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Thoracic Endovascular Aortic Repair: Single-Center Experience

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Thoracic Endovascular Aortic Repair: Single-Center Experience

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Resumo

Introdução: As doenças que envolvem a aorta torácica são uma importante causa de mortalidade nos países desenvolvidos. O tratamento endovascular da aorta torácica (TEVAR) tornou-se o tratamento preferencial para a maioria das patologias da aorta torácica descendente, devido a associar-se a menores taxas de morbilidade e mortalidade, particularmente, em doentes de elevado risco. Contudo, trata-se de um procedimento recente, pelo que informação relativa aos seus benefícios a longo termo, reintervenções e mortalidade tardia ainda é escassa. Este estudo tem como objetivos avaliar as características dos doentes e analisar resultados, como mortalidade, complicações e necessidade de reintervenções, entre os doentes submetidos a TEVAR no nosso centro, ao longo da última década.

Métodos: Foi realizado um estudo retrospetivo observacional dos 54 doentes submetidos a TEVAR no Centro Hospitalar Universitário do Porto entre janeiro 2010 e agosto 2020. Variáveis demográficas, pré-operatórias, operatórias e pós-operatórias foram recolhidas dos processos médicos eletrónicos, relatos cirúrgicos, meios complementares de diagnóstico e meios imagiológicos. Foram analisadas complicações após TEVAR inicial e avaliados fatores contribuintes para mortalidade e reintervenção. A análise de sobrevivência e sobrevivência livre de reintervenção foi realizada com recurso aos gráficos de Kaplan Meier.

Resultados: Foram incluídos 54 doentes com uma mediana de idade de 68 anos (IIQ 61.5 — 78). Em 7.3% dos casos ocorreu isquemia medular pós-operatória. A taxa de reintervenção foi de 25.5%. A sobrevida livre de reintervenção a 1 ano foi de 74.6% (± 5.8%) e de 69% (± 8.4%) aos 5 anos. Verificou-se endofugas em 27.3% dos doentes; sendo esta complicação um preditor significativo da necessidade de reintervenção (HR 3.94, P=0.02). A necessidade de reintervenção está significativamente associada à mortalidade pós-operatória. A mortalidade bruta a 30 dias foi de 9.3%. A sobrevida bruta foi de 73.8% (± 6%) a 1 ano, 65.5% (± 7%) aos 3 anos e 46.5% (± 9,6%) aos 5 anos de seguimento.

Conclusão: A mortalidade a 30 dias e a taxa de isquemia medular permanecem elevadas, ainda assim, concordantes com as percentagens descritas na literatura. Observamos uma relação significativa entre a reintervenção e a mortalidade. Complicações com endofugas são preditores de necessidade de reintervenção.

Palavras-chave: Cirurgia Aorta Torácica; Cirurgia Doenças Aórticas; Lesões Aorta Torácica; Implantação de Prótese Vascular; Prótese Endovascular; Procedimentos Endovasculares; Complicações Pós-operatórias; Stents

Abstract

Objective: Thoracic aortic diseases are an important cause of death in the developed world**.** Thoracic endovascular aortic repair (TEVAR) has become the elected treatment for the majority of the descending thoracic aorta pathologies, owing to its association with decreased morbidity and mortality rates, particularly in those with elevated clinical risk. However, it is a recent procedure which still lacks information regarding long-term benefits, reintervention and late mortality. This study aims to assess patients' characteristics and to analyze outcomes, such as mortality, complications and need for reintervention, among patients who underwent TEVAR at our center over the last decade.

Methods: We performed a retrospective observational study of 54 patients who underwent TEVAR at Centro Hospitalar Universitário do Porto between January 2010 and August 2020. Demographics, preoperative, operative and postoperative variables were collected from patients' medical records, operative reports, laboratory and radiographic registries. Complications after index TEVAR, factors contributing to both mortality and reintervention were analyzed; survival and reintervention-free survival were evaluated through Kaplan-Meier curves.

Results: A total of 54 patients with a median age of 68 years (IQR 61.5 — 78) were included. Postoperative spinal cord ischemia (SCI) occurred in 7.3% of the cases. Reintervention rate was 25.5%. Freedom from reintervention at 1 year was 74.6% (± 5.8%) and 69% (± 8.4%) at 5 years. Endoleaks occurred in 27.3% of patients and were a significant predictor for reintervention (HR 3.94, P=0.02). The need for reintervention was significantly associated with mortality. The 30-day all-cause mortality rate was 9.3%. Freedom from all-cause mortality was 73.8% (± 6%) at 1 year, 65.5% (± 7%) at 3 years and 46.5% (± 9,6%) at 5 years of follow-up.

