# Endovascular repair of ruptured thoracic aortic aneurysms is associated with high perioperative mortality and morbidity

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***Purpose:*** **To analyze early and midterm results after endovascular treatment of ruptured thoracic aortic aneurysms (rTAA).**
***Methods:*** **Between January 1997 and January 2009, a total of 236 patients received thoracic aortic repair in our institution; 23 patients (14 men; median age, 75 years; range, 60-88 years) due to a ruptured thoracic aortic aneurysm (rTAA). Rupture was defined according to computed tomography angiograpy (CTA) criteria with definite sign for hemorrhage outside the aortic wall. Patients with symptomatic TAA but with normal CT scans were excluded. A retrospective analysis of these patients was performed. Median follow up was 28 months (range, 0.1-82.5 months) and included serial aortic imaging at discharge, six, and 12 months and annually thereafter.**
***Results:*** **Technical success rate was 87%. The overall in hospital mortality was 48% with predominantly (50%) cardiac complications. Neurological complications occurred in three patients, two patients suffered from a transient ischemic attack (TIA)/stroke, and one patient experienced paraplegia after early conversion to open surgery. Primary endoleaks were seen in four of 25 patients (16%); no secondary endoleak was observed. Early conversion was necessary in two patients caused by an aortoesophageal fistula. The one- and three-year survival rates were 37.3% and 29.9% with no aortic or procedure-related death during follow up. Reintervention was necessary in four of 25 patients (16%). Cox regression analysis revealed preoperative renal insufficiency (hazard ratio [HR] 5.85, $P = .0073$) as an independent predictor of perioperative death.**
***Conclusions:*** **The endovascular treatment of ruptured thoracic aortic aneurysms is associated with a high perioperative mortality and morbidity as well as poor midterm survival. Renal insufficency proved to be an independent risk factor for perioperative death.**

Since its first description in 1998 by Dake et al, endovascular treatment of thoracic aortic pathologies (TEVAR) has become a first line treatment method in many centers.[1-3] The potential benefits include minimal invasive surgical access, avoidance of aortic cross clamping, and single lung ventilation. An increasing number of studies have thus reported a reduced morbidity and mortality for TEVAR compared with open surgery in an elective setting.[4-7] Due to its minimal invasive character and fast applicability, TEVAR seems especially appealing in emergency situations. Large meta-analysis have recently proved its benefit in selected patients with acute aortic transections.[8-10] However, only a few data exist regarding the results of emergency TEVAR procedures in ruptured atherosclerotic thoracic aortic aneurysms.[11-13]

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The aim of this retrospective study was therefore to review our experience in patients with ruptured thoracic aortic aneurysms regarding perioperative mortality and morbidity as well as midterm outcome.

## METHODS

**Patient population.** Between January 1997 and January 2009, a total of 236 patients received thoracic aortic repair in our institution, 23 patients (14 men; median age, 75 years; range, 60-88 years) due to a ruptured thoracic aortic aneurysm (rTAA). Rupture was defined according to computed tomography angiography (CTA) criteria that included verification of contrast agent outside the aorta and/or hemothorax. (Figs 1, 2). Patients with symptomatic TAAs but with normal CT scans, traumatic aortic transections, ruptured penetrating aortic ulcers, or ruptured aortic dissections were excluded from this analysis. All patients had a preoperative CT scan for procedure planning. After diagnosis/referral (defined as arrival of the patient in our emergency room), the patients were immediately transferred to the operation theatre and the median time from referral to operation was 1.25 hours (range, 0.5-240 hours). One hemodynamic stable patient with a contained ruptured TAA initially refused treatment but returned from the referral hospital 10 days later with a request for treatment and received immediate TEVAR.

