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# Outcome After Endovascular Repair of Ruptured Descending Thoracic Aortic Aneurysm: A National Multicentre Study☆

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**WHAT THIS PAPER ADDS**

This nationwide multicentre study is one of the largest series of patients with ruptured descending thoracic aortic aneurysm (rDTAA) undergoing TEVAR. The short-term survival is considered acceptable but long-term survival is poor. The post-operative complication rate is high. An adequate proximal and distal aortic seal is essential for technical success, and early post-operative imaging is recommended. Age, history of stroke, and post-operative bleeding, stroke, and renal failure are all associated with mortality. High risk patients and post-operative complications need to be further addressed in an effort to improve outcome.

**Objective:** The purpose of this multicentre study was to analyse the outcome of thoracic endovascular aortic repair (TEVAR) in patients with ruptured descending thoracic aortic aneurysm (rDTAA).

**Methods:** This is a nationwide retrospective study including all patients who underwent TEVAR for rDTAA at six major vascular university centres in Sweden between January 2000 and December 2015. Outcome measures were analysed using Kaplan–Meier estimator and multivariable Cox regression.

**Results:** There were 140 patients (age [mean ± SD] 74.1 ± 8.8 years; 56% men; aneurysm size 64.8 ± 19 mm), with rDTAA. In 53 patients (37.9%), the left subclavian artery was covered, and in 25 patients (17.9%) arch vessel revascularisation was performed. In total, 61/136 patients (45%) had a major complication within 30 days post TEVAR. Stroke ($n = 20$; 14.7%) was the most common complication, followed by paraplegia ($n = 13$; 9.6%) and major bleeding ($n = 13$; 9.6%). TEVAR related complications during follow up included endoleaks 22.1% (30/136; 14 type 1a, six type 1b, 10 not defined). In total, re-interventions ($n = 31$) were required in 27/137 (19.7%) patients. The median follow up time was 17.0 months (range 0–132 months). The Kaplan–Meier estimated survival was 80.0% at one month, 71.7% at three months, 65.3% at one year, 45.9% at three years, and 31.9% at five years. Age (HR 1.03; 95% CI 1.00–1.07; $p = .046$), history of stroke (HR 2.35; 95% CI 1.19–4.63; $p = .014$), previous aortic surgery (HR 2.11; 95% CI 1.15–3.87; $p = .016$) as well as post-operative major bleeding (HR 4.40; 95% CI 2.20–8.81; $p = .001$), stroke (HR 2.63; 95% CI 1.37–5.03; $p = .004$), and renal failure (HR 8.25; 95% CI 2.69–25.35; $p = .001$) were all associated with mortality.

**Conclusions:** This nationwide multicentre study of patients with rDTAA undergoing TEVAR showed acceptable short- but poor long-term survival. Adequate proximal and distal aortic sealing zones are important for technical success. High risk patients and post-operative complications need to be further addressed in an effort to improve outcome.

**Keywords:** Thoracic aortic aneurysm, Rupture, TEVAR
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## INTRODUCTION

Ruptured thoracic aortic aneurysm (rTAA) is a rare but life threatening condition that requires prompt diagnosis and treatment. The incidence of this condition has been

estimated at 5 per 100,000 persons per year.[1] Approximately 30% of all thoracic aortic ruptures are localised in the descending aorta.[2,3] Open surgical repair of ruptured descending TAA (rDTAA) is associated with significant perioperative morbidity and mortality.[4,5] Several studies have reported a favourable outcome of endovascular repair for intact descending thoracic aortic aneurysm.[6,7] Early morbidity and mortality associated with rDTAA seem to be improved with endovascular repair when compared with open repair.[8–11] In recent guidelines, endovascular repair is recommended as the first treatment option for patients with rDTAA when the anatomy is appropriate.[3]Most reports in the literature are limited to single centre series.[11–17]

The aim of this nationwide multicentre study was to analyse the outcome of thoracic endovascular aortic repair (TEVAR) in patients with rDTAA.

## METHODS

### Study design

This is a nationwide retrospective cohort study including all patients who underwent TEVAR for rDTAA at six tertiary vascular centres (Göteborg, Linköping, Malmö, Stockholm, Uppsala, Örebro) between January 1, 2000 and December 31, 2015. Computed tomography (CT) angiography was performed before endovascular repair to assess the anatomical suitability. Ruptured thoracic aortic aneurysm was defined as any disruption of the aneurysmal aortic wall with extravascular haemorrhage. All aneurysm aetiologies were included, however, acute aortic dissection and traumatic aortic injury were excluded. The anatomical extent of the aneurysm was between the left subclavian artery and the coeliac axis. The outcome measures survival and mortality rate, major bleeding, stroke, paraplegia, and re-interventions, were analysed.