Conclusions: Thirty-day mortality and SCI rates remained appreciable, yet in accordance with percentages that have been reported in the literature. A statistically significant relation between reintervention and mortality in univariate analysis was observed in this analysis. Endoleak development significantly increases the risk of reintervention.

Keywords:

Aorta, Thoracic / surgery*; Aortic Diseases / surgery*; Aorta, Thoracic / injuries*; Blood Vessel Prosthesis Implantation / instrumentation*; Blood Vessel Prosthesis*; Endovascular Procedures / instrumentation* Postoperative Complications; Stents*

List of Abbreviations

AAS – Acute Aortic Syndromes

ATBAD – Acute Type B Aortic Dissection

CI- Confidence Interval

COPD – Chronic Obstructive Pulmonary Disease

CT- Celiac Trunk

CTBAD – Chronic Type B Aortic Dissection

CSF – Cerebrospinal fluid

DTA – Descending Thoracic Aorta

DTAA – Descending Thoracic Aortic Aneurysm

GOLD - Global Initiative for Chronic Obstructive Lung Disease

IMH – Intramural hematoma

IQR – Interquartile range

KDIGO - Kidney Disease: Improving Global Outcomes

LRA – Left Renal Artery

PAU – Penetrating aortic ulcer

RRA – Right Renal Artery

SCI – Spinal Cord Ischemia

SMA – Superior Mesenteric Artery

TAAA – Thoracoabdominal aortic aneurysm

TEVAR – Thoracic Endovascular Aortic Repair

USA – United States of America

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Introduction

The descending thoracic aorta (DTA) corresponds to the segment of the aorta between the isthmus (region between the origin of left subclavian artery and the ductus arteriosus) and the aortic hiatus in the diaphragm. There is a large spectrum of diseases involving the descending thoracic aorta, including degenerative, structural, congenital and traumatic pathologies.[1]

Specific descending thoracic aortic diseases can be divided in acute or chronic syndromes, depending on clinical presentation. Acute aortic syndromes (AAS) encompass a heterogeneous group of diseases that share similar anatomic and clinical characteristics. Acute aortic dissection, intramural hematoma (IMH), penetrating aortic ulcer (PAU), blunt aortic injury and ruptured aortic aneurysms are often included in this group; they may coexist in the same patient and can even progress to one another. At the histological level, they are characterized by disruption of the media of the aorta with bleeding between the layers or transmurally when rupture occur.[1,2]

Among chronic aortic diseases, chronic type B aortic dissection (CTBAD) is the most frequent, with a reported incidence between 2.9 and 4.0 per 100000 person-years. Thoracic and thoracoabdominal aneurysms may affect around 6 to 10.4 per 100000 person-years; less frequent entities include inflammatory diseases such as Takayasu arteritis, giant cell arteritis or Behçet disease, coarctation of the thoracic aorta, tumors or genetic syndromes such as Marfan syndrome.[1]

Thoracic aortic diseases are an important cause of death in the developed world, and its prevalence keeps increasing as the population grows older and the clinical awareness and diagnosis increases. Surgical repair of DTA diseases, particularly thoracic aneurysms, remain a serious challenge in vascular surgery because of the technical demands of the procedure and the physiologic stress it imposes on the patient, which can lead to stroke, paraplegia, renal failure, visceral ischemia, cardiopulmonary arrest or even death.[3]

Thoracic endovascular aortic repair (TEVAR) emerged in 1987, initially developed to the exclusion of thoracic aneurysms, it is currently the elected treatment for the majority of the descending thoracic aorta pathologies.[4,5]

TEVAR is a minimally invasive technique[5]. The indications include acute complicated type B aortic dissections, intramural hematoma, penetrating aortic ulcer, traumatic aortic injury and thoracic and thoracoabdominal aortic aneurysms.[1,6]

In what concerns to acute uncomplicated type B aortic dissection, guidelines advocate that endovascular intervention may be considered in selected cases.[1] Recent studies suggest an advantage of TEVAR for uncomplicated type B dissection.[7,8]

Likewise, TEVAR for chronic type B aortic dissection is also controversial. Guidelines indicate open repair as the standard treatment[1]**,** yet some studies have demonstrated benefits of endovascular treatment[9-11]

Severe complications, especially neurological, such as spinal cord ischemia (SCI) and stroke can occur after TEVAR; although it has a lower incidence of neurological complications compared to open repair, the risk is still significant.[12-14] SCI incidence after TEVAR is estimated between 2-10%[15] and a recent study demonstrated a stroke rate after TEVAR of 4.5%.[16]

