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# A standard experiment with emergency endovascular interventions on the descending thoracic aorta

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## Abstract

**Background:** Using emergency endovascular aortic repair to treat severe acute aortic disorders affecting the descending aorta is an appealing prospect.

**Aim:** This study's objective was to evaluate the efficacy of thoracic endovascular aortic repair (TEVAR) in the management of acute surgical emergencies involving the descending thoracic aorta.

**Methods:** The medical records of every patient who underwent TEVAR in a single centre since 2007 were retrospectively evaluated. Emergency criteria for inclusion were used to treat patients with aortic disease who had complicated spontaneous acute aortic syndrome (csAAS), traumatic aortic acute injuries (TAIs), and other symptoms calling for urgent treatment. The Society for Vascular Surgery reporting guidelines for thoracic endovascular aortic repair were used to evaluate the technical and clinical success with regard to patient mortality, survival, and re-operation rate (TEVAR).

**Results:** In 74 cases (51.0%), emergency procedures were required, including those involving patients with traumatic aortic acute injuries (TAIs) (31.1%) and complicated spontaneous acute aortic syndrome (csAAS) (64.8%; n = 48). Aortic iatrogenic dissection (AID) in one case and two other fistulas following the prior stent graft were also identified as implantation's. While 2 hybrid operations required extra approaches, all procedures were performed through surgically exposed femoral arteries. The main technical success rate was 95.9%; endoleak was recorded in 3 instances. In 94.5% of cases, the main clinical success was achieved. All of the patients made it through the endovascular procedures, however one of them passed away in the hospital as a result of multi-organ failure (early mortality: 1.3%). 11 patients passed away throughout the follow-up period, which lasted 6 to 164 months (median 67). The probability of survival over one year, five years, and 10 years was 86.4 ± 0.04%, 80.0 ± 0.05%, and 76.6 ± 0.06%, respectively. However, following TAI (95.2%) compared to scAAS (63.4%), the rate of 5-year survival was significantly greater (p=0.008). One person experienced temporary para-paresis right after the operation (1.3%). Throughout the post-discharge follow-up period, no more severe stent-graft-related adverse events were reported.

**Conclusion:** The probability of survival over one year, five years, and 10 years was 86.4 ± 0.04%, 80.0 ± 0.05%, and 76.6 ± 0.06%, respectively. However, following TAI (95.2%) compared to scAAS (63.4%), the rate of 5-year survival was significantly greater (p=0.008). One person experienced temporary para-paresis right after the operation (1.3%). Throughout the post-discharge follow-up period, no more severe stent-graft-related adverse events were reported.

**Keywords:** Emergency; Endovascular; Aortic repair; TEVAR; Efficacy

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## 1. Introduction

Specifically developed for elective interventions, thoracic endovascular aortic repair (TEVAR) is now a popular way to treat acute descending aortic syndromes (AASs) in emergency situations. There is a considerable risk of perioperative death and morbidity with traditional open surgery. The use of TEVAR resulted in a beneficial decrease in surgical mortality and morbidity. Complicated aortic dissection and disruption are the most prevalent forms with a poor prognosis that call for urgent treatments [1, 2]. A 25–50% 48-hour mortality rate is linked to complicated type B aortic dissections (cTBDs) [1, 2]. More than 30% of people who sustain severe blunt thoracic injuries have heart and major vascular damage, including traumatic aortic injuries (TAIs), which is the second leading cause of multiorgan trauma-related mortality. The consequences of complicated AAS such as hemorrhage, hypovolemic shock, or organ and tissue malperfusion make AAS as life-threatening conditions [3]. Acute aortic disorders must be viewed as a multidisciplinary entity that should engage experts in surgery (both cardiac and vascular), interventional radiology, anaesthesia, and cardiology, especially when confined also to the descending section. This method immediately affects treatment outcomes by speeding up the diagnostic and therapeutic processes for critically ill patients who have sustained multiorgan trauma. The Society for Vascular Surgery reporting criteria for thoracic endovascular aortic repair (TEVAR) have not yet been applied to any single-center retrospective, observational, cohort studies [4]. Also, the high rate of technical and clinical success may be attributed to our center's stringent adoption of the TEVAR procedure safety standards, which includes a minimal proximal and distal Landing Zone of 20 mm (since 2019-25 mm) [5, 6]. The purpose of this study was to evaluate the efficacy of thoracic endovascular aortic repair (TEVAR) for the management of acute surgical emergencies involving catastrophic events involving the descending thoracic aorta.