The study was approved by the local ethics committee (2015/2239-31), which also waived the need for informed consent.

### Data collection

Patients were identified from local hospital records and the Swedish vascular registry (Swedvasc) at the participating centres. Medical records were reviewed for all patients. Data collection included demographic information, patient comorbidities, procedure details, and the patient's hospital course. The Swedvasc registry is cross linked to the population registry for full completeness on survival data.

Pre-operative comorbidities included hypertension (>140/90 mmHg; antihypertensive medication), diabetes mellitus (oral hypoglycaemic medications and/or insulin), stroke (ischaemic or haemorrhagic stroke), chronic obstructive pulmonary disease, heart disease (myocardial infarction, angina, heart failure, or atrial fibrillation), previous aortic surgery, and renal failure (creatinine level $>$ 150 µmol/L). Thirty day complications defined as a major complication included major haemorrhage (bleeding requiring surgical treatment including thoracotomy or chest drain), myocardial infarction (diagnosed by ECG or blood tests), stroke (diagnosed by CT scan), renal failure (need for dialysis), and paraplegia (partial or complete impairment in motor or sensory function of extremities at 30 day follow up). Endoleaks were defined as TEVAR related complications.

CT angiography reported on aneurysm size, haemothorax, bronchial/oesophageal fistulas, contained rupture, mycotic aneurysm, aneurysm secondary to chronic aortic dissection, or penetrating aortic ulcer. The Ishimaru classification was used to define the stent graft landing zones.[18]

### Endovascular management

Each hospital had its own management protocol for patients with rDTAA. Some patients were transferred from an outside hospital to the university centre. Participating centres had a stock of thoracic endografts, usually from two manufacturers. All patients underwent CT angiography of chest and abdomen. In general, patients were transferred rapidly to a hybrid operating room. A multidisciplinary team was involved including vascular surgeons, anaesthetists, and interventional radiologists depending on local routines. General and/or local anaesthesia was used. A spinal drain was not used systematically. Stent grafts were sized and deployed according to the manufacturer's instruction for use. Chest drains were preferentially placed after stent graft deployment. Post-operative care was initially in the intensive care unit.

### Statistical analysis

Normally distributed continuous variables are summarised using mean, standard deviation, and range, while categorical variables are presented with proportions. Survival rates were estimated using Kaplan–Meier analysis, and hazard ratios were estimated using multivariable Cox regression, including patient characteristics, patient comorbidities, and post-operative complications.

For the binary outcomes concerning complications within 30 days of surgery, univariable and multivariable logistic regression were used. In the multivariable models, patient characteristics, comorbidities, and technical factors were used as covariables. Time trends were analysed dividing the study cohort arbitrarily into two time periods; the first 11 years (2000 - 2010) and the last five years (2011 - 2015) of the study period. Two sided $p$ values $< 0.05$ were considered statistically significant throughout. All the analyses were performed with Stata release 13 (Statacorp, College Station, TX, USA).

## RESULTS

### Patient demographics

There were 140 patients (mean age 74.1 $\pm$ 8.8 [range 34–91] years), 56% men (79 men; 61 women), with rDTAA identified from six vascular centres. Patient characteristics are presented in Table 1. All patients underwent CT angiography at the time of presentation. The mean descending aortic

**Table 1. Patient characteristics**

| Patient characteristics ($n$ = 140) | No. (%) |
|---|---|
| Age, mean ± SD (range), y | 74.07 ± 8.8 (34 - 91) |
| Men | 79 (56%) |
| Aneurysm diameter, mean ± SD (range), mm | 64.8 ± 19 (23 - 135) |
| Hypertension | 101/138 (73.2) |
| Stroke | 17/139 (12.2) |
| Heart disease | 24/139 (17.3) |
| Diabetes | 14/139 (10.1) |
| Chronic obstructive pulmonary disease (COPD) | 37/139 (26.6) |
| Renal insufficiency | 9/139 (6.5) |
| Previous aortic surgery | 28/139 (20.1) |
| Coronary artery bypass graft (CABG) | 6/139 (4.3) |

SD: standard deviation; CABG: coronary artery bypass graft; COPD: chronic obstructive pulmonary disease; y: years.