Endoleaks are also a potential complication of TEVAR; an endoleak can be defined as blood flow outside the endograft lumen, promoting pressurization of the excluded aortic segment.[17,18] Type I and III endoleaks may increase the risk of rupture and often need intervention.[18,19]

Another disadvantage of TEVAR in comparison to open repair is an elevated rate of reintervention ranging from 11-15% in current literature.[20]

Despite the potential complications, TEVAR is generally associated with decreased morbidity and mortality rates, particularly in those with high clinical risk, leading to an increase in intervention rates in patients that were former refused as considered to be at high surgical risk.[5] However, enthusiasm for TEVAR should be tempered by the paucity of follow-up data and requirement for lifelong follow-up. It still lacks information regarding long-term benefits, reintervention and late mortality.[4,5,21]

The aim of this study was to assess epidemiologic characteristics and to analyze outcomes, such as mortality, complications and need for reintervention, among patients who underwent TEVAR at our center over the last decade.

Methods

We performed a retrospective observational study of 54 patients who underwent TEVAR at Centro Hospitalar Universitário do Porto between January 2010 and August 2020. No exclusion criteria were applied.

This study complied with the Declaration of Helsinki and was approved by the ethics committee of our institution. The informed consent was waived due to the non-intervention nature of the study, all the information collected being available in medical charts, not requiring direct contact with patients, and the decision of treatment being independent of the decision of including the patient in the study and a result of current clinical practice.

We analyzed patients' medical records, operative reports, laboratory and radiographic registries to obtain data regarding demographics (sex, age, date and cause of death), comorbid and past conditions (hypertension, smoking habits, diabetes, chronic obstructive pulmonary disease, hyperlipidemia, renal insufficiency, hemodialysis, prior abdominal aortic intervention, carotid atherosclerosis disease, arch or descending thoracic aorta atherosclerosis, congenital, hereditary and autoimmune syndromes), clinical presentation, thoracic aortic disease and its characteristics as well as preoperative C-reactive protein and hemoglobin levels. Operative variables included date of intervention, priority of the procedure, use of branched, chimney and periscope stent grafts, proximal landing zone, debranching or revascularization of aortic arch vessels, debranching or revascularization of abdominal visceral vessels, use of prophylactic cerebrospinal fluid drainage, intraoperative complications and conversion to open surgery. Postoperative variables included the development of endoleak, complications related to prosthesis, vessels or ischemia, need for reintervention, date of reintervention, postoperative hemoglobin and C-reactive protein levels, need for transfusion and date of hospital discharge.

Statistical analysis

Descriptive statistics were applied according to data type: categorical variables were presented as frequencies and continuous variables as means with standard deviations or median with interquartile range, depending on the normality of their distribution. Categorical variables were compared using Pearson's Chi-square test or Fisher's exact probability test when appropriate. In order to assess factors contributing to mortality and to reintervention, variables with statistical significance ($p<0.05$) in univariate analysis were then included in multivariate Cox Regression analysis. Kaplan-Meier curves were used to evaluate survival and event-free survival after the index TEVAR procedure. Statistical analysis was performed using IBM® SPSS® Statistics 26 (National Opinion Research Center, USA).

Results

Demographic characteristics

A total of 54 patients with a median age of 68.5 years were included, of whom the majority 79.6% were male. The most prevalent comorbid condition was hypertension (79.6%), followed by dyslipidemia (70.4%). Around 68.5% of the cohort were active or former smokers. Only 5 patients (9.3%) had an established diagnosis of diabetes. Around one quarter had chronic obstructive pulmonary disease, of which 7 patients were classified as GOLD 3. There were 2 patients with stage 4 chronic kidney disease and 11 with stage 3. Twenty-one patients (38.9%) had arch and/or descending aorta atherosclerosis. Seven patients had ischemic heart disease, five had heart failure and four patients had peripheral artery disease. One patient had Marfan syndrome and another one had Takayasu arteritis. One patient was diagnosed with familial non syndromic thoracic aortic disease and had four prior aortic surgeries (for type A dissection and thoracic aneurysm) including a Bentall procedure performed at different institutions. Six patients had a prior abdominal aortic intervention: half had endovascular intervention and half was an open surgery. Baseline characteristics are listed in table I.

Clinical presentation and procedural characteristics

Fifty-five TEVAR were performed (one patient underwent two procedures, in which the second was not related to the first). The procedures were elective in 44, urgent deferred in 6 and emergent in 5 cases. Acute aortic syndromes justified 17 cases and the remaining 39 cases were performed due to chronic aortic diseases. One patient had both an acute aortic syndrome and a chronic aortic pathology, specifically a complicated intramural hematoma plus a thoracoabdominal aortic aneurysm. A different patient presented with both a type B acute aortic dissection and a ruptured TAAA. Among the AAS, uncomplicated PAU and/or IMH was the most frequent indication (47.1%), followed by complicated PAU and/or IMH (23.5%). In what concerns to chronic pathologies, the majority were descending thoracic aortic aneurysms (59%), followed by thoracoabdominal aneurysms (25.6%) (table II).

