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Original Article

Endovascular intervention in patients with blunt traumatic thoracic aortic injury: Early results

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Abstract

Aim: Mortality rates are high in thoracic aortic injuries caused by blunt trauma. Thoracic endovascular aortic repair (TEVAR) is the most commonly employed surgical strategy for patients with blunt traumatic thoracic aortic injuries (BTTAI) due to its favorable outcomes. This study aims to present our endovascular experience in treating Type B aortic dissections resulting from blunt trauma.

Material and Methods: Our retrospective study included 70 patients who underwent TEVAR for Stanford Type B aortic dissection due to blunt aortic injury. Patients who were under 22 and over 70 years of age, those who underwent emergency TEVAR, died in a hospital emergency, and had penetrating aortic injury, head traumas with neurological symptoms and requiring intervention, aortic pathology other than Type B aortic dissection, or aortic rupture were excluded from the study.

Results: Of the patients, 34.3% (n=24) were female, and 65.7% (n=46) were male, with a mean age of 48.54±10.00 years. The most common cause of injury was motor vehicle accidents (81.4%, n=57). No statistically significant difference was found between patients regarding the locations of the landing zones ($p>0.05$).

Conclusion: Early outcomes in selected patients demonstrate high survival rates following TEVAR for trauma-induced Type B dissections.

Keywords: Aorta, endovascular procedure, trauma

INTRODUCTION

Blunt traumatic thoracic aortic injuries (BTTAI) have high mortality and morbidity rates, despite being relatively rare. Head trauma is the most common cause of death in blunt trauma cases, followed by thoracic aortic injuries [1-3]. Eighty percent of injured patients die on-site due to severe bleeding, shock, and hypoxemia [4-6]. BTTAI is frequently caused by motor vehicle accidents [7]. In Stanford Type B aortic dissections resulting from these injuries, open surgery offers limited benefit due to high mortality and the risk of paraplegia [8].

For aortic injuries resulting from blunt trauma, the initial imaging modality should be computed tomographic angiography (CTA) [9-11]. Treatment options include conservative management, open surgery, or TEVAR, with a significant shift towards TEVAR in the past two decades due to its superior short-term outcomes [12]. The Society for Vascular Surgery (SVS) Clinical Practice Guidelines were used to classify the severity of aortic trauma. Blunt traumatic thoracic aortic injuries (BTTAI) are graded

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between I and IV based on the severity of the injury assessed using CT [13]. Grade I involves simple contusion intimal tears, Grade II involves injuries extending to the media, intramural hematoma, or dissection, Grade III refers to pseudoaneurysms, and Grade IV indicates tears due to rupture. In 2022, The ACC/AHA guideline recommended TEVAR as the primary treatment for blunt traumatic aortic injuries [13]. This study aims to evaluate the efficacy and outcomes of TEVAR applied to patients with aortic dissection (Stanford Type B) caused by blunt trauma.

MATERIAL AND METHODS

Study Design

This retrospective study included 70 patients who underwent TEVAR for Stanford Type B aortic dissection due to blunt aortic injury at the Cardiovascular Surgery Clinic of Bakirkoy Dr. Sadi Konuk Training and Research Hospital between January 2012 and January 2022. Ethical approval was obtained from the ethics committee of Bakırkoy Dr. Sadi Konuk Training and Research Hospital (Decision Number: 2023-21-01). Patients who were under 22 and over 70 years of age, those who underwent emergency TEVAR, died in a hospital emergency, and had penetrating aortic injury, head traumas with neurological symptoms and requiring intervention, aortic pathology other than aortic rupture, or aortic dissection (Stanford Type B) were excluded from the study. Baseline data, treatment details, and postoperative outcomes of patients with Stanford Type B aortic dissection were retrospectively analyzed. Collected data included age, gender, Glasgow Coma Scale (GCS), injury severity score (ISS) to assess the anatomic severity of injuries in trauma patients in predicting mortality, a referral from another hospital, type and grade of injury, time of presentation to the hospital, TEVAR graft size and number, duration of TEVAR procedure, whether the left subclavian artery closed or not, length of hospital stay, length of intensive care unit, and complications. We were informed about these patients upon admission to the emergency department. If they were hemodynamically stable, routine blood tests were performed first, followed by thoracoabdominal CTA. CTA results were used to assess the absence of occlusive lesions in the iliac arteries, the absence of the tortuous nature of the aorta, and the presence of 2 cm of normal aortic tissue between the lesion and the proximal end of the endovascular graft and 10 cm of normal aortic tissue between the distal ends.