To determine the preoperative hemodynamic status of the patients, lowest preoperative hemoglobin level (mg/dL)

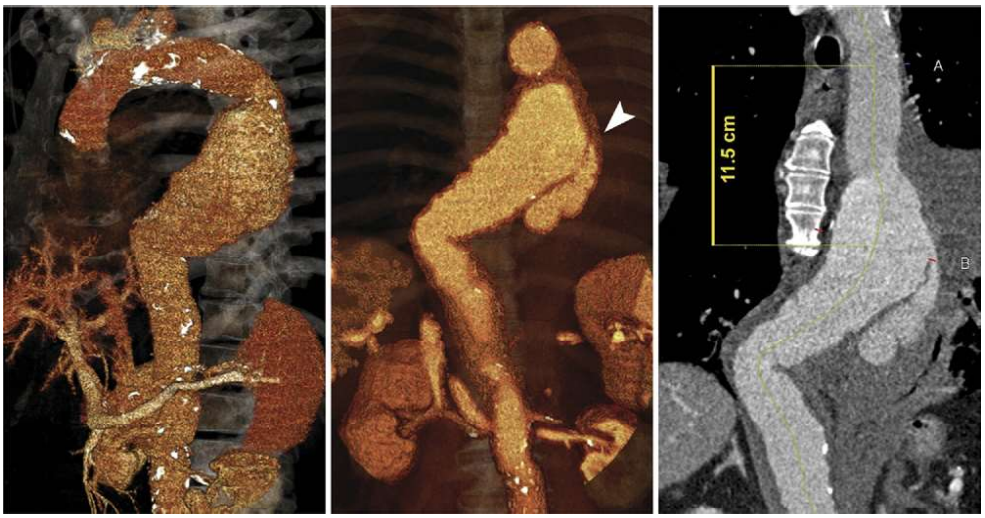


**Fig 1.** Preoperative computed tomography angiography shows a contained ruptured TAA (white arrow) with centerline analysis (green line). *TAA,* Thoracic aortic aneurysm.

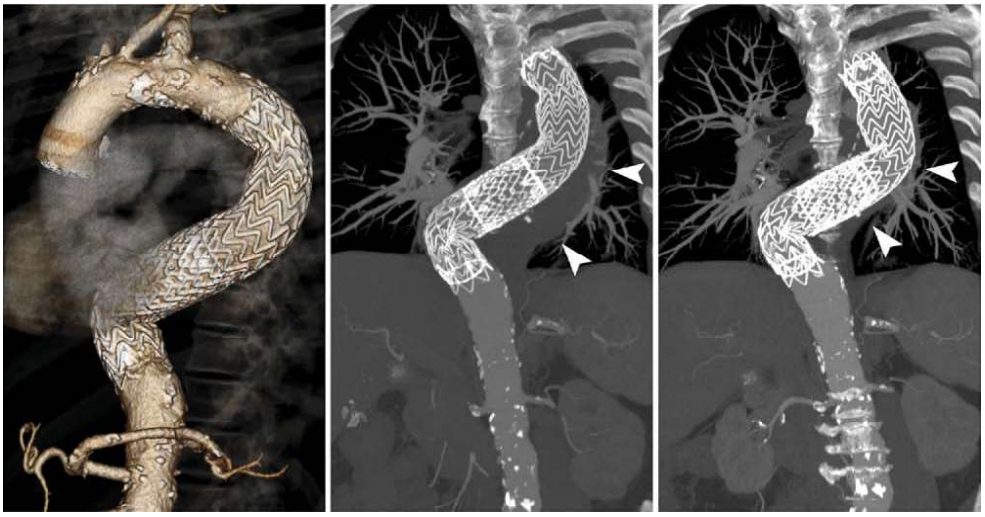

**Fig 2.** Three-D volume rendering of the control computed tomography angiographies show the exclusion of the rTAA with shrinkage of the aneurysm sack (white arrows) during follow up. *rTAA,* Ruptured thoracic aortic aneurysm.

and positive shock index (systolic blood pressure/heart rate $< 1$) was used. The median preoperative hemoglobin level was 9.9 (range, 6-14) and 30% of our patients showed a positive shock index. In total, six patients were considered as hemodynamic unstable, receiving preoperative inotropes and volume therapy with blood transfusion.