**Table 2. Computed tomography angiography (CTA) findings at time of presentation**

| CTA findings ($n$ = 140) | No. (%) |
|---|---|
| Haemothorax | 89/139 (64) |
| Contained rupture | 56/140 (40) |
| Ruptured mycotic aneurysm | 15/140 (10.7) |
| Rupture secondary to chronic aortic dissection | 15/140 (10.7) |
| Penetrating aortic ulcer (PAU) | 19/140 (13.6) |
| Aortic-bronchial/esophageal fistula | 5/140 (3.6) |

CTA: computed tomography angiography; PAU: penetrating aortic ulcer.

aneurysm size was 64.8 ± 19 mm (range 23—135 mm). Haemothorax was present in 64% (89/139) of patients on admission; CTA findings are presented in Table 2.

When comparing demographics between the time periods 2000 - 2010 ($n$ = 79) and 2011 - 2015 ($n$ = 61); female gender (35.4% vs. 54.1%; $p$ = .027), pre-operative hypertension (62.0% vs. 85.2%; $p$ = .002), heart disease 21.5% vs. 36.1%; $p$ = .049), and previous aortic surgery (12.7 vs. 29.5%; $p$ = .012) were more common during the later time period. There was no difference when analysing age, aneurysm size, contained rupture, ruptured mycotic aneurysms, penetrating aortic ulcer, or pre-operative renal failure, but there were fewer patients with haemothorax ($p$ = .031) or ruptured aneurysm secondary to chronic aortic dissection ($p$ = .012) during the later time period.

### Endovascular procedure

Eighty (58.8%; 80/136) patients underwent TEVAR under general anaesthesia (GA), 48 patients (35.3%) under local anaesthesia (LA), and eight patients (5.9%) had combined LA/GA. A spinal drain was used in 23 patients (16.4%). The dominating proximal and distal landing zones were zones 3 (39.6%; 55/139) and 4 (54%; 75/139), respectively (Fig. 1).

The median stent graft coverage was 241 mm (range 100—800 mm) and the median number of stent grafts used was 2.0 (range 1—6). One stent graft was required in 56

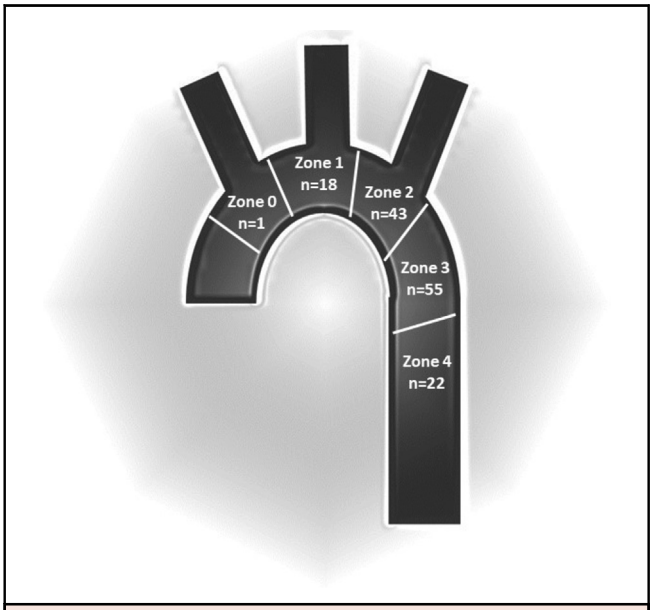


**Figure 1.** Distribution of proximal landing zones according to the Ishimaru classification[17] ($n$ = 139).

(40.0%) patients, two in 48 (34.3%) patients, and three in 29 (20.7%) patients. Out of 139 stent grafts; there were 66 from Gore, 40 from Cook, 16 from Medtronic, and 17 combinations of grafts/miscellaneous.