The primary outcome was technical success, defined as complete closure of BTTAI without early (30-day) mortality. Secondary outcomes were morbidity and mortality associated with endoleaks and distal progression of dissection, and reinterventions during follow-up.

Surgical Procedure

All operations were performed under general anesthesia. TEVAR was performed in the angiography unit of cardiovascular surgery. Cerebrospinal fluid (CSF) drainage catheter was inserted by an anesthesiologist. Blood pressure was monitored via the right radial artery, and a central venous catheter (CVC) was placed in the right jugular vein. Patients were placed in the supine position, and TEVAR grafts were customized based on the same-day CTA measurements. Patients were sterile stained and covered from the chest level to both knees. The aorta was accessed through bilateral femoral arteries. One side was surgically evaluated while the other side was percutaneously cannulated. Heparin (100 U/kg) was administered intravenously before the procedure, and an activated clotting time (ACT) [Abbott i-STAT] of 200-250 seconds was maintained. Arterial puncture was performed on the surgically explored side, and a guidewire followed by a stiff wire (super-stiff Backup Meier guidewire (Boston Scientific/Schneider, Bülach, Switzerland)) was advanced to the ascending aorta. A "pig-tail" catheter (Alfa Flow Optimed, Ettlingen, Germany or Cordis, Waterloo, Belgium) was advanced through a 5F (F=French) or 7F Intraducer placed on the percutaneous cannulation side into the aortic arch. Thus, the lesion location was precisely identified by the aortography performed before the procedure. Two types of TEVAR grafts were used in our patients: the Valiant Thoracic Stent Graft System (Medtronic Vascular, Santa Rosa, Calif), and the Ankura (Lifetech Scientific, Shenzen, China). The stent grafts were placed at least 2 cm proximal to the lesion. Systolic blood pressure was reduced under 100 mmHg with anesthetics and intravenous antihypertensive drugs to prevent graft migration during opening and to ensure opening in the desired location. Post-procedural imaging confirmed correct stent placement, endoleak absence, and patency of vascular structures such as the carotid artery and left subclavian artery. In case of endoleak or incomplete penetration of the proximal and distal ends of the stent into the aorta, balloon dilation was performed, or extra stent graft was used. The system was separated from artery, the artery was repaired continuously with 5/0 polypropylene suture, and the pulse distal to the cannulation was checked. After bleeding control, a Hemovac drain was placed on the site, and the subcutaneous tissues and skin were closed according to the anatomical plan.

Postoperative Intensive Care Follow-up

Patients were closely monitored postoperatively for blood pressure, blood gases, and pulses in the left upper extremity. Electrolytes and lactate levels were checked regularly via hourly blood gas analyses. Intravenous (IV) isotonic solution (100 cc per hour) was administered to prevent contrast nephropathy,

ensuring diuresis. Aggressive antihypertensive therapy was applied both intravenously and through nasogastric tubes, targeting a mean arterial pressure of 100 mmHg. In patients who underwent CSF drainage, CSF pressure was maintained between 9 and 12 mm Hg. All patients were extubated in the cardiovascular surgery intensive care unit. Patients with stable progress were transferred to the cardiovascular surgery service on postoperative day 1. Patients were administered a single daily dose of 100mg acetylsalicylic acid.

Thoracoabdominal CTA was performed in the 1st month, 1st year, and 2nd year of follow-up to evaluate any complications following TEVAR.

Patient Follow-up After TEVAR

After the TEVAR procedure, follow-up was given to identify complications such as acute renal failure (ARF), contrast nephropathy, distal embolism, bowel ischemia, visceral organ malperfusion, rupture, pleural and pericardial effusion, graft kinking, paraplegia, cerebrovascular accident (CVA), inguinal hematoma, seroma, limb ischemia, and vertebrobasilar insufficiency. Left arm pulses were monitored for ischemia, especially in patients who underwent carotid-subclavian bypass (CSB) or where the graft was placed in the aortic arch. Special attention was paid to distal embolism or ischemia of the limbs or visceral organs caused by closure of the false lumen. Isolated lactate elevation could indicate limb or visceral ischemia, as well as severe rupture or graft folding. Hemoglobin levels were carefully monitored to detect any signs of rupture.