## 2. Material and methods

### 2.1. Study Design

The medical data of every patient who underwent TEVAR in a single centre since 2007 were retrospectively reviewed. The Department of Heart Surgery and Transplantology, a facility that serves as a referral TEVAR centre for over 5 million residents, has treated 145 patients with descending aorta diseases since 2007. Among them, emergency TEVAR procedures—defined as interventions that start before the start of the next working day—were carried out in 74 cases (51%). Patients with the aortic disease treated on an emergency inclusion criteria were complicated spontaneous acute aortic syndrome (csAAS), traumatic aortic acute injuries (TAIs), and other indications requiring emergent intervention. Patients with elective descending aorta aneurysm (DAA), uncomplicated Type B aortic dissections, and requiring elective TEVAR reinterventions were excluded. The STROBE checklist (Figure 1) is applied in this study.

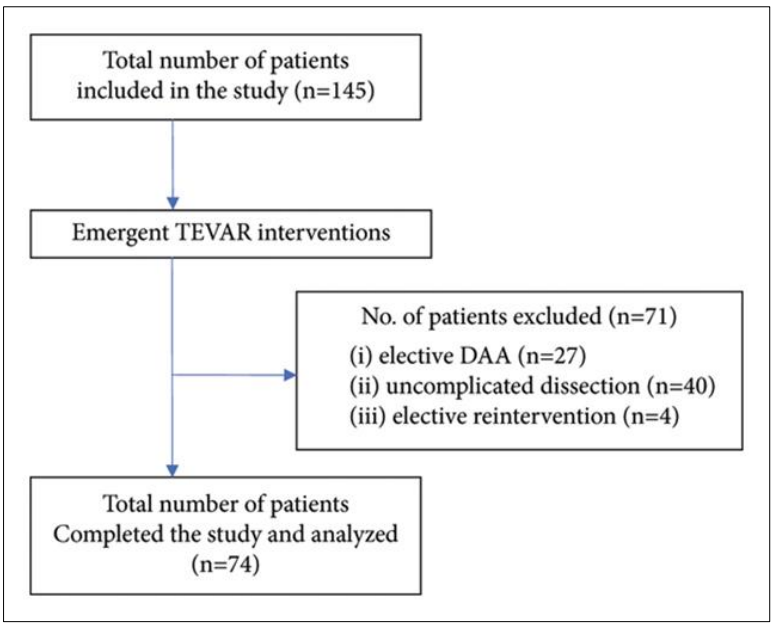


**Figure 1** STROBE diagram for various phases of the study (STROBE: strengthening the reporting of observational studies in epidemiology; DAA: descending aorta aneurysm)

According to the rules of the Local Bio-ethical Committee of our university, the Statement of Ethics Approval is not required for retrospective data analysis of patients treated with the use of the standard and accepted methods.

#### *2.1.1. Main Variables of Interest*

We gathered preoperative data, particular data based on the repair indication, intraoperative data, and postoperative data from each patient. The Society for Vascular Surgery reporting guidelines for thoracic endovascular aortic repair (TEVAR) were used to evaluate the technical and clinical success with regard to patient mortality, survival, and re-operation rate [4]. For each medical condition, the emergency indications for complicated spontaneous acute aortic syndrome (csAAS), traumatic aortic acute injuries (TAIs), and other reasons necessitating emergent care were specifically examined. These clinical issues included intestinal ischemia, postoperative bleeding necessitating additional surgery, postoperative paraplegia, cerebrovascular accident (CVA), acute coronary events, renal failure necessitating dialysis, infection, and postoperative bleeding. Also, we looked at survival at 30 days and a follow-up period of 6–164 months.

### 2.2. Postoperative Evaluation

Computed tomographic angiography (CTA)-based physical exams were required as part of the Department protocol following the implantation of a thoracic stent graft at 1, 3, 6, and 12 months, as well as once a year after that. For the first 3 years, patients who underwent hybrid operations also received additional follow-up visits every 3 months.