The most common symptom was thoracic/dorsal/interscapular pain (18.2%), followed by lumbar pain (9.1%) and abdominal pain (7.3%). Two patients had atheroembolism, one patient had hemoptysis and one had a pleural effusion. Two patients presented with hypotension at admission.

Preoperative prophylactic cerebrospinal fluid drainage was performed in 18.2% of the procedures. Upon stent graft deployment, the most used proximal landing zone was zone 4 in

46.3% of the situations (table II). Adjunctive arch vessels procedures were performed in 13 patients (23.6%) and left common carotid artery to left subclavian artery bypass was the most frequent supra-aortic trunk revascularization (46.2%). One patient required the stent graft to be proximally landed at zone 0, so complementary right common femoral artery to right axillary artery bypass and chimney stent grafting of left common carotid artery and left subclavian artery were also performed. The techniques used in adjunctive arch vessels revascularization are described in table III along with the corresponding TEVAR stent graft proximal landing zone.

When needed, adjunctive procedures for revascularization of visceral aortic vessels were performed in 10.9% of the cases. The techniques used are detailed in table IV.

Intraoperative complications occurred in 6 procedures (10.9%): two patients had blood loss requiring transfusion; one patient developed hypovolemic shock with peri-arrest arrhythmia requiring adrenergic support; other patient had a self-limited ventricular tachycardia episode; one procedure had a type 3 endoleak at the control angiography that was resolved intra-operatively; one patient had left brachial artery iatrogenic lesion caused by the 8Fr sheath used in this artery, which was resolved with thromboembolectomy and inlay brachio-brachial bypass with reversed great saphenous vein. Worth noting in two different patients, there was also iatrogenic laceration of the left common iliac vein and the duodenum that were immediately controlled with proper suture. There was no conversion to open surgery and no intraoperative mortality.

Postoperative outcomes

Median inpatient length of stay was 12 days (IQR 5 — 23). The minimum stay was one day, corresponding to the death of a patient, who was in hypovolemic shock and had a cardiorespiratory arrest. On the other side, a polytrauma patient who had a PAU resulting from blunt injury in the DTA later complicated with a meningitis had a maximum stay of 302 days.

Transfusion support was needed in 5 cases within the first 24 hours postoperative (9.1%) and in 10 cases at 48-72 hours postoperative (18.2%). Table V shows the mean or median values of hemoglobin and c-reactive protein preoperatively and at 24 and 48-72 hours postoperative.

Endoleaks ensued in 15 of the 55 TEVAR performed (27.3%). Isolated type 1 and isolated type 2 endoleak occurred in equal proportions (9.1% each) as shown in table VI. One patient developed both a type 1 and type 2 endoleak. Moreover, one patient had a type 2 and a type 3 endoleak, making endoleak type 2 the most frequent.

Two patients developed aortobronchial fistulas and another patient had a pseudaneurysm that complicated with an aortoesophageal fistula. Another patient developed an anastomotic pseudoaneurysm of the right common iliac artery to celiac trunk bypass, whose dehiscence lead to intra-abdominal hemorrhage. Likewise, one patient who had been submitted to a left common carotid artery to left subclavian artery bypass had a cervical hematoma. Postoperative thrombosis of the left common femoral artery and visceral revascularization bypass occurred in two patients, respectively, requiring surgical thrombectomy. One patient, who underwent TEVAR for type I TAAA progressed with an aortic arch aneurysm.

Two patients developed postoperative splanchnic ischemia, one of them had concomitantly renal ischemia. One patient suffered a non-ST-segment elevation myocardial infarction 6 days after TEVAR.

Postoperative SCI occurred in 7.3% of the cases. Corresponding to 4 patients, 3 of them had transient SCI, with symptoms reverting with drainage of cerebrospinal fluid. The patient who maintained paraplegia had been submitted to prophylactic drainage, though, he presented multiple recognized risk factors for the development of spinal cord ischemia such as renal insufficiency, hypertension, ruptured TAAA and the use of three stents with extensive aortic coverage.[15,22]

No stroke or transient ischemic attack were registered after TEVAR. However, one patient developed total anterior circulation cerebral infarction after a reintervention that consisted of a proximal extension of the stent graft to zone 1 and a right common carotid artery to left common carotid artery bypass. In this case, factors that might have contributed to the development of stroke are coverage of left subclavian artery and/or embolization due to manipulation of wires and catheters, which are risk factors associated with the occurrence of stroke after TEVAR.[18]

Around 9% of patients developed acute kidney injury, 6 had nosocomial pneumonia, 2 developed septic shock, 2 had new onset atrial fibrillation during hospitalization and 2 patients had acute pancreatitis.