In 53 patients (37.9%), the left subclavian artery was covered to extend the proximal landing zone. In 25 patients (17.9%) arch vessel revascularisation was performed; chimney left carotid artery ($n$ = 14), chimney left subclavian artery ($n$ = 7), carotid-carotid-subclavian bypass ($n$ = 2), and left carotid-subclavian bypass ($n$ = 2). The coeliac trunk was covered in 15 cases (10.7%) to achieve adequate distal landing zone. A periscope was placed in the SMA in six cases (4.3%) and in the coeliac trunk in one case (0.7%). In two patients a multi-branched stent graft was used. There was no association between stent graft length or subclavian coverage and paraplegia (OR 1.00, 95% CI 0.998—1.01; $p$ = .32, and OR 0.56, 95% CI 0.14—2.31; $p$ = .42; respectively) or subclavian coverage and stroke (OR 1.40, 95% CI 0.46—4.31; $p$ = .56).

### Post-operative complications

There were 15/140 (10.7%) and 29/140 (20.7%) deaths within 24 h and 30 days, respectively. In total, 61/136 patients (45%) had a major complication within 30 days post TEVAR; three patients moved to another hospital directly after intervention and were therefore lost to follow up (Table 3). Post-operative stroke ($n$ = 20; 14.7%) was the most common complication followed by paraplegia ($n$ = 13; 9.6%) and major bleeding ($n$ = 13; 9.6%). Post-operative stroke was associated with older age and male sex (OR 1.1, 95% CI 1.01—1.21; $p$ = .027; and OR 0.26, 95% CI 0.072—0.92; $p$ = .037; respectively).

TEVAR related complications during follow up included endoleaks 22.1% (30/136) and stent graft migration 2.2% (3/137). The type of endoleak detected was 14 type 1a and six type 1b. Ten endoleaks were not defined.

**Table 3. Post-operative complications**

| Post-operative complications | No (%) |
|---|---|
| *Major complications* | 61/136 (44.9) |
| Major bleeding | 13/136 (9.6) |
| Cardiac | 5/136 (3.7) |
| Stroke | 20/136 (14.7) |
| Renal failure | 5/136 (3.7) |
| Paraplegia | 13/136 (9.6) |
| Partial | 6 |
| Complete | 6 |
| Undefined | 1 |
| Pulmonary | 5/136 (3.7) |
| Deaths within 30 days | 29/140 (20.7) |

Post-operative complications within 30 days after (TEVAR) thoracic endovascular aortic repair.

### Post-operative re-interventions

In total, re-interventions ($n = 31$) were required in 27/137 (19.7%) patients; 19/137 (13.9%) within 30 days. The median time to re-intervention after the primary procedure was 0.10 months (3 days) (range 0—84 months). There were 12 re-interventions within 24 h of the primary TEVAR procedure (haemothorax evacuation, $n = 2$; endoleaks type 1A, $n = 5$; endoleaks type 1B, $n = 1$; axillo-femoral by pass, $n = 1$; percutaneous coronary intervention, $n = 1$; access complications, $n = 2$). Nine re-interventions were required during post-operative days 2—30 (endoleaks type 1a, $n = 4$; endoleaks type 1b, $n = 2$; access complication, $n = 1$; fistula to the oesophagus, $n = 1$; type A dissection, $n = 1$). After one month there were 10 re-interventions (endoleaks type 1a, $n = 3$; reTEVAR, $n = 4$; FEVAR, $n = 1$; fistula to the lung, $n = 1$; access complication, $n = 1$). Multivariable logistic regressions analysis did not show any association between pre-operative characteristics and post-operative complications. Post-operative bleeding was the only major complication associated with re-intervention (OR 3.39, 95% CI 1.05—11.0; $p = .042$).

### Survival

The median follow up was 17 months (range 0—132 months). The Kaplan—Meier estimated survival was 80.0% at one month, 71.7% at three months, 65.3% at one year, 45.9% at three years, and 31.9% at five years (Fig. 2). Multivariable analysis for associations with mortality were assessed with Cox regression (Table 4); age (HR for every 1-year increment 1.03; 95% CI 1.00—1.07; $p = .046$), history of stroke (HR 2.35; 95% CI 1.19—4.63; $p = .014$), previous aortic surgery (HR 2.11; 95% CI 1.15—3.87; $p = .016$) as well as post-operative major bleeding (HR 4.40; 95% CI 2.20—8.81; $p = .001$), stroke (HR 2.63; 95% CI 1.37—5.03; $p = .004$), and renal failure (HR 8.25; 95% CI 2.69—25.35; $p = .001$) were all associated with mortality. The causes of death after endovascular treatment of rDTAA are listed in Table 5. In total, there were 92 deaths at the end of follow up. Aorta related mortality ($n = 28$, 30%) was the most common cause of death.