Statistical Analysis

The study's data were analyzed using NCSS (Number Cruncher Statistical System) 2020 Statistical Software (NCSS LLC, Kaysville, Utah, USA) (License No: 1675948377483; Serial No: N7H5-J8E5-D4G2-H5L6-W2R7). Descriptive statistical methods (mean, standard deviation, median, frequency, percentage, minimum, and maximum) were applied. The Shapiro-Wilk test and graphical analysis were used to assess whether quantitative data (e.g., age, hemogram, creatinine) conformed to normal distribution. A statistical significance level of $p<0.05$ was considered.

RESULTS

The study involved 70 patients, 34.3% (n=24) of whom were female and 65.7% (n=46) of whom were male, with a mean age of 48.54±10.00 years. The Glasgow Coma Scale (GCS) indicated moderate neurological damage in 54.3% (n=38) of the patients. Additionally, 35.7% (n=25) had an injury severity score between 15 and 24, 60% (n=42) between 25 and 49, and 4.3% (n=3) between 50 and 74 (Table 1).

Table 1. distribution of descriptive characteristics

		n (%)
Age	**Mean±SD**	48.54±10.00
	Median (Min-Max)	49 (22-70)
Gender	**Female**	24 (34.3)
	Male	46 (65.7)
Hypertension		29 (41.4)
Diabetes mellitus		27 (38.6)
Chronic obstructive pulmonary disease		8 (11.4)
Peripheral artery disease		4 (5.7)
Coronary artery disease		3 (4.3)
Chronic renal failure		3 (4.3)
Smoking		42 (60.0)
Referral from another hospital		3 (4.3)
Glasgow coma scale	**Moderate**	38 (54.3)
	Mild	32 (45.7)
Injury severity score	**15-24**	25 (35.7)
	25-49	42 (60.0)
	50-74	3 (4.3)
Preoperative cardiac arrest		1 (1.4)
Preoperative hemoglobin	**Mean±SD**	12.48±1.02
	Median (Q1-Q3)	12.6 (11.8.-13.1)
Postoperative hemoglobin	**Mean±SD**	11.60±1.50
	Median (Q1-Q3)	11.9 (10.5-12.8)
Preoperative creatine	**Mean±SD**	1.13±0.81
	Median (Q1-Q3)	0.96 (0.88-1.1)
Postoperative creatine	**Mean±SD**	1.13±0.85
	Median (Q1-Q3)	0.95 (0.84-1.10)

Q1-Q3: Percentiles %25-%75

The most common type of injury was motor vehicle accidents (81.4%, n=57). Other injuries included head injuries without neurological symptoms and not requiring intervention (7.9%, n=7), multiple rib fractures (36%, n=32), lung contusions (2.2%, n=2), upper extremity fractures (27%, n=24), lower extremity fractures (16.9%, n=15), pelvic injuries (2.2%, n=2), liver injuries (2.2%, n=2), spinal fractures (2.2%, n=2), maxillofacial

injuries (2.2%, n=2), and pneumothorax (1.1%, n=1) (Table 2). The preoperative descending aortic diameters ranged between 27 and 56.06 mm, with a mean of 31.75±4.18 mm. In the blunt trauma classification, 61 patients (87.1%) had Grade II injuries, and 9 patients (12.8%) had Grade III injuries. No patients had Grade I or IV trauma.

The preoperative dissection levels were distributed as follows: T4 in 22.9% (n=16), T5 in 30% (n=21), T6 in 38.6% (n=27), T7 in 2.9% (n=2), T8 in 2.9% (n=2), and T9 in 2.9% (n=2) of the patients (Table 2).

Table 2. Distribution of characteristics related to the disease

		n (%)
Type of injury	**Vehicle accident**	57 (81.4)
	Motorcycle accident	5 (7.1)
	Pedestrian collision	5 (7.1)
	Fall	1 (1.4)
	Bicycle	2 (2.9)
•Sites of injury	**Head Trauma**	7 (10.0)
	Multiple rib fractures	33 (47.1)
	Lung contusion	16 (22.9)
	Limb injury	30 (42.9)
	Pelvic injury	1 (1.4)
	Liver injury	1 (1.4)
	Spine fracture	1 (1.4)
	Maxillofacial injury	1 (1.4)
	Pneumothorax	1 (1.4)
Time to reach the hospital (minutes)	**Mean±SD**	45.90±24.29
	Median (Q1-Q3)	40 (31-50)
Preoperative descending aortic diameter (mm)	**Mean±SD**	31.75±4.18
	Median (Q1-Q3)	30.23 (29.3-32.7)
Preoperative dissection level	**T4**	16 (22.9)
	T5	21 (30.0)
	T6	27 (38.6)
	T7	2 (2.9)
	T8	2 (2.9)
	T9	2 (2.9)

Q1-Q3: Percentiles %25-%75 •Multiple injuries were observed.

