	2	3.4	0	0	0	0	1	14.3	0	0
Thrombus	2	3.4	1	4.5	0	0	1	14.3	0	0
Myocardium infarct	2	3.4	1	4.5	1	5.6	0	0	0	0
Femoral artery dissection	1	1.7	0	0	0	0	0	0	0	0
Aortic rupture	1	1.7	0	0	0	0	0	0	0	0
Endoleak (type 1B)	1	1.7	1	4.5	0	0	0	0	0	0
Paraplegia	0	0	0	0	0	0	0	0	0	0
Migration	0	0	0	0	0	0	0	0	0	0
Loss of graft integrity	0	0	0	0	0	0	0	0	0	0
Buckling	0	0	0	0	0	0	0	0	0	0

DAA, descending aorta aneurysms; SBD, Stanford type-B dissection; TT, traumatic transections; RAA, ruptured descending aortic aneurysm.

hospitalization after surgery, the patient presented ischemic stroke which resulted in mortality in the second month after TEVAR. In terms of 11 patients who needed bypass and debranching surgery, mortality was seen in 2 (18.2%) patients (both with aortic dissections); 1 had early and 1 had late mortality.

Regarding complications, 17 (29.3%) cases had at least 1 complication related to TEVAR. The most common complication was endoleak in 7 (12.1%) patients, including 6 (10.3%) type-1A and 1 (1.7%) type-1B endoleak. These endoleaks were managed as follows: 5 patients with type-1A endoleaks and stable CTA findings did not require additional intervention during the follow-up periods, and 2 patients with type-1A and type-1B endoleaks required secondary intervention with TEVAR. The highest complication rate was observed in patients treated for descending aortic aneurysms, whereas the highest mortality rates were seen in patients treated for ruptured aortic aneurysms. Among 11 patients who needed bypass and debranching surgery, the rate of having at least 1 complication was 27.3% (in 3 patients). These complications were endoleak, acute renal failure, and hospital infection.

Bivariate analysis of mortality and having at least 1 complication with the patient and procedure-related variables are given in Table 3. Having acute symptoms and complications of stroke and acute renal failure were significantly associated with mortality ($P = .020$, .049, and .009, respectively).

Mortality and having a complication were not associated with age (mean age in patients with mortality was 58.17 ± 17.62, mean age in surviving patients was 60.27 ± 13.08, $P = .720$, mean age in patients with at least 1 complication was 59.0 ± 15.35, patients with no complications was 60.49 ± 12.75, $P = .705$).

Discussion

This study reported the outcomes of TEVAR treatment from a tertiary medical center in Turkey over 10 years. Mortality occurred more frequently in patients who underwent TEVAR due to ruptured aneurysms than in patients treated with TEVAR secondary to intact descending aortic aneurysms, traumatic transections, and Stanford type-B dissections. Having acute symptoms, stroke, and acute renal failure after the treatment were associated with mortality.

In the literature, mortality rates after TEVAR differ according to the aortic pathology. Our results showed that for the treatment of various pathologies, overall mortality was 10.3% in the first 3 months and 8.6% in the first month. Few studies addressed the mortality in various aortic pathologies. In a comprehensive study on TEVAR outcomes of more than 11 000 patients with intact and ruptured aneurysms, dissections, and traumas, the perioperative mortality rate was 7.4%.[10] In a recent single-center study from Germany, Fiorucci et al.[11] reported outcomes of 208 patients with various etiologies including dissections, thoracic aneurysms, PAUs, intramural hematomas, and traumatic ruptures treated with TEVAR over 8 years in which in-hospital mortality was 7.7% similar to our study.

When mortality rates are compared with the literature on TEVAR for different etiologies for intact descending aortic aneurysms, our mortality findings are similar to recent reports from the United States which reported 30-day mortality as 5.3%,[4] 5.2%,[10] 4.2%[12] and from Sweden as 4.1%[5] and 90-day mortality as 8.2%.[5] Long-term follow-up reveals higher mortality as shown by a comprehensive study on intact descending thoracic aorta aneurysm patients including 2470 cases treated with TEVAR.[6] Our study included only 3 ruptured descending aortic aneurysms with 1 perioperative mortality. It is difficult to compare with other studies as we have a limited number of cases, whereas our perioperative mortality rate of ruptured aneurysms seems higher than the previous reports between 18.9% and 24.0%.[3,10,13] For Stanford type-B dissections, the 1-month mortality was 5.6% and the 3-month mortality rate was 11.1% which are similar to literature that reported, respectively, 9.1%[10] and 8%.[14]

Having acute symptoms, stroke, and renal failure after TEVAR were associated with higher mortality in our study. A study that included only symptomatic aneurysms treated with TEVAR reported higher rates of in-hospital mortality (12.7%) that is similar to our findings.[8] However, Fiorucci et al.[11] reported that perioperative mortality was not different between symptomatic and asymptomatic patients undergoing TEVAR. Stroke was shown to be associated with higher mortality[8] similar to our findings. Increasing age was not found to be associated with higher mortality in our study as opposed to the previous reports on TEVAR outcomes;[8] however, our sample was relatively younger compared to other studies. Mortality rates and complication rates were more frequent in women; however, there was no statistically significant difference between sexes in our report. There are conflicting reports on sex and mortality. Some studies showed higher mortality in women,[16] whereas some showed no difference between sexes.[17]