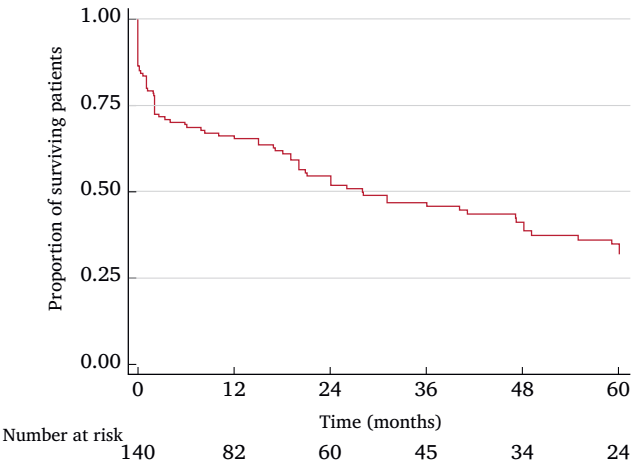


**Figure 2.** Kaplan—Meier estimated survival after thoracic endovascular aortic repair (TEVAR) in ruptured descending thoracic aortic aneurysm. rTEVAR: endovascular repair of ruptured thoracic aneurysm.

**Table 4. Multivariable analysis for associations with mortality after endovascular treatment of ruptured thoracic aortic aneurysms**

| Multivariable Cox regression | Mortality after rTEVAR | |
|---|---|---|
| | HR (95% CI) | *p* value |
| Age* | 1.03 (1.00 — 1.07) | .046 |
| Sex | 1.27 (0.78 — 2.07) | .343 |
| History of hypertension | 1.42 (0.85 — 2.38) | .184 |
| History of heart disease | 1.01 (0.59 — 1.72) | .979 |
| History of pulmonary disease | 1.37 (0.82 — 2.27) | .225 |
| History of diabetes | 1.52 (0.68 — 3.38) | .308 |
| History of stroke | 2.35 (1.19 — 4.63) | .014 |
| Previous aortic surgery | 2.11 (1.15 — 3.87) | .016 |
| Post-operative major bleeding | 4.40 (2.20 — 8.81) | .001 |
| Post-operative stroke | 2.63 (1.37 — 5.03) | .004 |
| Post-operative renal failure | 8.25 (2.69 — 25.35) | .001 |
| Post-operative MI | 2.27 (0.68 — 7.52) | .181 |
| Post-operative paraplegia | 0.65 (0.28 — 1.54) | .331 |

CI: confidence interval; MI: myocardial infarction; HR: hazard ratio; rTEVAR: endovascular repair of ruptured thoracic aneurysm.
* for every 1-year increment.

## DISCUSSION

Rupture of DTAA is an acute condition with high mortality requiring urgent treatment. This nationwide multicentre study showed a 30 day survival of 80% after endovascular treatment. Almost half of the patients had a major complication within the first month, with stroke being the most common. Most re-interventions within the first month were caused by type 1a endoleaks, which emphasises the importance of an adequate proximal sealing zone. Post-operative bleeding was the only major complication associated with re-interventions, which were required in one fifth of patients. Long-term outcome was 32% survival at five years. Patient characteristics such as age, history of stroke, and previous aortic surgery, as well as post-operative stroke, major bleeding, and renal failure were all associated with mortality.

**Table 5. Causes of death after endovascular treatment of ruptured thoracic aortic aneurysms**

| Causes of death | No. (%) Total *N* = 92 | 30 days *N* = 29 | 31 - 90 days *N* = 15 | >90 days *N* = 48 |
|---|---|---|---|---|
| Aorta related | 28 (30.4) | 14 (48.3) | 2 (13.3) | 12 (25) |
| Cardiac | 16 (17.4) | 5 (17.2) | 1 (6.7) | 10 (20.8) |
| Respiratory | 11 (12) | 3 (10.3) | 2 (13.3) | 6 (12.5) |
| Stroke | 8 (8.7) | 4 (13.8) | 2 (13.3) | 2 (4.2) |
| Infection | 10 (10.9) | 1 (3.4) | 2 (13.3) | 7 (14.6) |
| Unknown | 4 (4.3) | | 1 (6.7) | 3 (6.3) |
| Cerebral bleeding | 3 (3.3) | | 1 (6.7) | 2 (4.2) |
| Liver failure | 2 (2.2) | | 1 (6.7) | 1 (2.1) |
| Cancer | 2 (2.2) | | 1 (6.7) | 1 (2.1) |
| Visceral ischaemia | 2 (2.2) | | 1 (6.7) | 1 (2.1) |
| Renal failure | 1 (1.1) | | | 1 (2.1) |
| Gastrointestinal bleeding | 1 (1.1) | | | 1 (2.1) |
| Multiple organ failure | 1 (1.1) | 1 (3.4) | | |
| Pancreatitis | 1 (1.1) | | 1 (6) | |
| Peritonitis | 1 (1.1) | | | 1 (2.1) |
| Spleen rupture | 1 (1.1) | 1 (3.4) | | |

