TJVS Turkish Journal of Vascular Surgery

Turk J Vasc Surg 2025;34(1):70-8
DOI: 10.9739/tjvs.2025.02.013

Available online at www.turkishjournalofvascularsurgery.org

Original Article

Long-term results of endovascular repair in thoracic aortic pathologies: 14 years of single center experience

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Received: February 19, 2025 Accepted: March 15, 2025 Published online: March 20, 2025

Abstract

Aim: Although short- and medium-term efficacy and safety of endovascular interventions in thoracic aortic pathologies have been proven, their long-term results and effects on survival are still controversial. The main purpose of this study is to investigate the effects of pathology type, emergency and elective intervention, and accompanying diseases on long-term survival and development of complications in long-term follow-up.
Material and Methods: A total of 142 patients who underwent Thoracic Endovascular Aortic Repair (TEVAR) between July 2010 and December 2024 were included. Retrospective analysis was performed. Patients were divided into groups as emergency and elective and also according to pathology type and analyses were performed. Primary outcome was determined as thoracic aortic pathology types and 5 and 14-year survival in emergency and elective patients, and secondary outcomes were determined as the effects of factors such as age, gender, and additional diseases on the development of complications and survival. Statistical significance was determined as p value <0.05.
Results: A total of 156 stents were implanted in 142 patients in the study. While 58 (40.84%) of the patients were in the emergency group, 84 (59.15%) were evaluated in the elective group. While the 5 and 14-year survival rates of elective cases were found to be significantly higher than those of emergency cases (p=0.037, p=0.046), the average survival time of aneurysm cases was found to be significantly higher than those of other groups in the analysis performed according to pathology types (p=0.023). No significant relationship was found between gender and the development of endoleaks and complications (p<0.001). It was observed that the presence of diabetes increased the risk of complications by 16.2 times (OR=16.257, CI=2.709-97.575, p<0.01), and the presence of PAH increased the risk by 10.1 times (OR=10.187, CI=1.373-75.578, p=0.02).
Conclusion: TEVAR continues to be an effective and safe treatment for both emergency and elective thoracic aortic pathologies. Close monitoring is required due to the long survival expectation and the risk of re-intervention. We recommend TEVAR as the first choice for the treatment of all thoracic aortic pathologies.

Keywords: Aneurysm, endovascular, dissection, rupture

INTRODUCTION

Since the use of thoracic endovascular aortic repair (TEVAR) for the treatment of thoracic aortic aneurysms, this method has become the preferred method for the treatment of different thoracic aortic pathologies [1]. In the last two decades, there has been a significant shift towards TEVAR treatment due to its superior short-term results [2]. Thoracic aortic aneurysms, Type B dissections, traumatic transections, intramural hematomas and penetrating ulcers are still life-threatening conditions that cause serious mortality and morbidity today and are the riskiest pathologies for vascular surgeons. Open surgery for these pathologies is associated with a high mortality rate of around 20%, and the rate of developing complications such as paraplegia and renal failure in survivors is as high as 15% [3].

TEVAR has much lower morbidity and mortality rates compared to open surgery. It is recommended as the first choice due to the presence of successful early results in elective cases and emergency cases such as thoracic rupture, dissection, and

CITATION
Tayfur K, Borulu F. Long-term results of endovascular repair in thoracic aortic pathologies: 14 years of single center experience. Turk J Vasc Surg. 2025;34(1):70-8.

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transection [4]. In recent years, anatomical suitability criteria have also expanded with the developments in graft technologies. Especially in emergency cases, TEVAR application provides significant advantages compared to open surgery [5]. Although TEVAR has been proven to be effective and safe in the short and medium term, its long-term results and effects on survival are still controversial. Most of the literature investigating long-term results reports a follow-up period of up to 5 years [6]. The type of thoracic aortic pathology, whether it is urgent or elective, accompanying comorbidities and landing site are the main factors affecting the results of the intervention and the development of complications. The main purpose of this study is to contribute to the literature by investigating the effects of pathology type, urgent and elective intervention and accompanying comorbidities on long-term survival and the development of complications in a 14-year long-term follow-up.

MATERIAL AND METHODS

This single-center retrospective study included 142 patients who underwent TEVAR between July 2010 and December 2024. Fifty-eight of 142 patients (40.84%) were in the emergency group (those who were admitted 24 hours after symptom onset and surgery). 84 patients (59.15%) were evaluated in the elective group (those who were admitted at least 24 hours after diagnosis). Patients with thoracic aneurysm, traumatic transection, penetrating ulcer, Type B dissection, and aneurysm rupture were included in the study. Patients with ascending aorta and abdominal aortic aneurysm were excluded from the study. The mean age of the patients was 68.4±9.5 (range 37 - 87), 102 patients were male (71.8%), and 40 patients were female (28.16%). The study was approved by the Ordu University Scientific Research Ethics Committee with the decision numbered 208 and dated 20.12.2024. Preoperative, intraoperative, and postoperative data of all patients were retrospectively reviewed from a previously established database. Hypertension (HT), Chronic obstructive pulmonary disease (COPD), Diabetes mellitus (DM), Peripheral artery disease (PAD), Previous coronary surgery (CABG), Chronic kidney disease (CKD), Cancer (CA), Congestive heart failure (CHF) and Hyperlipidemia were accepted as comorbid factors. All patients were classified according to the American Society of Anesthesiologists (ASA) score. Before the procedure, all patients underwent contrast-enhanced tomography (CT) with at least 3 mm sections and the appropriate stent-graft selection was planned by considering anatomical suitability, proximal and distal landing diameters. Up to 10% size was planned for dissection and rupture patients and up to 20% size was planned for aneurysm patients. Signed informed consent forms were obtained from all patients before the procedure. The primary outcome of the study was determined as thoracic aortic pathology types and 5- and 14-year survival rates in emergency and elective patients, while secondary outcomes were determined as the effects of factors such as age, gender and comorbidities on the development of complications and survival.