### 2.3. Definitions

- **Emergent Interventions :** Operation following the decision to operate till the start of the following working day (EuroSCORE).
- **Critical Preoperative State :** Acute renal failure is characterized as anuria or oliguria of less than < 10 mL/hr, as well as ventricular tachycardia, fibrillation, or aborted abrupt death, cardiac massage, ventilation before arriving in the operating room, inotropes, IABP, or VAD before arriving in the operating room (EuroSCORE).
- **Post-Implantation Syndrome (PIS):** The Velazquez syndrome, called also post-implantation syndrome (PIS), was defined by the presence of leukocytosis (>12,000 leukocytes/μL) and the occurrence of fever (>38°C–auricular temperature) but without following markers of infection such as increased concentrations of high sensitivity C-reactive protein and procalcitonin when infectious complications were excluded (no clinical evidence of infection, negative blood cultures, and absence of local complications of the surgical wound) [4].
- **Primary Technical Success:** This is defined on an intent-to-treat basis that begins with the implantation procedure and requires the successful introduction and deployment of the device in the absence of surgical conversion to open repair, death <24 hours, type I or III endoleaks as evidenced by procedural angiography, or graft obstruction [4].
- **Primary Clinical Success:** This can only occur without any of the following: death as a result of treatment or as a result of the original pathology that was treated; type I or III endoleak, infection, or aortic thrombosis; aneurysm expansion (diameter >5 mm, volume >10% or greater than two times interobserver variability) or rupture; conversion to open repair; or failure to arrest the original pathologic process (e.g., embolization from penetrating ulcer) or causing a new thoracic aortic pathology as a result of the intervention (e.g., pseudoaneurysm, dissection, and intramural hematoma) [4].
- **Secondary Clinical Success:** This is defined as clinical success obtained initially but temporarily interrupted by a failure that is corrected with the use of an additional, secondary surgical procedure; for example, a type I endoleak develops in an initially excluded aneurysm due to endograft migration at 2 years and is corrected by placement of a new, more proximal endograft. Conversely, clinical failure includes death as a result of treatment or as a result of the original pathology that was treated or a pathology caused by the initial procedure (e.g., aneurysm rupture, or dissection extending to cause mesenteric ischemia and resulting in death), type I or III endoleak, graft migration, infection, or thrombosis, aneurysm expansion (as defined elsewhere in this document; aneurysm rupture), conversion to open repair, failure to arrest the original pathologic process, or appearance of a new thoracic aortic pathology as a result of intervention [4].

### 2.4. Principal Procedure: Stent-Graft Implantation

The skilled team of two cardiac surgeons and one interventional radiologist performed all endovascular procedures, primarily in the vascular intervention room. A vascular surgeon assisted two complicated procedures that were performed in the hybrid room as an exception. Also, all but two received general anaesthesia for their treatments. Due to a confirmed tracheal injury, these two patients had to undergo treatments under local anaesthetic and sedation without endotracheal intubation. Routine antibacterial prophylaxis was employed and all patients obligatory got 5,000 IU of heparin. One patient who experienced trauma and had a fractured base of the skull was an exception. In each

case, a femoral surgical approach through the right common femoral artery was used to implant a stent transplant. By using Seldinger's technique, the left femoral artery was perforated percutaneously in order to situate the landing zone target in the ascending aorta using a 6F straight catheter with side holes on a pigtail 5F catheter. Over an Amplatz 0.35 guidewire, the stent grafts were inserted into the thoracic aorta. To verify the final position and tightness of the prosthesis, DSA (Digital Subtraction Angiography) was done in five to ten sessions using an ionic contrast medium.

### 2.5. Adjunctive Procedure: Hemi-Arch Transposition

In two instances, a multidisciplinary team chose to undertake a two-step procedure in a hybrid room following CT scan analysis. Following carotid-to-carotid anastomoses with FEP Ringed GORE-TEX STRETCH vascular graft prostheses (8 mm in diameter) from Gore & Associates in Flagstaff, Arizona, USA, the stent grafts were eventually implanted distally to the brachiocephalic trunk while still covering the orifices of the left common carotid and left subclavian arteries.

### 2.6. Statistical Analysis

Using the Shapiro-Wilk W test, the quantitative variables' normality distribution was examined. They were reported as mean with standard deviation if they were normal distributed else as median with range (minimum; maximum). Categorical variables were represented as percentages (%) and numbers (n). The Kaplan-Meier method was used to stratify the likelihood of survival, and the Cox F test was used to compare results when appropriate. A statistically significant difference was regarded to be indicated by a p-value of less than 0.05. Statistica 13.3 was used to carry out the statistical analysis (TIBCO Software Inc., 2017, USA).