**Table 6. Summary of recent studies on patients with ruptured descending thoracic aortic aneurysm undergoing thoracic endovascular aortic repair (TEVAR)**

| Investigated study characteristics/ outcomes | Gopaldas et al.[11] USA | Jonker et al.[19] Netherlands/ Italy/USA | Carmona et al.[12] Spain | Botsios et al.[13] Germany | Minami et al.[14] Japan | Etienne et al.[15] France | Present study Sweden |
|---|---|---|---|---|---|---|---|
| Study type | Retrospective | Retrospective | Retrospective | Retrospective | Retrospective | Retrospective | Retrospective |
| Study period | 2006 – 2008 | 2002 – 2009 | 2005 – 2011 | 2001 – 2011 | 2008 – 2013 | 1997 – 2015 | 2000 – 2015 |
| Patients (*n*) | 364 | 87 | 25 | 21 | 23 | 25 | 140 |
| Post-op stroke, % | 6.9 (neurological complication) | 8.0 | 4.0 | | 26.1 (cerebral complication) | 12 | 14.7 |
| Post-op paraplegia, % | | 8.0 | 0 | | 8.7 | 8.0 | 9.6 |
| Cardiac complication, % | | 5.7 | | | 4.3 | | 3.7 |
| 30 day re-intervention, % | | | | 9.5 | 17.4 | | 13.9 |
| 30 day mortality, % | 23.4 (in hospital) | 18.4 | 20 | 9.5 | 4.3 | 36.0 | 20.0 |
| One year mortality, % | | 25.4 | 28.0 | | 27.3 | | 34.7 |
| Two year mortality, % | | | | | 42.2 | 44 | |
| Three year mortality, % | | 25.4 | | | | | 54.1 |
| Four year mortality, % | | 25.4 | | | | | |
| Five year mortality, % | | | | 52.6 | | | 68.1 |

Data on post-operative complications and survival from recent studies are summarised in Table 6. These series reported early mortality rates between 3.6% and 36% after TEVAR for rDTAA.[11–15,19] In a US nationwide study, 364 patients underwent TEVAR between 2006 - 2008 for ruptured descending thoracic aortic aneurysm with a peri-operative survival of 77%.[11] A meta-analysis identified 143 patients undergoing TEVAR with 30 day outcomes including mortality of 19% ($n = 27$), myocardial infarction of 3.5%, and stroke 4.1%.[20] In this analysis five additional patients in the TEVAR group died of aneurysm related causes after 30 days during a median follow up of 17 months. In comparison, the 30 day mortality rates after EVAR in randomised trials for ruptured abdominal aortic aneurysm (rAAA) are in the range of 27–35%.[21]

No association was found between pre-operative risk factors and post-operative complications. However, post-operative stroke, bleeding, and renal failure were all associated with mortality. Haemothorax was present in 64% of patients on admission, and a previous study reported that haemothorax was associated with 30 day mortality.[19] In this series, there were only two post-operative chest drains for haemothorax evacuation but no data are available on pre- and peri-operative chest drains.

Long-term survival was 65%, 46%, and 32%, at one, three, and five years, respectively. Recent studies reported a one year survival rate of 72–73%.[12,14] There are few studies with longer survival data for TEVAR in patients with rDTAA. A study of emergency endovascular interventions for thoracic aortic ruptures, including traumatic ruptures, reported a four year survival of 73%.[22] Jonker et al. reported in their meta-analysis an estimated aneurysm related survival three years after TEVAR of 71%.[20]

The stroke rate was 14.7% in this series, and this has previously been reported at between 7% and 26%.[13–15,19] Stroke is an important cause of mortality in this patient

group and older patients in particular are at risk of developing post-operative stroke.[23] The paraplegia rate has been consistent between 8% and 10%.[14,15,19] Adjunctive measures to minimise these risks in the acute setting are challenging.