Surgical Technique

All procedures were performed by the same cardiovascular surgery team in the angiography laboratory. Local anesthesia was used in patients for whom general anesthesia was risky. The femoral artery to which the stent-graft would be sent was surgically explored while the other side was percutaneously cannulated. Before the procedure, 5000 units of heparin were administered intravenously (IV) and an activated clotting time (ACT) of 200-250 seconds was targeted. Additional doses of heparin were administered in prolonged procedures. Two types of stent-grafts were used: Valiant thoracic stent-graft (Medtronic vascular, Santa Rosa, California) and TAG Gore (WL GoreQ Assoc, Flagstaff, Arizona). In order to prevent migration during the opening phase of the graft and to ensure its adhesion in the appropriate location, systolic blood pressure was kept around 100 mmHg with antihypertensive and anesthetic agents. No pacing was applied to any patient. In appropriate cases, balloon dilatation was performed on the distal and proximal parts of the graft. The procedures were terminated after control angiography. The left subclavian artery was closed in patients who underwent emergency intervention and those who were to be moved down to Zone 2. Extremity circulation was monitored.

Follow-up

All patients were extubated after the procedure and were followed up in the intensive care unit. In patients whose subclavian artery was closed, upper extremity circulation was controlled with pulse and temperature monitoring. Close hemoglobin and blood gas monitoring was performed especially in patients who underwent emergency surgery. Patients whose follow-up in the intensive care unit was completed were taken to the ward rooms. Patients who had no problems in their ward follow-up were discharged. Acute renal failure (ARF), distal embolism, mesenteric ischemia, myocardial infarction (MI), stroke (CVO), paraplegia, pneumonia, rupture and wound infection were accepted as postoperative complications. All patients were followed up with CT at 1, 6, 12 months and annually thereafter.

Statistics

This study analyzed data from 142 patients (102 males, 40 females) who underwent thoracic endovascular aortic repair (TEVAR). The study population was stratified into emergency (n=58) and elective (n=84) cases. Demographic data, comorbidities, operative parameters, and postoperative outcomes were recorded using standardized data collection forms. The normality of continuous variables was assessed through both analytical (Shapiro-Wilk test) and visual methods (Q-Q plots, histograms), while variance homogeneity was evaluated using Levene's test. Independent samples t-test was employed for normally distributed variables, and Mann-Whitney U test for non-normally distributed variables. Relationships between categorical variables were analyzed using Pearson's Chi-square or Fisher's exact test.

For multiple group comparisons, the Kruskal-Wallis H test was applied due to non-normal distribution, with Dwass-Steel-Critchlow-Fligner (DSCF) test used for post-hoc analyses. Survival analyses were performed using the Kaplan-Meier method, with differences between groups assessed by log-rank test. The impact of risk factors on mortality and complications was examined using Cox proportional hazards regression model, with the proportional hazards assumption verified using Schoenfeld residuals. Statistical analyses were conducted using R (version 4.4.2), JASP, SPSS (version 26.0), and MedCalc (version 20.1), with type I error level set at α=0.05.

RESULTS

A total of 156 stents were placed in the study in which 142 patients were included. Fifty-eight of 142 patients (40.84%) were in the emergency group. 84 patients (59.15%) were evaluated in the elective group. Stent grafts were successfully placed in all patients. Technical success was 100%. The mean follow-up period was 73.6 months (range: 18 - 156, SD: 33.9) and 8 patients (5.63%) died in the first 30 days. Carotid-subclavian bypass was performed in 8 of the patients whose subclavian artery needed to be closed. General anesthesia was used in 130 patients. Local anesthesia was used in 12 high-risk patients.

Polytetrafluoroethylene-coated (Gore TAG) stent grafts were placed in 52 patients and polyester-coated (Valiant) stent grafts were placed in 90 patients. The most common pathology was thoracic aneurysm with 81 (57.04%). The mean proximal landing zone diameter was 34.4±3.7 mm, the distal landing zone diameter was 31.8±3.4 mm, and zone 3 was the most commonly used landing zone.