Reintervention was necessary in a quarter of all TEVARs performed (14 out of 55). The detailed reasons for reintervention as well as the description of the procedures are reported in table VII. The most frequent indication for reintervention was endoleak, and as revealed in table VIII, a multivariate analysis using the Cox proportional hazards models showed that the development of endoleak is a significant predictor for reintervention with a hazard ratio of 3.94 (95% CI 1.24 — 12.51).

As shown in figure I, freedom from reintervention (± standard error) at 1 year was 74.6% (± 5.8%) and 69% (± 8.4%) at 5 years. The 30-day all-cause mortality was 9.3%. Freedom from all-cause mortality (± standard error) was 73.8% (± 6%) at 1 year, 65.5% (± 7%) at 3 years and 46,5% (± 9.6%) at 5 years (figure II). Median follow-up time was 25 months (IQR 8 — 57).

Discussion

TEVAR is currently the preferred treatment for the majority of the descending thoracic aorta pathologies[4,5] making it important to evaluate its short and long term outcomes. Multiple studies have documented mortality[23-25], neurological complications[15,23,26] and reintervention[20,27,28] rates after TEVAR for multiple aortic pathologies. This study aimed to analyze these same outcomes in the cohort of patients who underwent TEVAR at our center over the last decade.

Results from the Study to Assess Outcomes After Endovascular Repair for Multiple Thoracic Aortic Diseases (SUMMIT) showed a 30-day all-cause mortality, stroke, paraplegia and paraparesis rates of 1.7%, 3.1%, 1.2% and 2.3%, respectively.[23]

In our study 30-day mortality was much higher, with a rate of 9.3%. This proportion was similar to the one registered by another study reporting a single-center review of patients that underwent TEVAR between 1998 and 2009, which showed a 30-day mortality rate of 9.5%.[24]

We observed an in-hospital SCI rate of 7.3%, which is greater than the sum (3.5%) of paraplegia and paraparesis rates demonstrated in the SUMMIT study.[23] However, many studies have reported different frequencies of SCI, with the overall incidence being estimated between 2-10%.[15] More recently, a study based on USA national registry demonstrated an overall rate of SCI after TEVAR of 3.7%, with 1.6% being transient and 2.1% being permanent.[26]

In our analysis there was not any stroke or transient ischemic attack after index TEVAR.

SUMMIT demonstrated a freedom from all-cause mortality of 92% (± 1%) at 1 year, 81% (±2%) at 3 years and 70% (±3%) at 5 years.[23] In this analysis we found an estimated freedom from all-cause mortality of 73.8% (±6%) at 1 year, 65.5% (±7%) at 3 years and 46.5% (±9,6%) at 5 years. This discrepancy might be due to small number of patients, differences in patients' baseline characteristics, procedural details and techniques and type of the endografts used.

Age, congestive heart failure, serum creatinine, blood transfusion and spinal cord ischemia were identified as significant predictors for all-cause mortality in the SUMMIT study.[23] In our analysis these characteristics were not associated with an increased risk of mortality. Scali ST et al. found adjunctive procedures, coronary artery disease and COPD as predictors of 1-year mortality[25] however, similarly, we did not find a statistically significant association. This might be due to our small sample size. Nevertheless, we observed a statistically significant relation between reintervention and mortality in univariate analysis.

The rate of reintervention after index TEVAR ranges from 11-15% in current literature.[20] In our study we obtained a reintervention rate of 25.5%, this compares to the rate of 27% reported by Giles KA et al. of secondary aortic intervention after TEVAR for type B aortic dissection.[28]

In our analysis the Kaplan-Meier estimated freedom from reintervention at 1 year was 74.6%(±5.8%) and 69% (±8.4%) at 5 years. One study reported rates of freedom from reintervention of 94%(±3.5%) at 2 years and 48.9% (±10.5%) at 5 years.[27]

The above mentioned study of Son Sa et al. identified endoleaks as an independent risk factor for aortic reintervention.[27] In our study, endoleak was also associated with an increased risk for reintervention (HR 3.939, P=0.020 in multivariate Cox regression).

An average overall endoleak rate after TEVAR is estimated in 18%. When looking at early endoleaks, type 1 is the most frequent with a reported rate of 8.4%, followed by type 2 with 4% and type 3 with 2.1%.[19] We observed an endoleak rate of 27.3% in our study.