Proximal stent graft sizes ranged between 30 and 40 mm, with a mean of 35.27±3.35 mm, and distal stent graft sizes ranged between 26 and 40 mm, with a mean of 32.79±4.24 mm. Stent graft lengths ranged between 90 and 230 mm, with a mean of 157.29±32.12 mm. Left subclavian artery revascularization was performed in 5.7% (n=2) of the patients who developed left upper extremity ischemia postoperatively, and in 5.7% (n=2) whose subclavian artery closure was confirmed during pre-procedure measurements (Table 3).

Table 3. Distribution of characteristics related to the disease

		n (%)
Procedural success		70 (100.0)
Proximal stent graft size (mm)	**Mean±SD**	35.27±3.35
	Median (Q1-Q3)	36 (32-38)
Distal stent greft size (mm)	**Mean±SD**	32.79±4.24
	Median (Q1-Q3)	34 (29.5-36)
Stent graft length (mm)	**Mean±SD**	157.29±32.12
	Median (Q1-Q3)	160 (130-200)
Landing zone (LZ)	**LZ II**	2 (2.9)
	LZ III	59 (84.3)
	LZ IV	9 (12.9)
Number of grafts used per patient	**1 Graft**	69 (98.6)
	2 Grafts	1 (1.4)
Primary endoleak	**Balloon angioplasty + stent placement**	1 (1.4)
Left subclavian artery revascularization	**Yes**	4 (5.7)
	None	66 (94.3)
TEVAR fluoroscopy time (minutes)	**Mean±SD**	60.33±21.43
	Median (Q1-Q3)	56 (45-65,8)
Total surgery time (minutes)	**Mean±SD**	135.19±35.85
	Median (Q1-Q3)	130 (115-145)

Q1-Q3: Percentiles %25-%75

Intensive care unit stay was between 1 and 3 days, with a mean of 1.40±0.60 days, and the average hospital stay was 5.33±0.86 days (Table 4).

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Table 4. Distribution of characteristics related to the disease

		n (%)
CSF drainage catheter placement		5 (7.1)
Ventilator time (minutes)	**Mean±SD**	272.36±51.03
	Median (Q1-Q3)	250 (240-313)
Reintubation		3 (4.3)
Total intensive care length (days)	**Mean±SD**	1.40±0.60
	Median (Q1-Q3)	1 (1-2)
Length of hospitalization (days)	**Mean±SD**	5.33±0.86
	Median (Q1-Q3)	5 (5-6)
Complication	**Yes**	54 (77.1)
	None	16 (22.9)
Complications	**Transient neurological deficit**	5 (7.1)
	Acute renal failure	3 (4.3)
	Need for dialysis	1 (1.4)
	Pulmonary complication	26 (37.1)
	Infectious complication (femoral region)	20 (28.6)
	Distal organ malperfusion	1 (1.4)
	Endoleak	1 (1.4)
	MI	2 (2.9)
	Stent migration	1 (1.4)
Postoperative 1st month- follow-up CTA	**Normal**	65 (92.9)
	Type 1 endoleak	1 (1.4)
	Femoral site infection	4 (5.7)
Postoperative 1st year- follow-up CTA	**Normal**	67 (95.7)
	Migration	2 (2.9)
	Dead	1 (1.4)
Postoperative 2nd year - follow-up CTA	**Normal**	66 (94.3)
	Pseudoaneurysm (femoral artery)	1 (1.4)
	Dead	3 (4.3)

Q1-Q3: Percentiles %25-%75 •Multiple complications were observed.

Regarding the complications of the participating patients (Figure 1), the most common complication was pulmonary complication with 37.1% (n=26). Other complications included infectious complications (28.6%), transient neurological deficits (7.1%), and acute renal failure in 5.7% (n=4) of the patients, with only 1.4% (n=1) requiring dialysis. Follow-up CTA results from the first month are shown in Figure 2.