The mean age of elective cases was significantly higher than that of emergency cases (p=0.019). The duration of operation, intensive care and hospital stay were also found to be longer in emergency cases (p<0.001). The demographic data and analysis of clinical measurements of the patients are given in Table 1 (Table 1). A total of 26 patients were lost during follow-up. Eight of these were TEVAR-related in-hospital mortality.

Survival analysis between pathology types and emergency and elective groups was performed using Kaplan–Meier analysis and significant differences were detected in the log-rank test. While the 5- and 14-year survival rates of elective cases were found to be significantly higher than emergency cases (p=0.037, p=0.046), the mean survival time of aneurysm cases was found to be significantly higher than other groups in the analysis performed according to pathology types (p=0.023) (Tables 2,3). Since mortality was observed in some patients without monthly follow-up, Kaplan Meier analyses were based on days in order to ensure precise estimations and to avoid minimal deviations in the analysis results (Figure 1 A,B, Figure 2 A,B). The 14-year survival rate was 40.52% in the emergency group and 59.48% in the elective group. No mortality was observed in the trauma group.

During follow-up, endoleak was detected in 28 patients, 17 of which were Type 1. Secondary intervention was performed in 22 patients, while additional stents were placed in 9 patients. Endoleak was removed in 13 patients by balloon dilatation. The most common complication was CVO (% patients), while ABY (4 patients) was the second most common. No significant relationship was found between gender and endoleak and complication development (p<0.001). When the relationship between pathology type and complication and endoleak development was examined, no significant relationship was found between endoleak development (p=0.925), while a significant relationship was found between complication development (p<0.001, chi-square test). No complications were observed in 87.7% of aneurysm cases. ABY complication was seen only in rupture cases, and mesenteric ischemia and MI were seen only in dissection cases.

Cox regression analysis was performed for the effects of additional diseases on the occurrence of complications, overall mortality and endoleak formation. It was observed that the presence of diabetes increased the risk of complications by 16.2 times (OR=16.257, CI=2.709-97.575, p<0.01) and the presence of PAH by 10.1 times (OR=10.187, CI=1.373-75.578, p=0.02). The risk of mortality in patients with COPD increased by 7.6 times, but did not reach statistical significance (OR=7.632, p=0.082). Mortality was also observed to be 69.5% lower in elective cases (OR=0.305, CI=0.099-0.940, p=0.039) (Table 4).

A strong relationship was also found between the proximal landing zone and the development of complications. The complication rate was significantly higher in emergency cases performed by landing in Zone 2 (p<0.001) (Table 5).

The positive correlation between ASA scores and age with spearman correlation analysis (r=0.308, p<0.001) reflects the increase in comorbidity with increasing age. The mean ages according to the types of complications were analyzed with Kruskal-Wallis H test and showed significant differences (p=0.002). It was observed that neurological complications were especially common in the advanced age group. No statistically significant relationship was observed between age and endoleak development.

Comparative analyses of clinical measurements according to different pathology types were analyzed with Kruskal-Wallis H test. Statistically significant differences were detected (p<0.001). The duration of intensive care and hospital stay was longest in trauma cases (2.5±0.8 days, 5.3±1 days). The highest use of opaque was observed in trauma and rupture cases (66.7±5.2cc, 60.9±11.8cc). The effects of additional diseases on survival between emergency and elective groups were analyzed with log-rank test. It was found that the presence of CHF and CA significantly reduced survival in emergency cases (p=0.009, p=0.014) (Table 6).

Table 1. Descriptive statistics of patients' demographic and clinical measurements