The limitations of this study are: i) retrospective nature of the study such as the quality of the registries consulted; ii) small size of our sample which increases the risk of a type II error; iii) median follow-up time of 25 months, which does not allow us to infer about long term outcomes; iv) single center analysis, there is a potential for selection bias and limited external validity.

Conclusions

In this study, 30-day mortality and SCI rates remained appreciable but were in accordance with percentages that have previously been reported. A statistically significant relation between reintervention and mortality in univariate analysis was observed in this study. Endoleak was associated with an increased risk for reintervention. As already pointed out TEVAR has become the elected treatment for the majority of the descending thoracic aorta pathologies, owing to its association with decreased morbidity and mortality rates, particularly in those with elevated surgical risk. However, it is a recent procedure which still lacks information regarding long-term benefits, reintervention and late mortality.

Appendices

Table I. Demographics and medical history.

N	**54**
Sex	*n (%)*
Male	43 (79.6)
Female	11 (20.4)
Age, years	*median (IQR)*
All	68.5 (61.5 — 78)
Male	68 (63 — 78)
Female	65 (46 — 80)
Smoking	*n (%)*
Ever	37 (68.5)
Never	17 (31.5)
Comorbidities	
Diabetes mellitus	5 (9.3)
Hypertension	43 (79.6)
Dyslipidemia	38 (70.4)
COPD, GOLD classification	
Stage I	3 (5.6)
Stage II	4 (7.4)
Stage III	7 (13.0)
Chronic kidney disease, KDIGO classification *(N = 50)*	
Stage 3	11 (22)
Stage 4	2 (4)
Stage 5	0 (0)
Ischemic heart disease *(N = 47)*	7 (14.9)
Peripheral artery disease *(N = 47)*	4 (8.5)
Carotid atherosclerosis (*N = 18*)	5 (27.8)
Aortic arch/thoracic atherosclerosis	21 (38.9)
Heart failure *(N = 47)*	5 (10.6)
Inflammatory and genetic diseases	
Takayasu arteritis	1 (2)
Familial thoracic aortic disease	1 (2)
Marfan syndrome	1 (2)

Previous abdominal aortic intervention	
None	48 (88.9)
Open	3 (5.6)
Endo	3 (5.6)

IQR: interquartile range; COPD: chronic obstructive pulmonary disease; GOLD: The Global Initiative for Chronic Obstructive Lung Disease; KDIGO: Kidney Disease Improving Global Outcomes

Table II. Procedure indications, type of procedure and proximal landing zone.

	***N* (%)**
Acute aortic syndromes	17
Non-complicated ATBAD	2 (11.8)
Non-complicated IMH/PAU	8 (47.1)
Complicated IMH/PAU	4 (23.5)
Ruptured TAAA	1 (5.9)
Blunt traumatic thoracic aortic injury	1 (5.9)
Ruptured TAAA + ATBAD	1 (5.9)
Chronic thoracic aortic diseases	*39*
CTBAD	2 (5.1)
DTAA	23 (59)
TAAA	10 (25.6)
DTA symptomatic thrombus	1 (2.6)
DTA pseudo-aneurysms	3 (7.7)
Type of intervention	
Elective	44 (80)
Deferred urgency	6 (10.4)
Emergent/urgent	5 (9.1)
Prophylactic CSF drainage	10 (18.2)
Endoprosthesis proximal landing zone	
Zone 0	1 (1.8)
Zone 1	6 (10.9)
Zone 2	6 (10.9)
Zone 3	18 (32.7)
Zone 4	24 (43.6)

ATBAD: acute type B aortic dissection; IMH: intramural hematoma; PAU: penetrating aortic ulcer; TAAA: thoracoabdominal aortic aneurysm; CTBAD: chronic type B aortic dissection; DTAA: descending thoracic aortic aneurysm; DTA: descending thoracic aorta; CSF: cerebrospinal fluid

Table III. Stent graft proximal landing zone and corresponding supra-aortic trunk revascularization.

Patient	Landing zone	Supra-aortic trunk revascularization
#1	3	Left common carotid artery to left subclavian artery bypass
#2	1	Right common carotid artery to left common carotid artery to left subclavian artery bypass
#3	2	Left subclavian artery to left common carotid artery transposition
#4	1	Left common carotid artery to left subclavian artery bypass
#5	1	Right common carotid artery to left common carotid artery to left subclavian artery bypass
#6	0	Right common femoral artery to right axillary artery bypass Left common carotid artery and left subclavian artery chimney
#7	1	Left internal carotid artery to left subclavian artery bypass
#8	2	Left common carotid artery to left subclavian artery bypass
#9	1	Right common carotid artery to left subclavian artery bypass and left common carotid artery transposition to bypass
#10	2	Left common carotid artery to left subclavian artery bypass
#11	2	Left common carotid artery to left subclavian artery bypass
#12	1	Right common carotid artery to left common carotid artery to left subclavian artery bypass
#13	2	Left common carotid artery to left subclavian artery bypass

Table IV. Occluded aortic visceral vessels and corresponding revascularization.