## 3. Results

### 3.1. Patients

This study involved 74 patients with emergent TEVAR including 48 (64.8%) patients with complicated spontaneous AAS (csAAS), including complicated typical TBD (cTBD) (n = 23; 31.1%), the same number with ruptured descending thoracic aortic aneurysms (RTAA) and 2 (2.7%), one with penetrating atherosclerotic ulcers (PAU) and one intramural hematoma (IH). In 23 cases (31.1%) indication for emergent TEVAR was (31.1%) TAI, and among them 14 with traumatic aortic disruption (TAD). In one case aortic iatrogenic dissection (AID) with mesenteric ischemia and in the other 2 subjects aorto-oesophageal fistulas were the other indications for emergent TEVAR. The baseline characteristics of all patients are outlined in Table 1, whereas indications for emergency TEVAR together with some procedural details are in Table 2.

**Table 1** Demographic data and risk factors

| # | **N = 74** |
|---|---|
| Age (years) | 59.5 (18; 82) |
| Gender (male/female) | 48 (64.8%)/26 (33.2%) |
| Diabetes mellitus | 52 (70.2%) |
| COPD | 27 (36.4%) |
| Cerebrovascular diseases | 12 (16.2%) |
| History of smoking | 57 (77%) |
| Hypertension | 58 (78.3%) |
| ASA class III to V | 60 (81%) |
| Previous cardiovascular surgery | 12 (16.2%) |
| Critical preoperative state | 19 (25.6%) |

# continuous variables are expressed as median with range (within bracket) while categorical data as numbers (n) with percentage (%). COPD: chronic obstructive pulmonary disease; ASA: American society of anesthesiologists classification.

**Table 2** Indications and perioperative characteristics

| | **Indications** | **Age** | **Male** | **LZ*** | **Primary technical success*** |
|---|---|---|---|---|---|
| csAAS n = 48 | cTBD [n = 23]<br>RTAA [n = 23]<br>PAU/IH [n = 2] | 60.5 (26; 82) | 30 (62.5%) | LZ3-4: 21<br>LZ2: 26<br>LZ1: 2 | 45/48 (93.7%) |
| TAI n = 23 | TAD [n = 14], type IV*<br>Pseudoaneurysm [n = 9], type III | 59 (18; 76) | 17 (73.9%) | LZ3-4: 17<br>LZ2: 6 | 23/23 (100%) |
| Others n = 3 | AID [n = 1]<br>Fistula [n = 2] | 50 (35; 66) | 1 (33.3%) | LZ3-4: 2<br>LZ2: 1 | 3/3 (100%) |
| Total | n = 74 | 59.5 (18; 82) | 48 (64.8%) | LZ3-4: 38<br>LZ2: 34<br>LZ1: 2 | 71/74 (95.9%) |

# continuous variables are expressed as median with range (within bracket) while categorical data as numbers (n) with percentage (%); * according to society of vascular surgery society [4]. csAAS: complicated spontaneous acute aortic syndrome; cTBD: complicated aortic dissection; PAU: penetrating atherosclerotic ulcer; IH: intramural hematoma; RTAA: ruptured descending thoracic aortic aneurysm; TAI: traumatic aortic injury; TAD: traumatic aortic disruption; AID: aortic iatrogenic dissection; LZ: landing zone.

In the majority of patients, Zenith stent grafts (Cook Inc., USA) were implanted. In one case Jotec (JOTEC GmbH, Stuttgart, Germany) and in the other four GORE (Gore Medical, Flagstaff, USA) stent grafts were used (Zenith n = 69; GORE n = 4; JOTEC n = 1). The mean prostheses diameter was 33.1 ± 5.2 mm, whereas the length was 161.7 ± 27.1 mm, respectively. Single stent grafts were used in 70 cases; two stents in 4 patients. In 38 cases, the proximal graft landing zone was below the orifice of the left subclavian artery (LZ 3 and 4), in the other 34 (45.9%) the prosthesis covered the orifice of the left subclavian artery (LZ 2). In 2 subjects operated on in the hybrid room, the landing zone was more proximal (LZ 1) and it was forced to cover the left common carotid artery. Intra-procedural data with a 95.9% primary technical success rate are presented in detail in Table 2.

### 3.2. Intraoperative Results

All of the patients made it through the endovascular procedures, however one of them passed away in the hospital as a result of multiorgan failure (early mortality: 1.3%). Endoleak type I was noted during hospital stays in 3 patients, and the primary clinical success rate was 94.5% overall [4].

#### *3.2.1. Initial 30-Day Clinical Success*

On the 19th postoperative day, one of the patients passed away as a result of multiorgan failure while still hospitalized (early mortality rate: 1.3%). The patient underwent surgery for aorto-oesophageal fistulas, but infection later caused severe MOF and the patient's death. After primary TEAR, the second patient experienced a major stroke, never left the hospital, and passed away 46 days later. Total TEVAR-related deaths were 2.6%. (Table 3).