Quantitative measurements		Case type															p
		Emergent					Elective					Total					
		Mean	SD	Median	Min	Max	Mean	SD	Median	Min	Max	Mean	SD	Median	Min	Max	
Age		66.0	11.1	67.5	37	87	70.0	7.8	70.5	50	87	68.4	9.5	69.0	37	87	**0.019**[b]
Proximal diameter/mm		34.6	3.7	35.0	26	42	34.3	3.8	34.0	27	42	34.4	3.7	34.0	26	42	0.592[a]
Distal diameter/mm		32.1	3.3	32.0	26	40	31.6	3.5	32.0	25	40	31.8	3.4	32.0	25	40	0.401[a]
Operation time/min		59.1	11.0	60.0	35	85	48.9	8.2	50.0	30	65	53.1	10.7	55.0	30	85	**<0.001**[b]
Opaque/cc		56.8	9.2	55.0	35	75	50.4	8.8	50.0	35	70	53.0	9.5	52.5	35	75	**<0.001**[a]
Follow-up period (months)		81.9	35.8	73.0	18	150	68.3	31.8	60.0	18	156	73.6	33.9	70.0	18	156	**0.023**[a]
Intensive care hospitalization (days)		1.9	0.7	2.0	1	4	1.3	0.4	1.0	1	2	1.5	0.6	1.0	1	4	**<0.001**[a]
Hospitalization (days)		4.2	1.0	4.0	3	7	3.3	0.6	3.0	2	5	3.7	0.9	3.0	2	7	**<0.001**[a]
ASA score		2.8	0.8	3.0	1	4	2.6	0.8	3.0	1	4	2.7	0.8	3.0	1	4	0.274[a]
Qualitative measurements		**N**	**Row (%)**		**Column (%)**		**N**	**Row (%)**		**Column (%)**		**N**		**Column (%)**			**p**
Gender	**Male**	44	43.1		75.9		58	56.9		69.0		102		71.8			0.375[d]
	Woman	14	35.0		24.1		26	65.0		31.0		40		28.2			
Cigarette	**There is**	13	39.4		22.4		20	60.6		23.8		33		23.2			0.847[d]
	None	45	41.3		77.6		64	58.7		76.2		109		76.8			
Pathology	**Aneurysm**	0	0		0		81	100.0		96.4		81		57.0			**<0.001**[d]
	Penetrating ulcer	0	0		0		3	100.0		3.6		3		2.1			
	Rupture	17	100.0		29.3		0	0		0		17		12.0			
	TIPB dissection	35	100.0		60.3		0	0		0		35		24.6			
	Trauma	6	100.0		10.3		0	0		0		6		4.2			
Hypertension	**There is**	48	47.5		82.8		53	52.5		63.1		101		71.1			**0.011**[d]
	None	10	24.4		17.2		31	75.6		36.9		41		28.9			
Diabet	**There is**	15	37.5		25.9		25	62.5		29.8		40		28.2			0.612[d]
	None	43	42.2		74.1		59	57.8		70.2		102		71.8			
COPD	**There is**	18	42.9		31.0		24	57.1		28.6		42		29.6			0.752[d]
	None	40	40.0		69.0		60	60.0		71.4		100		70.4			
CABG	**There is**	7	35.0		12.1		13	65.0		15.5		20		14.1			0.566[d]
	None	51	41.8		87.9		71	58.2		84.5		122		85.9			
Prp. Arterial disease.	**There is**	5	31.3		8.6		11	68.8		13.1		16		11.3			0.407[d]
	None	53	42.1		91.4		73	57.9		86.9		126		88.7			
CRF	**There is**	5	35.7		8.6		9	64.3		10.7		14		9.9			0.681[d]
	None	53	41.4		91.4		75	58.6		89.3		128		90.1			
CHF	**There is**	2	25.0		3.4		6	75.0		7.1		8		5.6			0.348[d]
	None	56	41.8		96.6		78	58.2		92.9		134		94.4			
Cancer	**There is**	9	33.3		15.5		18	66.7		21.4		27		19.0			0.378[d]
	None	49	42.6		84.5		66	57.4		78.6		115		81.0			
Hyperlipidemia	**There is**	1	14.3		1.7		6	85.7		7.1		7		4.9			0.143[d]
	None	57	42.2		98.3		78	57.8		92.9		135		95.1			

COPD: chronic obstructive pulmonary disease, CABG: coronary bypass, CRF: chronic renal failure, CHF: congestive heart failure, CA: cancer, Prp: peripheral

DOI: 10.9739/tjvs.2025.02.013

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Table 2. Kaplan -Meier survival analysis at 5 and 14 years depending on case type

Time period	Case type	Mean	SE	95% CI		Log rank (Mantel-Cox)	
				Lower bound	Lower bound	Chi square	p
5-years	Urgent	939.182	371.266	211.500	1666.864	4.346	**0.037**
	Elective	2410.667	377.520	1670.728	3150.606		
	General	1862.987	319.846	1236.089	2489.886		
14-years	Urgent	806.455	327.060	165.417	1447.492	3.995	**0.046**
	Elective	1802.333	264.482	1283.949	2320.718		
	General	1381.000	224.466	941.048	1820.952		

Table 3. Kaplan -Meier survival analysis at 5 and 14 years depending on pathology

Time period	Pathology	Mean	SE	95% CI		Log rank (Mantel-Cox)	
				Lower bound	Upper bound	Chi square	p
5-years	Aneurysm	2410.667	377.520	1670.728	3150.606	7.531	**0.023**
	Rupture	1165.000	454.774	273.643	2056.357		
	TIPB dissection	376.200	323.980	.000	1011.201		
	General	1862.987	319.846	1236.089	2489.886		
14-years	Aneurysm	1802.333	264.482	1283.949	2320.718	8.537	**0.014**
	Rupture	1165.000	498.180	188.567	2141.433		
	TIPB dissection	376.200	362.221	.000	1086.153		
	Overall	1381.000	224.466	941.048	1820.952		

Table 4. Cox regression analysis results for the effect of comorbidities on overall mortality , complications and endoleak formation