Patient	Occluded vessel	Visceral revascularization
#9	CT, SMA	Right external iliac artery to common hepatic artery bypass and superior mesenteric artery transposition to bypass
	LRA	Left kidney autotransplantation
#10	CT, SMA	Right external iliac artery bifurcated bypass to superior mesenteric artery and splenic artery
#14	CT, SMA	Right common iliac artery to celiac trunk bypass and superior mesenteric artery transposition to bypass
	RRA, LRA	Right renal and left renal arteries periscopes
#15	CT, SMA, RRA	Right common iliac artery trifurcated bypass to right renal artery, superior mesenteric artery and splenic artery
#16	CT, SMA	Right common iliac artery bifurcated bypass to superior mesenteric artery and celiac trunk
#17	CT, SMA, RRA, LRA	Right common iliac artery bypass with four branches to left and right renal arteries, superior mesenteric artery and splenic artery

CT: celiac trunk; SMA: superior mesenteric artery; LRA: left renal artery; RRA: right renal artery.

Table V. Perioperative analytic values of hemoglobin and C-reactive protein.

Hemoglobin	*mean (SD)*
Preoperative (*N* = 54)	12.4 (2.2)
24 hours postoperative (*N* = 55)	10.7 (1.7)
48-72 hours postoperative (*N* = 47)	9.9 (2)
C-reactive protein	*median (IQR)*
Preoperative (*N* = 51)	15.7 (3.6 — 69.7)
24 hours postoperative (*N* = 55)	53 (18.9 — 110.1)
48-72 hours postoperative (*N* = 47)	141.4 (94.6 — 243.8)

SD: standard deviation; IQR: interquartile range.

Table VI. Endoleaks during follow-up.

	***N* (%)**
Type I	5 (9.1)
Type I and II	1 (1.8)
Type II	5 (9.1)
Type II and III	1 (1.8)
Type III	2 (3.6)
Type IV	1(1.8)

Table VII. Reinterventions after TEVAR.

Patient	Complication	Reintervention
#14	Anastomotic pseudoaneurysm of visceral revascularization bypass	Exclusion of pseudoaneurysm with covered stent graft
#10	Type I endoleak	Proximal extension of the stent graft and right common carotid artery to left common carotid artery bypass
	Type II endoleak	Left subclavian artery, left common carotid artery and superior mesenteric artery plug embolization
#18	Aortobronchial fistula	Endoprosthesis removal by left thoracotomy, reconstruction of the thoracic aorta with dacron tube, reconstruction of the left bronchial wall with patch of calf pericardium and intercostal muscle
#16	Type II endoleak	Right nephrectomy
#19	Type I endoleak	Proximal extension of the stent graft and left common carotid artery to left subclavian artery bypass
	Left common femoral artery thrombosis	Surgical thrombectomy
#20	Type II endoleak	Left subclavian artery coil embolization
#21	Type I endoleak	Proximal extension of the stent graft
#6	Inguinal wound dehiscence	Surgical wound revision
#22	Type III endoleak	TEVAR graft balloon angioplasty
#23	Cervical hematoma	Cervical hematoma drainage
#9	Visceral revascularization bypass thrombosis	Surgical thrombectomy
#24	Type II endoleak	Left subclavian artery coil embolization
#25	Type I endoleak	Distal extension of the stent graft
#26	Type I endoleak	Proximal and distal extensions of the stent graft

Table VIII. Cox proportional hazards models for reintervention after TEVAR.