One patient experienced temporary para-paresis (n = 1, 1.3%), there were two strokes (2.6%), and there were three incidences of type I endoleaks. Early neurological adverse events were 4.0% of all occurrences. Two further patients were eligible for re-intervention after we identified a hemo-dynamically insignificant endoleak in one case. He was released with good clinical state, remained asymptomatic, and had a stable view on the subsequent CTA exams. In 18 patients, a drain had to be placed in the left pleural cavity, however this was done a few days after TEVAR. In particular, pre-procedural bleeding's were the main causes. In the initial postoperative phase, The post-implantation syndrome (PIS) was present in 50% of patients. No other complications associated with the implantation of the stent graft during the perioperative period were noticed. In our group, the median length of stay in the intensive care unit (ICU) was 1 day, whereas the total hospitalization time was 6 days.

**Table 3** Primary and secondary clinical success, mortality, and cause of death

| | csAAS | TAI | Others | Total |
|---|---|---|---|---|
| Primary clinical success* | 45/48 (93.7%) | 23/23 (100%) | 2/3 (66.6%) | **70/74 (94.5%)** |
| Secondary clinical success* | 44/48 (91.6%) | 23/23 (100%) | 2/3 (66.6%) | **69/74 (93.2%)** |
| TEVAR related deaths* | 0 | 0 | 2 (2.6%) | **2 (2.6%)** |
| <30 days mortality | 0 | 0 | 1 (1.3%) | **1 (1.3%)** |
| >30 days mortality | 10 (13.5%) | 0 | 1 (1.3%) | **11 (14.8%)** |
| Causes of death | 10 (13.5%) | 0 | 2 (2.6%) | **12 (15.4%)** |
| Multiorgan failure | 0 | 0 | 2 (2.6%) | **2 (2.6%)** |
| Stroke | 1 (1.3%) | 0 | 0 | **1 (1.3%)** |
| No TEVAR related deaths | 9 (12.1%) | 0 | 0 | **9 (12.1%)** |

# categorical data are presented as numbers (n) with percentage (%); *according to society of vascular surgery society [4].

*3.2.2. Long-Term Clinical Success Follow-Up Results*

During the post-discharge follow-up period that lasted 6 through 164 months (median time 67), 11 patients died. Annual, five- and ten-year probability of overall survival was 86.4 ± 0.04%, 80.0 ± 0.05%, and 76.6 ± 0.06%, respectively. However, the rate of 5-year survivors was significantly higher after TAI (95.2 ± 3.2%) than csAAS (63.4 ± 5.9%) (p=0.001) (see Figures 2(a) and 2(b)).