Illness	n	Mortality (General)	OR	CI	p	Complication	OR	CI	p	Endoleak	OR	CI	p
Hypertension	101	19	0.969	0.171-5.501	0.972	19	3.570	0.653-19.523	0.142	22	1.199	0.330-4.359	0.782
Diabetes	40	7	1.165	0.181-7.490	0.872	9	16.257	2.709-97.575	0.002	8	0.820	0.288-2.337	0.711
COPD	42	8	7.632	0.771-75.559	0.082	6	4.333	0.723-25.962	0.108	3	0.205	0.048-0.866	0.031
CABG	20	5	2.655	0.439-16.064	0.288	7	2.411	0.244-23.846	0.452	4	0.973	0.102-9.300	0.981
Prp. arterial disease	16	2	0.404	0.019-8.365	0.557	4	10.187	1.373-75.578	0.023	4	0.523	0.115-2.366	0.400
CRG	14	4	2.453	0.268-22.467	0.427	1	0.00	0.00	0.982	1	0.147	0.015-1.439	0.100
CHF	8	3	0.697	0.109-4.473	0.704	2	9.736	1.473-64.342	0.018	3	2.934	0.564-15.262	0.201
Cancer	27	10	2.868	0.326-25.207	0.342	8	11.298	0.885-144.176	0.062	5	1.161	0.140-9.651	0.890
Hyperlipidemia	7	0	-	-	-	0	-	-	-	1	0.423	0.048-3.772	0.441
Case type (elective)	84	15	0.305	0.099-0.940	0.039	10	.283	.092-0.868	0.027	18	1.684	0.703-4.034	0.243

COPD: chronic obstructive pulmonary disease, CABG: coronary bypass, Prp: peripheral, CRF: chronic renal failure, CHF: congestive heart failure

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Table 5. Distribution of landing zone in complication and endoleak development groups in emergency and elective patients

		Case type								p
		Emergent				Elective				
		Landing zone				Landing zone				
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Complication status	**None**	0 (0)	8 (18.2)	29 (65.9)	7 (15.9)	2 (2.7)	34 (45.9)	33 (44.6)	5 (6.8)	
	There is	0 (0)	5 (35.7)	9 (64.3)	0 (0)	0 (0)	3 (30.0)	7 (70.0)	0 (0)	
Complication type	**Acute kidney**	0 (0)	3 (75.0)	1 (25.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**<0.001**[d]
	Distal embolism	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (100)	0 (0)	
	Mesentery ischemia	0 (0)	1 (50)	1 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	MI	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	Neurological CVA	0 (0)	0 (0)	3 (100)	0 (0)	0 (0)	1 (50)	1 (50)	0 (0)	
	Paraplegia	0 (0)	0 (0)	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	Pneumonia	0 (0)	1 (50)	1 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	Rupture	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (50)	1 (50)	0 (0)	
	Wound infection	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (25)	3 (75)	0 (0)	
Endoleak status	**None**	0 (0)	11 (22.9)	30 (62.5)	7 (14.6)	2 (3.0)	30 (45.5)	31 (47)	3 (4.5)	
	There is	0 (0)	2 (20)	8 (80)	0 (0)	0 (0)	7 (38.9)	9 (50)	2 (11.1)	
Endoleak type	**Type 1**	0 (0)	2 (33.3)	4 (66.7)	0 (0)	0 (0)	5 (45.5)	5 (45.5)	1 (9.1)	**0.001**[d]
	Type 2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (33.3)	1 (33.3)	1 (33.3)	
	Type 3	0 (0)	0 (0)	3 (100)	0 (0)	0 (0)	1 (50)	1 (50)	0 (0)	
	Type 4	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	2 (100)	0 (0)	

[d]Chi Square test, MI: myocardial infarction, CVA: cerebrovascular accident

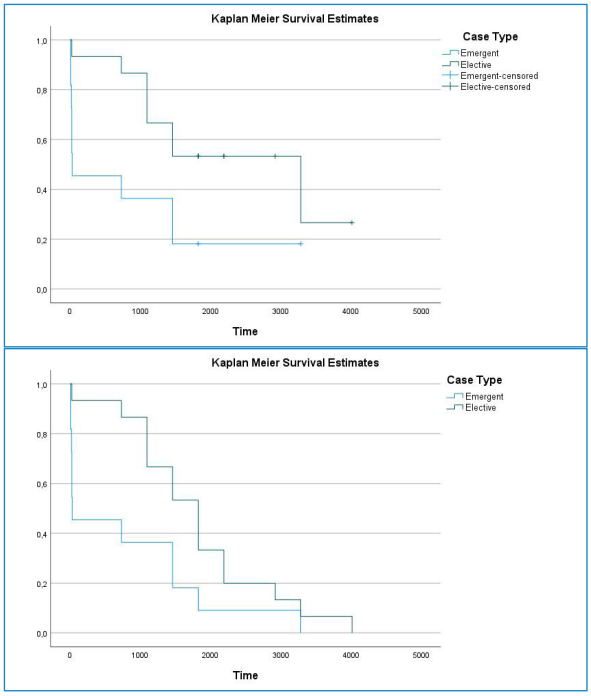

Figure 1. A. Censored Kaplan-Meier survival analysis curves obtained based on emergency and elective cases; **B.** uncensored Kaplan-Meier survival analysis curves obtained based on emergency and elective cases