Variables	HR	95% CI	*P* value
Adjunctive visceral vessels revascularization	2.01	0.58 — 6-98	0.271
Endoleak	3.94	1.24 — 12.51	0.020

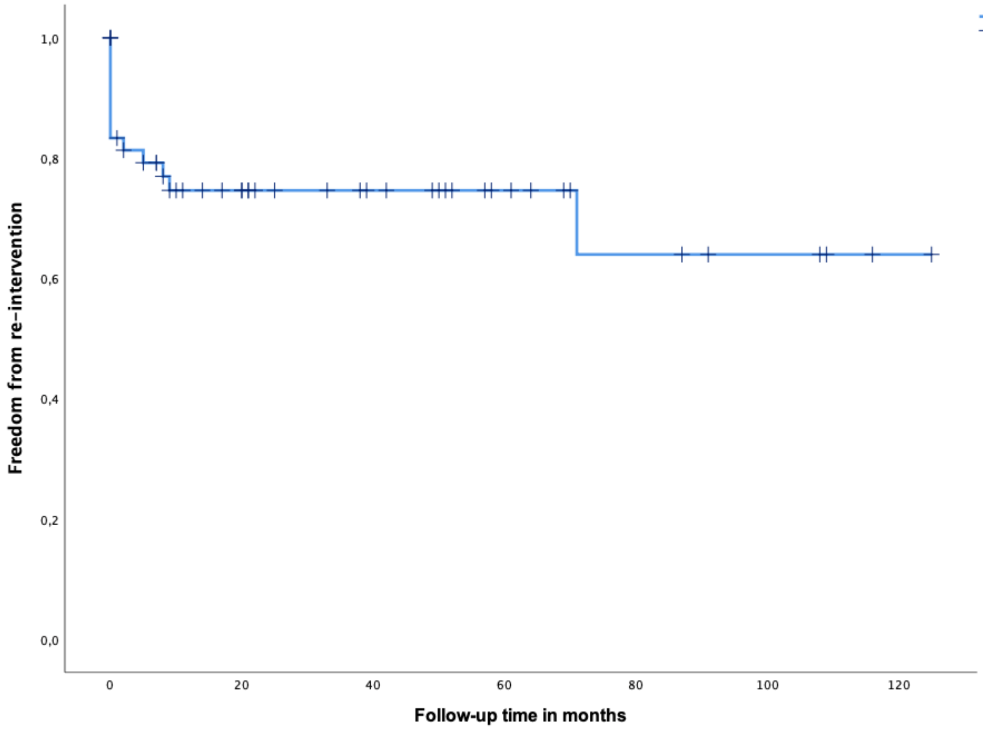
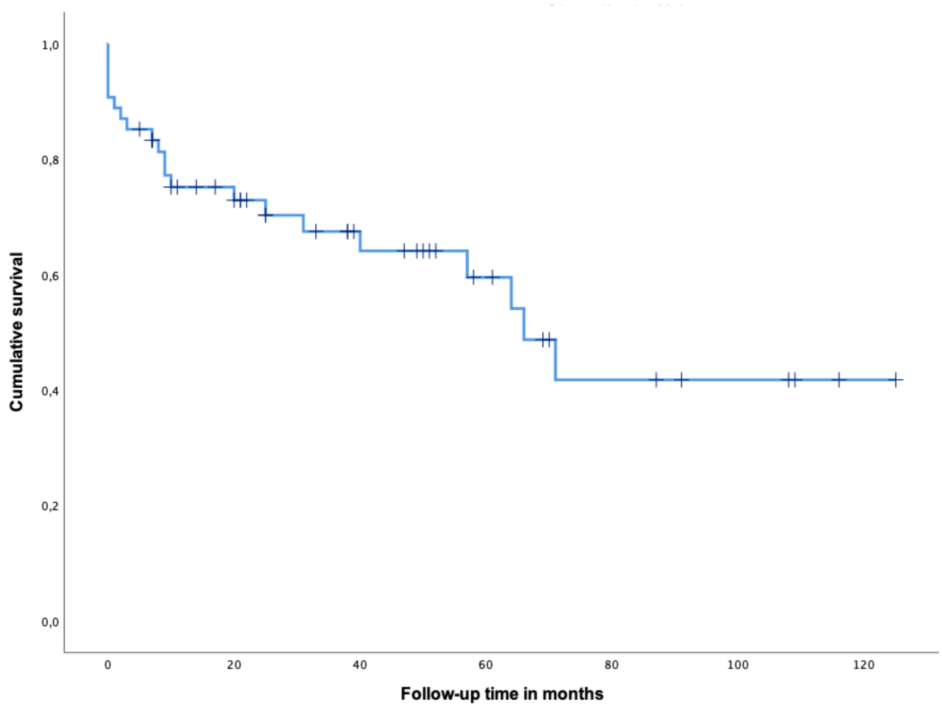


Figure I. Kaplan-Meier analysis of freedom from reintervention.



Time, years	Number at risk	Died	Censored	Survival probability
0	54	13	6	0.759
1	35	1	6	0.738
2	28	2	3	0.685
3	23	1	4	0.655
4	18	1	5	0.619
5	12	3	3	0.464
10	1	0	1	0.464

Figure II. Kaplan-Meier analysis of all-cause mortality, with survival table.

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