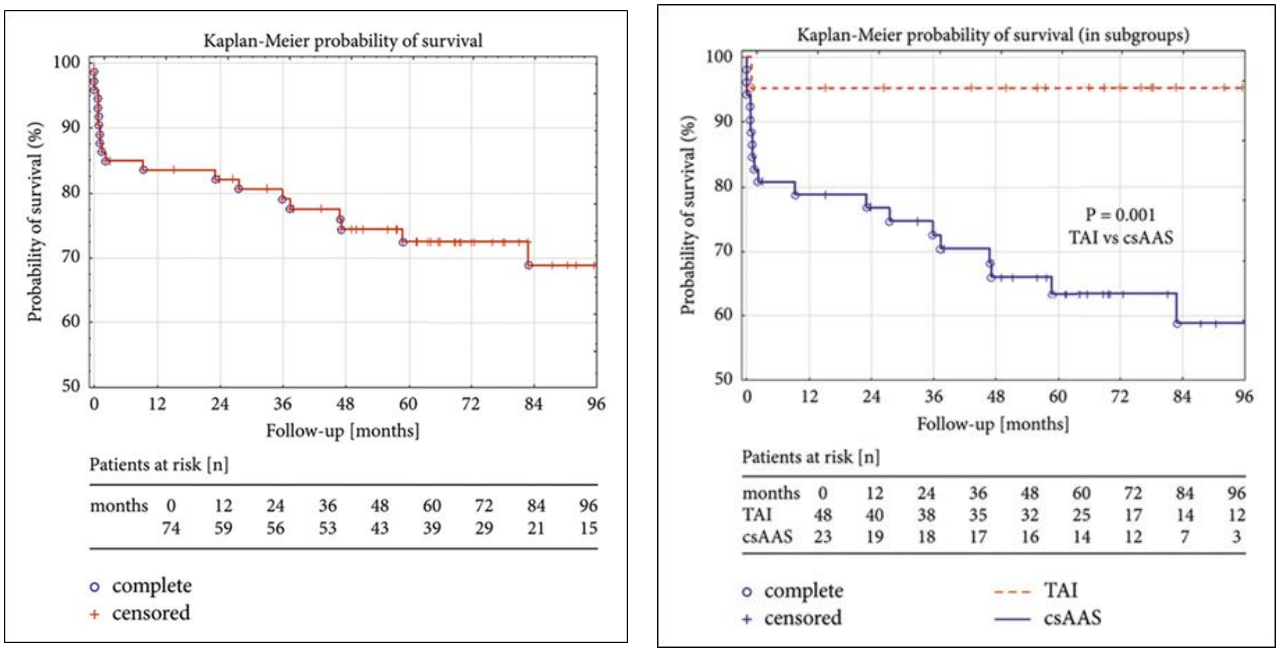


**Figure 2** Probability of survival after TEVAR: (a) total probability and (b) probability in csAAS and TAI subgroups. csAAS: complicated spontaneous acute aortic syndrome; TAI: traumatic aortic injury

Two of the patients needed further TEVAR re-intervention, one in 14 months of observation and the second in 5 years after primary TEVAR. No other serious stent-graft-related adverse events, infection, or migration were noted during the follow-up period (Tables 3 and 4). The secondary clinical success rate was 93.2% (Table 3) [4].

**Table 4** Postoperative complications, other interventions, reinterventions, and causes of death

| Complications | N (%) | Mild* | Moderate* | Severe* |
|---|---|---|---|---|
| Concomitant hemothorax | 18 (24.3%) | - | 18 | - |
| ARI/hemodialysis | 7 (9.4%) | 7 | - | |
| Respiratory failure | 4(5.4%) | - | 2 | 2 |
| Mesenteric ischemia | 1 (1.3%) | - | - | 1 |
| PIS | 37 (50%) | 37 | - | - |
| Paraplegia | 1 (1.3%) | - | 1 | - |
| Stroke | 2 (2.6%) | - | - | 2 |
| Endoleak (type I) | 5 (6.8%) | | | |
| Early < 24 months | 4 (3.9%) | 1 | 2 | 1 |
| Late > 24 months | 1 (1.3%) | - | - | 1 |
| Reinterventions 4 (5.2%)<br>Early < 24 months 3 (3.9%)<br>Late > 24 months 2 (1.3%)<br>Paraplegia 1 (1.3%) (spinal cord ischemia grading system—1)*<br>Stroke 2 (2.6%) (mild and severe)* | | | | |

ARI: acute renal insufficiency; PIS: post-implantation syndrome. # categorical data are presented as numbers (n) with percentage (%); according to Society of Vascular Surgery society.

## 4. Discussion

TEVAR, which was initially created for elective operations to treat degenerative aneurysms, quickly became a preferred approach for urgent instances. Due to the widespread use of these procedures, both the risk of open surgery and the mortality linked to these disorders have been decreased. It can be difficult to treat urgent thoracic aorta lesions like severe aorto-oesophageal fistulas, TAI, or csAAS. Despite improvements in surgical methods and after care, emergency conventional repair of these disorders is still associated with high morbidity and mortality [7, 8]. This form of surgery also continues to carry a very high risk. Endovascular procedures are now preferred over conventional ones in emergency conditions because of the favourable morbidity-mortality documented in the literature [7, 8]. TEVAR has demonstrated superior perioperative results when compared to the conventional technique, according to recent meta-analyses of 14,580 patients. Nonetheless, there are relatively few research studies that evaluate 10-year results and survival following endovascular treatments [7].

### 4.1. Emergency Indications for TEVAR and Outcomes

Our first findings in the TAI subgroup are encouraging and consistent with earlier trials, with a death rate of 0% and a low risk of neurological sequelae. As an illustration, Richens et al. reported 7,768 patients who had TEVAR in TAD with 9% early death and 3% neurological problems [9-11]. Open TAD surgery, on the other hand, carries a neurological risk of about 30% and a death rate of over 28%. According to the Azizzadeh categorization supported by the Society of Vascular Surgery (SVS), 39.1% of the TAI in our series were of type III, and 60.9% were of type IV [4, 12]. Under these circumstances, the European Society for Vascular Surgery (ESVS) suggests immediate repair (recommendation 27: class I, level of evidence C) [11, 13]. Based on the overall risk of aortic rupture and other complications, the ultimate decision regarding whether to perform an urgent or delayed intervention repair should be made. The minimally invasive endovascular TEVAR is desirable and helpful for treating unstable patients in an emergency situation since it requires fewer blood transfusions, has a lower death rate, and requires a shorter hospital stay [6]. There are currently no reliable data on the long-term follow-up results of TAI stent-graft implants over a period of 10 to 15 years. In our investigation, we did demonstrate outstanding primary and secondary clinical success and long-term results, 95% likelihood of 10-year survival following TAI treated with emergent TEVAR, as well as in the most severe injuries (type III and IV). Our findings are consistent to those from Demetriades and colleagues' publication on the greatest volume TEVAR comparison with open surgery in TAI instances. Less blood transfusions were given to the TEVAR group patients, who also displayed a decreased mortality rate and shorter hospital stay (6). The specific traumatic aortic illness known as