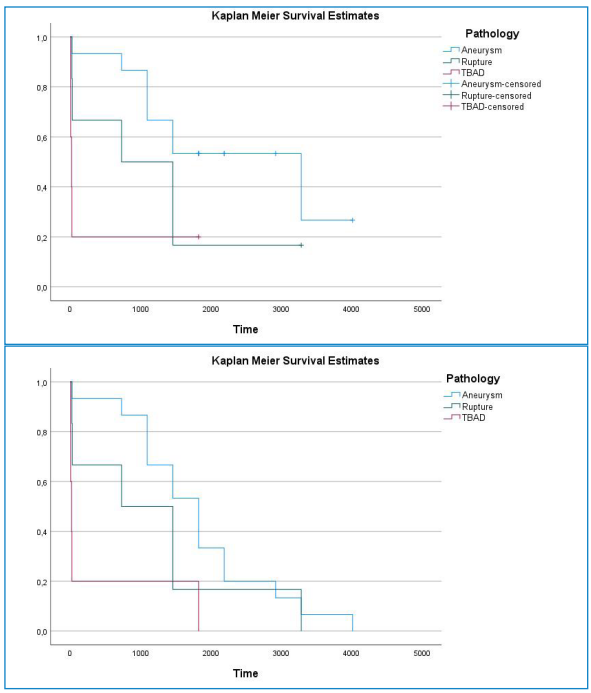

Figure 2. A. Censored Kaplan-Meier survival analysis curves obtained based on pathology types; **B.** uncensored Kaplan-Meier survival analysis curves obtained based on pathology types

DISCUSSION

Despite all advances, surgical treatment of thoracic aortic pathologies is still associated with serious morbidity and mortality. Mortality rates have been reported to be around 27% [7]. TEVAR, which was initially used only for the repair of thoracic aortic aneurysms, has now become the first choice in the treatment of all thoracic aortic pathologies due to its low mortality and morbidity rates [8]. TEVAR has been shown to be effective in stopping aortic dilation and preserving the true lumen [9]. In this study, the results of different thoracic aortic pathologies and emergency or elective interventions were analyzed and compared with the literature.

In an 8-year study including 208 patients with different thoracic aortic pathologies, in-hospital mortality was reported as 7.7% [10]. In another recent study with 58 patients, 30-day mortality was reported as 8.6% [11]. In our study, the 30-day mortality rate was observed as 5.63%, which is consistent with the literature. In a long-term study including 300 patients with different thoracic aortic pathologies like our study, 5-year survival was reported as 63% [12]. In a large-scale study including 11,996 patients, 5-year survival was shown as 60%, and it was reported that isolated thoracic aneurysms were associated with low mortality [13]. In another study including 71 patients, 5-year survival rate was reported as 42.4% [14]. In our study, while the 5-year survival rate in emergency cases was 39.2%, the 5-year survival rate in the elective group including aneurysms was 60.8% and the 14-year survival rate was 59.48%. In addition, the mortality rate in elective cases was 69.5% lower, consistent with the literature. Survival rates in elective cases were found to be significantly higher than in emergency cases.

The effect of gender on mortality and outcomes is still a matter of debate. While Deery et al. [15] reported that mortality was higher in female patients, another study reported that male gender increased 5-year mortality by 4.3 times compared to female gender [14]. An analysis of 9 studies on TEVAR showed that mortality was similar between males and females [16]. Although previous studies on gender-related outcomes after TEVAR suggested worse outcomes in females, these studies were mostly evaluated with a single pathology, and gender-related outcomes in patients with different pathologies were not examined in detail [17]. In this study, where patients with different pathologies were followed up for a long time, we believe that we have made a different contribution to these discussions by showing that gender did not have a significant contribution to mortality and complication development.

Different studies have reported different risk factors for mortality. One study reported that age, COPD, and previous aortic surgery increased the risk of mortality, while another study reported that male gender, COPD, and previous cardiac surgery were risk factors [12,18]. Another article reported that advanced age and the presence of diabetes increased mortality [14]. Geisbüsch et al. [19] reported that the presence of renal failure and emergency surgery were risk factors that increased mortality. In this study, it was observed that COPD and emergency surgery were risk factors that increased mortality, and in emergency cases, the presence of CHF and cancer significantly decreased survival, contrary to the literature. It has been reported in the literature that patients who underwent TEVAR due to trauma have the best long-term results, even having a long-term survival rate of 100% [18,20]. In our series, no mortality was observed in patients who underwent TEVAR due to trauma.

A controversial issue is the closure of the left subclavian artery, and there is still no consensus. In addition to studies reporting that revascularization is necessary in patients with left arm dialysis fistula, left internal mammary graft, and patients who will cover a long aortic segment, there are also studies recommending that subclavian artery revascularization be postponed in TEVAR to be applied to zone 2 [21,22]. In our series, we closed the subclavian artery in patients who underwent emergency intervention and in patients who would undergo a procedure to zone 2. We monitored the patients in terms of circulation. We did not encounter any complications requiring revascularization in patients other than 6 patients.