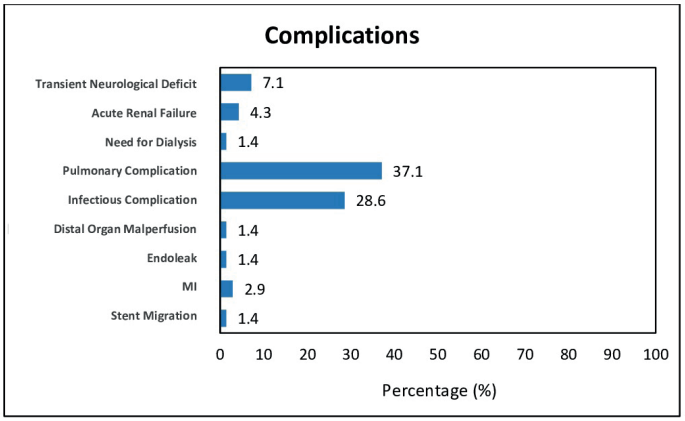

Figure 1. Distribution of complications

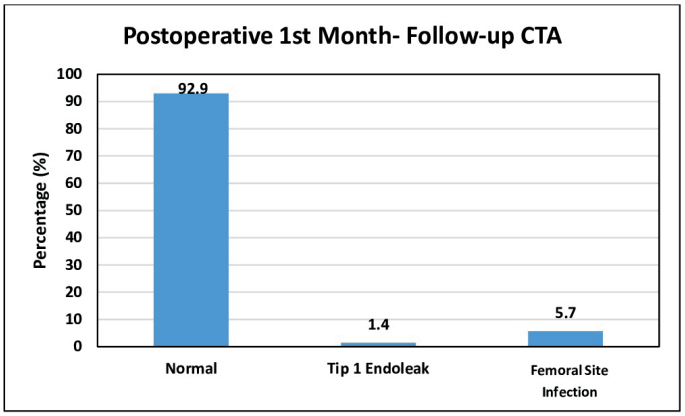

Figure 2. Postoperative 1st month - follow-up CTA distribution

By the first year of follow-up, 95.7% (n=67) of patients had normal CTA results, while 2.9% (n=2) had migration. One patient (1.4%) died due to cardiac issues unrelated to the TEVAR procedure.

DISCUSSION

Our findings suggest that TEVAR offers better outcomes compared to open surgery for the treatment of blunt traumatic thoracic aortic injuries. Patients who undergo TEVAR experience shorter hospital stays and quicker recoveries. Yigit G. et al. [14] performed CSB for left upper extremity ischemia after TEVAR procedure. Similarly, in our study, we performed CSB when left upper extremity ischemia developed. Furthermore, Askin G. et al. [15] reported no death attributable to the TEVAR procedure, aligning with our study results. However, our study had several limitations. First, its single-center, retrospective design and relatively small patient population might have introduced selection bias, affecting the results. Second, there was no long-term follow-up of the patients. Third, material was

not commercially available; therefore, we did not have a stock of stent grafts for emergencies, and the graft sizes could not be precisely dimensioned in some patients.

The Society of Vascular Surgeons (SVS) Clinical Practice Guidelines recommend immediate TEVAR within 24 hours for Grade II to IV BTTAI [16]. In our clinic, we opt for semi-urgent TEVAR for Grade II aortic injuries and urgent TEVAR for Grade III and IV injuries, with favorable early outcomes. In Grade I patients, surveillance imaging is performed, and a personalized treatment plan is decided by multidisciplinary consensus. The optimal timing of intervention remains unclear, and treatment should be individualized based on various factors, such as the presence of other injuries, comorbidities, patient's physiological status and the severity of the aortic injury. For cases involving extravasation or extensive aortic injuries, repair should be performed urgently within hours of diagnosis.

The devices used today are primarily designed to treat aneurysms, which occur more frequently in older populations. Trauma patients, however, tend to be younger, meaning that commercially available devices are not always suitable in terms of size. Some young patients have aortic diameters smaller than 20 mm, which remain small even when choosing devices with diameters 10-15% larger than those recommended for standard use. In adolescents and young adults, the sharper curvature of the aortic arch presents a challenge, as the limited flexibility of current devices can prevent a complete fit to the vessel wall. Despite these limitations, TEVAR grafts yield excellent short- and mid-term results, though long-term data is still lacking. Given the long life expectancy of young patients post-TEVAR, close monitoring for complications and regular control imaging are essential.

TEVAR is a viable treatment option for thoracic aortic pathologies. In open thoracic aorta replacement, mortality rates vary between 0 and 27%, despite the advancements in surgical techniques [17]. In the INSTEAD trial, a group that received only medical treatment was compared with a group that underwent TEVAR, with the latter group demonstrating better thrombosis of the false lumen. Therefore, TEVAR was found to be more effective in limiting aortic dilatation and preserving the true lumen [18].