TAI can produce the best outcomes across the board for emergency purposes. The long-term outcomes depend on the severity of further injuries and are complicated.

Patients with complicated TBD require immediate invasive management to prevent death or injury from rupture or organ malperfusion. The IRAD (International Registry of Acute Aortic Dissections) register confirmed that in 25% of acute B dissection the course is complicated [14]. Trimarchi et al. showed from the same registry that among patients with refractory hypertension (requiring ≥3 different classes of anti-hypertensive treatment at the maximum tolerated doses), mortality after conservative treatment increased more than 20-fold (35.6% vs. 1.5%; p=0.0003) [15]. An alternative, open surgery due to cTBD carries a mortality rate exceeding 30% [16, 17]. The same findings applied to the treatment of RTAA [18, 19]. Advances in technical aspects of TEVAR and enormous experiences gained by dedicated "aortic teams" shifted management from surgical to endovascular repair, contributing to a fourfold increase in early survival in cTBD and RTAA, including also high-risk elderly population [20]. Our results support earlier findings that even in cTBD and RTAA early and medium-term outcomes can be perfect. Although, in our observation, a long-term probability of survival (approximately 60% after 10 years) following cTBD or RTAA is worse than after TAI but still presents a good primary and secondary clinical success rate, much better than treated medically. Previously, in medium-term 5-year observations, it was confirmed that the mortality rate in TEVAR compared to the optimal medical treatment in cTBD was significantly lower (16% vs. 29%;p=0.018 ), even despite the higher risk profile of the TEVAR group [21]. Data from IRAD and INSTEAD-XL (Investigation of Stent grafts in Aortic Dissection with extended length of follow-up) also confirm better 5-year results in patients with cTBD treated with TEVAR [22]. Patel et al. hypothesize that TEVAR may modify the natural course of aortic disease without an unacceptably higher risk of surgery-related death in cTBD [23]. In addition, the recent European guidelines on endovascular treatment of the descending thoracic aorta recommends endovascular repair as the first option in cases of RTAA, provided the anatomical characteristics are suitable (Management of Descending Thoracic Aorta Diseases: Clinical Practice Guidelines of the European Society for Vascular Surgery [CPG-ESVS]); recommendation 23: class I, level of evidence B) [24].

### *Complications*

Serious consequences are a possibility with endovascular interventions. Endoleaks, stent graft displacement, neurological issues, and retrograde aortic dissection are the most significant ones [25–27]. No patient in our sample experienced paraplegia that lasted forever. It is comparable to earlier emergency TEVAR cases that have been reported [2, 20]. Our series of emergency interventions did not involve the administration of a perioperative spinal drainage. In our series, there was only one instance of spinal ischemia, which thankfully resulted in temporary para-paresis and was grade 1 according to SVS. This patient had cTBD and needed to have two grafts implanted. Aortic segment prostheses longer than 205 mm have been demonstrated to enhance the risk of spinal ischemia [28, 29].Stent graft device manipulation within the arch or overstenting of one or more of the great vessels increase the risk of brain injury and ischaemic stroke to 10–15% [30–32]. In our series, two patients (2.6%) developed stroke and in one case it was the cause of death on the 46th day after the procedure.

Endoleaks, which some writers believe to be a failure of the implantation technique due to poor planning, are one of the most severe consequences after TEVAR surgeries. The length of the LZ, aortic angulation, and calcification are highlighted in the Tokyo Consensus indications [4-6, 33, 34]. In three emergency situations where type I endoleaks were discovered immediately following the surgeries, two of them required re-intervention, and another short graft had to be implanted due to a sizable endoleak and aneurysm extension. We found a type I endoleak in one instance that was hemo-dynamically insignificant. Retrograde type A dissection is a rare complication. It might be brought on by graft over-sizing, further balloon dilatation of proximal graft segments, and endovascular prosthesis with proximal bare springs. We followed strictly expert consensus that oversizing in type B dissection should be avoided [35–38].