The development of complications after TEVAR continues to be the biggest problem. Endoleaks are the most important of these complications. In the literature, endoleak development has been reported between 6% and 34% after TEVAR [23]. A recent study reported 15% endoleak development [24]. In our study, an endoleak rate of 19.7% was observed, and the most common type was Type 1 endoleak, consistent with the literature. Endoleaks are the most common reason for secondary intervention. In a study, the secondary intervention rate was 14.4% in a 5-year follow-up, while in a study similar to ours, this rate was reported as 11.3% [6,25]. In this series, the secondary intervention rate was observed as 15%, consistent with the literature. In addition, no relationship was found between the types of pathology and endoleak development. Since there is not enough information in the literature on this subject, it was seen as valuable data for us.

The most feared complications after TEVAR are neurological events [24]. In the literature, the rate of paraplegia after TEVAR is reported to be between 3 and 6%, while the rate of stroke is reported to be between 2 and 8% [26,27]. In a meta-analysis, the rate of postoperative paraplegia was reported as 3.2%, while in our series, the rate of paraplegia was observed as 1.40% [28]. In our study, routine cerebrospinal fluid (CSF) drainage was not applied due to the difficulty of catheter access, especially in emergency cases. There is still no clear evidence that CSF drainage reduces neurological complications [24]. However, when we look at the paraplegia and stroke rates in this series where we did not use CSF drainage, we do not think that CSF drainage is a very necessary method. Mesenteric ischemia can

be observed in approximately 0.6-2.8% after TEVAR, especially in Type B dissection patients, and it is extremely mortal [29]. In our study, mesenteric ischemia developed in 2 patients whose false lumen was completely closed after TEVAR and resulted in mortality. We would like to state that it is important to evaluate very well before TEVAR which lumen the celiac trunk and superior mesenteric artery originate from, especially in dissections extending to the diaphragm.

We observed that the presence of diabetes in particular increased the risk of developing complications by 16.2 times, and the presence of peripheral artery disease by 10.1 times. This study also showed that the landing zone and the type of pathology have no relationship with survival.

Limitations

The study has some limitations. First of all, it is a single-center retrospective study and the number of cases may affect the results. In addition, the number of cases between the groups was not homogeneous, the number of cases in the penetrating ulcer and trauma group was relatively less than the other groups. This may limit the analyses on mortality and complication rates. Another limitation is that the type of graft used was limited to 2 types and no analysis was made between the graft types. Finally, the lack of a control group to compare the results with open surgery seems to be another limitation.

CONCLUSION

TEVAR offers good results in the short and medium term, but there are still shortcomings in long-term results. However, TEVAR continues to be an effective and safe treatment for both emergency and elective thoracic aortic pathologies. With the development of devices and the increase in the flexibility of grafts, both re-intervention rates and morbidity and mortality rates will decrease further. Especially in young patients, close monitoring should be performed due to the long survival expectation and re-intervention risks. Long-term follow-up studies with larger number of cases are needed to correct the problems. As a final result of our study, we recommend TEVAR as the first choice in the treatment of all thoracic aortic pathologies.

Ethics Committee Approval: The approval of Ordu University Faculty of Medicine Clinical Research Ethics Committee, dated 20.12.2024 and decision no. 208 was obtained.

Patient Consent for Publication: Individual informed consent was waived due to the retrospective design.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors contributed equally to the article.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Dake MD, Miller DC, Semba CP, Mitchell RS, Walker PJ, Liddell RP. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. N Engl J Med. 1994; 331:1729-34
2. Toz H, Kuserli Y, Turkyılmaz G, Turkyılmaz S, Kavala A. Endovascular intervention in patients with blunt traumatic thoracic aortic injury: early results. Turk J Vasc Surg. 2024;33:152-9.
3. Benk J, Siepe M, Berger T, Beyersdorf F, Kondov S, Rylski B et al. Early and mid-term outcomes of thoracic endovascular aortic repair to treat aortic rupture in patients with aneurysms, dissections and trauma. Interact Cardiovasc Thorac Surg. 2022;35:ivac042.
4. Upchurch GR Jr, Escobar GA, Azizzadeh A, Beck AW, Conrad MF, Matsumura JS, et al. Society for vascular surgery clinical practice guidelines of thoracic endovascular aortic repair for descending thoracic aortic aneurysms. J Vasc Surg. 2021;73:55-83.
5. Choi E, Kwon TW. Endovascular treatment versus open surgical repair for isolated iliac artery aneurysms. Vasc Specialist Int. 2024;40:31.
6. Liisberg M, Baudier F, Akgül C, Lindholt JS. Long-term thoracic endovascular repair follow-up from 1999 to 2019: a single-center experience. Ann Vasc Surg. 2022:86:399-407.
7. Umaña JP, Miller DC, Mitchell RS. What is the best treatment for patients with acute type B aortic dissections-medical, surgical, or endovascular stentgrafting?. Ann Thorac Surg. 2002;74:S1840-63.
8. Azizzadeh A, Keyhani K, Miller CC 3rd, Coogan SM, Safi HJ, Estrera AL. Blunt traumatic aortic injury: Initial experience with endovascular repair. J Vasc Surg. 2009;49:1403-8.
9. Conrad MF, Crawford RS, Kwolek CJ, Brewster DC, Brady TJ, Cambria RP. Aortic remodeling after endovascular repair of acute complicated type B aortic dissection. J Vasc Surg. 2009;50:510-7.
10. Fiorucci B, Kölbel T, Rohlffs F.et al. The role of thoracic endovascular repair in elective, symptomatic and ruptured thoracic aortic diseases. Eur J Cardiothorac Surg. 2019;56:197-203.
11. Akın ME, Akkan K, Özer A, Ilgıt ET, Önal B, Oktar GL. Outcomes of endovascular treatment of thoracic aorta pathologies: 10-year single-center results. Diagn Interv Radiol. 2022;28:370-5.
12. Wiedemann D, Mahr S, Vadehra A, Schoder M, Funovics M, Löwe C et all. Thoracic endovascular aortic repair in 300 patients: long-term results. Ann Thorac Surg. 2013;95:1577-83.
13. Schaffer JM, Lingala B, Miller DC, Woo YJ, Mitchell RS, Dake MD. Midterm survival after thoracic endovascular aortic repair in more than 10,000 Medicare patients. J Thorac Cardiovasc Surg. 2015;149:808-20.