Our technical success was high and compatible with previous studies from different countries.[4,15] The rate of having at least 1 complication related to TEVAR was 29.3% in our study. The complication rate

Table 3. Factors associated with mortality and complications

	Mortality			Having any complication		
Factors	OR	95% CI	*P*	OR	95% CI	*P*
Female	2.75	0.43-17.61	.274	1.04	0.24-4.61	.615
Acute symptom	11.25	1.21-104.24	.020	1.92	0.60-6.09	.268
Emergent procedure	4.78	0.83-27.61	.096	1.27	0.33-4.95	.733
Revascularization surgery	2.39	0.38-15.10	.318	2.43	0.63-9.43	.173
DAA	0.30	0.03-2.71	.392	1.71	0.54-5.42	.532
SBD	1.13	0.19-6.78	1.000	0.37	0.09-1.50	.217
TT	1.28	0.13-12.70	1.000	2.85	0.62-13.05	.216
Endoleak	0.89	0.81-0.97	.507			
Stroke	12.5	1.37-113.81	.049			
Acute renal failure	14.0	5.44-35.99	.009			

OR, odds ratio; CI, confidence interval; DAA, descending aorta aneurysms; SBD, Stanford type-B dissection; TT, traumatic transections.

was 16% in Fiorucci et al.'s[11] study which is much lower than our study. This may be explained by different baseline chronic diseases between study samples.

Our endoleak rate was 12.1% which was the most common complication in our study. Although 5 types of endoleaks have been defined,[9,18] we have encountered only type 1 endoleaks which is the most prevalent type according to the literature.[9] Previous studies report endoleaks after TEVAR between 6% and 34%.[9,11,14-16,18] It should be noted that the endoleak rate can change with the type of imaging modality used for endoleak detection. At 60 months, the highest detection rate (91%) was observed using a combined approach of doppler ultrasound, CTA, and magnetic resonance imaging.[19] However, most of the centers, similar to our center, adopt the use of CTA with delayed images as the "gold standard" as it is the most cost-effective single modality for endoleak detection. We have performed CTA and found a relatively low rate of endoleak as our follow-up duration was much lower.

Managements of endoleak require a customized and relevant approach which may change from a conservative, observational approach to complex, interventional radiology techniques,[20] and research shows that new stent grafts may limit the incidence of endoleaks if correctly chosen for the specific patient.[20] The endoleaks in this study were managed mostly by observational follow-up as the CTA findings were stable in the 4 follow-up visits during the first year. Acute renal failure was observed in 3.4% of our sample and was consistent with previous reports.[11] In our sample, the rate of stroke observed during the follow-up is 6.9%. Complications such as paraplegia,[21] retrograde dissections, stent graft migration, loss of graft integrity,[22] and post-implantation syndrome[23] reported in the literature after TEVAR were not observed in our sample. Our results showed that the technical success, morbidity, and mortality of TEVAR procedures are mostly similar to the literature.

In our study, one-fifth of the patients applied a bypass or debranching surgery. The mortality rate in these patients was much higher than the overall sample. A study by Fanelli et al.[24] evaluated the consequences of intentional left subclavian artery occlusion in 37 patients with Stanford type-B dissection and thoracic aneurysms with short proximal neck. In this study, no immediate complications occurred, and during the 4-year follow-up, complications such as perfusion-related symptoms of the left arm, visual impairment, and endoleak had been observed.[24] Mortality was reported as 16.2% similar to our results (18.2%). During the follow-up, a type-2 endoleak originating from retrograde blood flow in the excluded left subclavian artery via subclavian steal phenomenon was observed in 10 of the 37 patients (27.0%), while in our study, the endoleak rate in patients with intentional left subclavian artery occlusion was 12.5% (1/8 patients). However, the mean follow-up duration was 4 years in the study by Fanelli et al.[24] much higher than the 1-year follow-up in our study.

Our study has some limitations. First, the patients comprising the study sample were from a single tertiary medical center and therefore may hinder the generalizability. In addition, the low number of cases in some aortic pathology types including PAUs and ruptured aneurysms restricts assumptions about mortality and complication rates. We also think that longterm follow-up for morphological changes in the aorta after TEVAR treatment is important. In a unique study, the authors followed the patients treated with TEVAR for aortic dissections for 3 years aiming to assess aortic remodeling.[25] This study reported that aortic remodeling consisting of false lumen thrombosis and shrinkage was more prominent in acute than in chronic dissections, especially within the first 18 months, as higher survival has been reported in the patients who achieved aortic remodeling. We think that prospective longterm follow-up studies exploring the morphological changes that occur in the stented segment and in the adjacent aorta in the longterm follow-up examinations are important for future studies.

In conclusion, in various thoracic aortic pathologies, TEVAR is applied with high technical success although mortality and complications have been reported in the first year of follow-up. Patients presenting with acute symptoms and who developed stroke and acute renal failure after the procedure should be carefully followed up as these factors were found to be associated with mortality.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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