The majority of the stent grafts were positioned distal to the left subclavian artery, but 45% required a more proximal seal zone in this series. This has previously been reported in up to 38% of patients, and most of these patients did not undergo left subclavian revascularisation.[10,11] Few patients in the present series underwent left subclavian artery revascularisation including bypass and chimneys. Chimneys were used for the left common carotid artery or left subclavian artery to reach a proximal sealing zone. Chimneys clearly dominated here over bypass surgery and may be explained as bailout solutions in the acute setting. No association was found between stent graft length or subclavian coverage and paraplegia or subclavian coverage and stroke. The need for revascularisation in these emergency cases is debatable. In patients who need urgent TEVAR for life threatening acute aortic syndromes where achievement of a proximal seal necessitates coverage of the left subclavian artery, the Society for Vascular Surgery Practice Guidelines suggest that revascularisation should be individualised and addressed expectantly on the basis of anatomy, urgency, and availability of surgical expertise.[24] The ESVS guidelines recommend revascularisation prior to left subclavian artery coverage in patients with a patent left mammary to coronary bypass or with a dominant or single left vertebral artery.[3]

The majority of re-interventions were during the first post-operative month. Type 1a endoleaks were the dominating cause requiring proximal extension or dilatation. The importance of an adequate proximal seal is paramount, and to detect such problems in the post-operative period early imaging control is needed. An extended proximal seal zone can be reached using chimneys to the left carotid or subclavian arteries in these acute cases but also surgical arch debranching can be considered. It would have been interesting to have the initial measurements of the proximal landing zones but unfortunately these data are lacking. Only a few patients required distal extension. The coeliac trunk was covered in one tenth of cases to achieve an accurate distal landing zone. In challenging distal thoracic aortic anatomy the coeliac trunk can be selectively covered, but even if collateral circulation exists ischaemic complications can occur.[3] A handful of patients received periscopes or branched devices to the visceral arteries.

The total volume of endoleaks was 23%, with not all of these requiring interventions. As a comparison, another multicentre study detected 18% endoleaks within the first month.[19] The majority of these endoleaks again consisted of type 1 endoleaks.

TEVAR has broadened treatment eligibility, with the majority of patients presenting with rTAA now undergoing operative intervention.[25,26] Patients undergoing DTAA repair in the modern era have a higher comorbidity burden and the rates of repair for ruptured aneurysm have increased.[24,25] Ultee et al. stated that this shift from open repair and non-operative treatment to TEVAR has resulted in decreased overall in hospital mortality in recent years.[26] This study confirms the poor long-term survival in this patient cohort. The multicentre coverage reflects real life experience. This acute condition requiring life saving procedures pushes anatomical boundaries, and patients should be selected with caution. Cardiovascular risk factors were more prevalent in recent years but not in an older patient cohort. No conclusions could be drawn about a shift in technical factors. Selection bias may influence the outcome and slightly different protocols at the centres may affect the choice of adjunctive operative measures.

There are several logistical aspects that are important in the management of patients with ruptured DTAA. Even if not specifically analysed in this study, the importance of rapid diagnosis, transfer to hybrid operation theatre, stocking of a wide range of thoracic stent grafts, multidisciplinary team approach, protocols for post-operative care to minimise the risk of complications, and follow up CTA all became apparent. These logistic considerations have successfully been applied in endovascular repair of ruptured AAA.[27] Some of these patients with rDTAA may be transferred to a more experienced and well equipped vascular centre to increase the chances of successful treatment.

In conclusion, this nationwide multicentre study is one of the largest series of patients with ruptured descending thoracic aortic aneurysm undergoing TEVAR. The short-term survival is considered acceptable but long-term survival is poor. The post-operative complication rate is high and re-interventions are required in one fifth of patients. For successful operative procedures, adequate proximal and distal aortic sealing zones are essential to avoid endoleaks and to exclude the ruptured aneurysm. Older age and history of stroke are risk factors associated with mortality and must be considered in patient assessment. All attempts to optimise peri- and post-operative technical and cardiovascular risk factors to minimise complications would be beneficial in this patient cohort.

## CONFLICTS OF INTEREST

None.

## FUNDING

None.

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