The infrequent erosion of the oesophagus (aorto-oesophageal fistula, AEF) or the left main bronchus are complex and challenging to treat problems [39]. According to Takeno et al., thoracic malignancy, primary aortic aneurysms, bone ingestion, and postoperative aortic disease were the most frequent causes of AEF. One patient in our group had a primary aorto-oesophageal fistula and a massive aortic aneurysm diameter. When the stent graft was implanted, the patient underwent oesophagus surgery to repair aorto-oesophageal fistulas, however sepsis soon set in, causing MOF and death on the patient's 19th postoperative day. The second patient experienced aorto-oesophageal fistula following the placement of a stent graft for a simple type B dissection in a different centre. He underwent complex and multistage treatment including another stent graft implantation, esophageal stenting, and open esophagus repair. Because of the infection's persistence, he was re-operated with graft replacement and aortic arch repair. Unfortunately, the further course was unfavorable and eventually the patient died of sepsis and multiorgan failure.

In 2002, Fillinger et al. proposed the division of the aorta into five landing zones (LZ) to enable proper planning of the TEVAR strategy, including also hybrid treatment [4–6, 33, 34]. Later, authors of the 2004 Tokyo Consensus recommended the minimum length of the aortic pathology-free segment for safe fixation should be >20 mm with LZ aortic diameter >38/40 mm to minimalize the risk of leakage (endoleak I) [4–6, 34, 39–45]. The next expert consensus proposed no stent-graft deployment in patients with a proximal and/or distal landing zone length of less than 25 mm or a maximum diameter of more than 38 mm and no graft oversizing in type B dissection [6]. In rather rare cases if pathology forces to choose LZ 0-1, hemi-arch (LZ 1), or total-arch (LZ 0) debranching precedes safe stent graft implantation. An alternative is a high risk open surgical repair but not in many, even high volume cardiac surgical centers, such emergent operations are routinely performed. Therefore, TEVAR methods seem to be preferable. In our group, in two patients (2.7%) we performed U-shaped carotid-to-carotid prosthesis bypass causes the stent graft distal implantation zone was in LZ 1. Safety criteria of the TEVAR procedure adopted strictly in our center and meeting the recommendations of the Tokyo Consensus including minimal proximal and distal Landing Zone—20 mm (since 2019–25 mm) may have positively impacted results in our center emergent TEVAR.

### *Limitations*

We are aware that the present study has a number of drawbacks. The statistical power of the study is firstly diminished by the retrospective non-randomized design and analysis of a small number of patients from a single site. The rates of mortality and morbidity are quite low, and overall results are positive. They might not therefore accurately represent the outcomes of the other centres. We must also emphasize that while mortality and morbidity were the main topics of this research, no estimates of survivors' quality of life were made. The latter factor would significantly boost the importance of this study, hence we want to carry out such a study in the very near future.

### *Abbreviations*

- **csAAS**: Complicated spontaneous acute aortic syndrome
- **cTBD**: Complicated type B dissection
- **ID:** Iatrogenic dissection
- **IH:** Intramural hematoma
- **LZ:** Landing zone
- **PAU:** Penetrating atherosclerotic ulcer
- **PIS:** Post implantation syndrome
- **RTAA**: Ruptured descending thoracic aortic aneurysm
- **TAA**: Traumatic aortic aneurysm
- **TAD:** Traumatic aortic disruption
- **TAI:** Thoracic aortic injury
- **TEVAR:** Thoracic endovascular aortic repair.

## 5. Conclusion

Endovascular procedures can be used in a skilled and committed team to treat descending aortic diseases that call for emergency interventions with the best outcomes and the lowest morbidity and mortality rates. They are famous for also enrolling patients with severe clinical condition, and they are characterized by significantly decreased mortality and morbidity. Proper approach design, including a minimal distal and proximal Landing Zone strategy, is essential for primary and secondary clinical success.

## Compliance with ethical standards

### *Acknowledgments*

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### *Disclosure of conflict of interest*

The authors declare that they have no conflicts of interest.

*Statement of ethical approval*

According to the rules of the Local Bio-ethical Committee of Lugansk State University of Medical Sciences, the Statement of Ethics Approval is not required for retrospective documentation research and literature research; therefore, no formal ethical approval was required.

*Statement of informed consent*

Informed consent was obtained from all individual participants included in the study.

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