The endovascular technique was first introduced for aortic pathologies in an experimental study on animals by Parodi et al. in 1991 [19]. The successful treatment of abdominal aortic aneurysms with the endovascular technique prompted investigations into its application in thoracic aortic pathologies. Initially used to treat thoracic aortic aneurysms in the early 2000s, TEVAR quickly became an alternative to open surgery for traumatic thoracic aortic injuries due to its lower mortality and morbidity rates [20].

In our study, the male population was predominant (65.7%), hypertension was the most common comorbidity (41.4%), and consistent with the 2022 ACC/AHA guidelines, vehicle accidents were the leading cause of injury (81.4%) [13-21].

Traumatic aortic injuries are often accompanied by other organ injuries. Wahl et al. and Fabian et al. reported a high incidence of multiple organ injuries among patients with traumatic aortic injury, including closed head trauma (51%), intracranial hemorrhage (24%), multiple rib fractures (46%), lung contusion (38%), and upper extremity fractures (20%) [22,23]. In our study, 7.9% (n=7) of patients had head trauma, 36% (n=32) had multiple rib fractures, 2.2% (n=2) had pulmonary contusion, 27% (n=24) had upper extremity fractures, 16.9% (n=15) had lower extremity fractures, 2.2% (n=2) had pelvic injury, 2.2% (n=2) had liver injury, 2.2% (n=2) had spinal fracture, 2.2% (n=2) had maxillofacial injury, and 1.1% (n=1) had pneumothorax. These results highlight the importance of managing organ injuries in patients with traumatic aortic injury, which can be assessed using the Injury Severity Score (ISS). In the study by Fabian et al., the mean ISS was 42.1 [22]. In this study, 35.7% (n=25) of patients had an ISS between 15 and 24, 60% (n=42) between 25 and 49, and 4.3% (n=3) between 50 and 74. They reported that left subclavian artery revascularization only covered the long aortic segment and was necessary for specific indications, such as patent hypoplastic right vertebral artery, left internal thoracic artery graft, or functioning dialysis fistula in the left upper extremity [24]. None of the patients in this study had an indication for left subclavian artery revascularization. However, some studies have reported a higher risk of posterior circulation paralysis and postoperative arm ischemia in patients whose left subclavian artery was intentionally closed compared to those in whom it was not [25-28]. In this study, the left subclavian artery was completely closed in 4 patients, all of whom developed postoperative pain and ischemia in the left hand. These patients underwent a bypass from the left carotid artery to the subclavian artery using a 6 mm polytetrafluoroethylene (PTFE) graft.

As noted in the 2022 AHA/ACC guidelines [13], TEVAR is recommended over open surgery for patients with blunt thorax trauma, provided that their anatomy is suitable. Utilization rates of TEVAR have risen from 12.1% to 25.7%. Although no studies have directly compared endovascular and open repair, trauma registry data and meta-analyses indicate that TEVAR has lower 30-day mortality rates and a reduced incidence of spinal cord ischemia and acute kidney injury. In this study, no mortality occurred, and neither acute kidney injury nor spinal cord ischemia developed.

Ehrlichet et al. [29] reported on 41 patients who underwent TEVAR a hospital mortality rate of 2.4% after thirteen months of follow-up. The procedure was technically successful in all patients (100%). In this study, the technical success rate was also 100%, with no patients requiring open aortic repair before the procedure. At 24 months of follow-up, 4 patients (5.7%) had died, though these deaths were unrelated to the TEVAR procedure.

Study Limitations

This study has several limitations. First, its single-center, retrospective design and relatively small patient population might have introduced selection bias, affecting the results. Second, there was no long-term follow-up of the patients. Third, material was not commercially available; therefore, we did not have a stock of stent grafts for emergencies, and the graft sizes could not be precisely dimensioned in some patients.

CONCLUSION

In conclusion, the early results indicate high survival rates in selected patients undergoing TEVAR for trauma-induced Type B dissections. Larger, randomized studies are needed due to the limited application of endovascular procedures for aortic pathologies in trauma populations.

Ethics Committee Approval: The ethical approval for this study was granted by the ethics committee of Bakirkoy Dr. Sadi Konuk Training and Research Hospital (Decision Number: 2023-21-01).

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

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