14. Gökkurt Y, Yürekli İ, Çakır H, İner H, Yeşilkaya N, et all. Mid- and long-term results in patients with thoracic endovascular aortic repair. Cardiovasc Surg Int. 2021;8:103-8.

15. Deery SE, Shean KE, Wang GJ, Black JH 3rd, Upchurch GR Jr, Giles KA, et al. Female sex independently predicts mortality after thoracic endovascular aortic repair for intact descending thoracic aortic aneurysms. J Vasc Surg. 2017;66:2-8.

16. Dias LR, Oliveira-Pinto J, Mansilha A. Gender differences in mortality and reinterventions after TEVAR for intact aneurysms of the thoracic aorta. International Angiol. 2019;38:115-20.

17. Yousef S, Brown J, Michel EA, Gallegos DS, Wang Y, Ogami T, Sultan İ. Sex-related differences in clinical outcomes after thoracic endovascular aortic repair. J Am Heart Assoc. 2023;12:e025520.

18. Gallo M, van den Berg JC, Torre T, Riggi M, Demertzis S, Ferrari E. Long-term outcomes and risk factors analysis for patients undergoing thoracic endovascular aorta repair (TEVAR), according to the aortic pathologies. Ann Vasc Surg. 2023;94:362-8.

19. Geisbüsch P, Kotelis D, Hyhlik-Dürr A, Hakimi M, Attigah N, Böckler D. Endografting in the aortic arch - does the proximal landing zone influence outcome?. Eur J Vasc Endovasc Surg. 2010;39:693-9.

20. Dufour C, Gamondes D, Mansuy A, Robin J, Boussel L, Douek P. Pathology-specific late outcome after endovascular repair of thoracic aorta: a single-centre experience. Eur J Cardiothorac Surg. 2015;48:923-30.

21. Kotelis D, Geisbüsch P, Hinz U, Hyhlik-Dürr A, von Tengg-Kobligk H, Allenberg JR, Böckler D. Short and midterm results after left subclavian artery coverage during endovascular repair of the thoracic aorta. J Vasc Surg. 2009;50:1285-92.

22. Czerny M, Funovics M, Schoder M, Loewe C, Lammer J, Grabenwöger M, et al. Transposition of the supra-aortic vessels before stent grafting the aortic arch and descending aorta. J Thorac Cardiovasc Surg. 2013;145:S91-7.

23. Cannavale A, Lucatelli P, Corona M, Nardis P, Basilico F, De Rubeis G, et al. Evolving concepts and management of endoleaks after endovascular aneurysm repair: where do we stand in 2019?. Clin Radiol. 2020;75:169-78.

24. Deniz G, Kasımzade F, Ozcınar E, Yazicioglu L, Eryılmaz S. Share Long-term outcomes of TEVAR for thoracic aortic diseases: a retrospective single-center study. J Cardiothorac Surg. 2024;19:405.

25. Foley PJ, Criado FJ, Farber MA, Kwolek CJ, Mehta M, White RA, et al. Results with the talent thoracic stent graft in the valor trial. J Vasc Surg. 2012;56:1214-21.

26. Sullivan TM, Sundt TM 3rd. Complications of thoracic aortic endografts: spinal cord ischemia and stroke. J Vasc Surg. 2006;43:85A-8.

27. Ullery BW, Wang GJ, Low D, Cheung AT. Neurological complications of thoracic endovascular aortic repair. Semin Cardiothorac Vasc Anesth. 2011;15:123-40.

28. Biancari F, Mariscalco G, Mariani S, Saari P, Satta J, Juvonen T. Endovascular treatment of degenerative aneurysms involving only the descending thoracic aorta: systematic review and meta-analysis. J Endovasc Ther. 2016;23:387-92.

29. Ultee KH, Zettervall SL, Soden PA, Darling J, Bertges DJ, Verhagen HJ, et al. Incidence of and risk factors for bowel ischemia after abdominal aortic aneurysm repair. J Vasc Surg. 2016;64:1384-91.