For preoperative risk stratification, the logistic EuroScore and the American Society of Anesthesiologists (ASA) classification was used. EuroScore is a preoperative risk stratification system for cardiac and open thoracic aortic surgery that includes demographic, cardiac related and surgery related variables.[14,15] Preoperative baseline characteristics of our patients are given in Table I and show a highly comorbid patient cohort with a median logEuroscore of 64 (range, 31-90).

**Preinterventional imaging.** Stentgraft sizing was based on preoperative contrast enhanced multislice CT angiography. For device selection, 15% oversizing was applied.

**Anesthesiological management.** Exclusion of the ruptured aneurysm and avoidance of free rupture into the pleural cavity is the first priority in treating rTAA. Therefore, we tried to minimize preoperative volume therapy and tolerate mean arterial blood pressures down to 60 mm Hg (permissive hypotension). Additionally, we avoided preoperative mechanical ventilation with concomitant muscle relaxation to maintain sympathetic-adrenergic stimulation and preferred local anesthesia, if possible.

**Follow up.** Follow–up included postoperative CTA before discharge, clinical examination, plain chest radiography, and CTA/MRA six and 12 months postoperatively

**Table I.** Baseline characteristics of all patients with rTAA (n = 23)

| | |
|---|---|
| Age (yrs) | 75 (60-88) |
| Gender (male) | 14 (61) |
| ASA III+IV | 23 (100) |
| logEuroscore | 64 (31-90) |
| Hypertension | 23 (100) |
| History of smoking | 19 (83) |
| CHD | 19 (83) |
| Previous myocardial infarction | 7 (30) |
| Renal insufficency | 10 (43) |
| COPD | 7 (30) |
| Diabetes | 5 (22) |
| Previous aortic surgery | 3 (13) |
| Lowest Hb preoperative (mg/dL) | 9.9 (6-14) |
| Shock index <1 | 7 (30) |
| Hematothorax | 17 (74) |
| Time referral – operation in hours | 1.25 (0.5-240) |
| Hemodynamic instable | 6 (26) |

*ASA,* American Society of Anesthesiologists; *CHD,* coronary heart disease; *COPD,* chronic obstructive pulmonary disease; *Hb,* hemoglobin; *rTAA,* ruptured thoracic aortic aneurysm.
Values are presented as median (range) or n (%).
Shock index = systolic blood pressure/heart rate.

**Table II.** Procedure-specific data

| | |
|---|---|
| Prosthesis | |
| TAG | 9 (39) |
| Talent/Valiant | 12 (52) |
| Zenith | 2 (9) |
| >1 stent graft | 14 (61) |
| Access site | |
| Femoral | 16 (70) |
| Iliac | 6 (26) |
| Other | 1 (4) |
| Anesthesia | |
| Local | 3 (13) |
| Spinal/epidural | 0 (0) |
| GA | 20 (87) |
| Adenosin-induced heart arrest | 7 (30) |
| Operation time (min) | 100 (60-253) |
| Proximal landing zone | |
| Zone 0 | 2 (9) |
| Zone 1 | 1 (4) |
| Zone 2 | 2 (9) |
| Zone 3 | 13 (57) |
| Zone 4 | 5 (21) |

*GA,* General anesthesia.
Values are presented as median (range) or n (%).

and annually thereafter. Median follow up was 28 months (range, 0.1-82.5 months).

**Definitions and statistical analysis.** Technical success in TEVAR procedures was defined according to the reporting standards of endovascular procedures by Chaikoff et al.[13]

Primary endoleaks were defined as present on intraoperative control angiography or first postoperative CTA control, secondary endoleaks as appearance during follow up. A retrospective analysis of the prospectively collected data was performed. Data are expressed as median (range). Survival analysis was calculated using the Kaplan Meier analysis. Cox proportional hazard model (Cox regression analysis) was used to identify independent preoperative risk factors affecting survival. All statistical analysis were performed using MedCalc (Version 9.5.2; MedCalc software, Mariakerke, Belgium). A $P$ value $< .05$ was defined statistically significant.

## RESULTS

**Procedure.** Twenty procedures (87%) were performed under general anesthesia; three patients received local anesthesia (Table II). Reasons for not using local anesthesia were the necessity to use adenosine induced cardiac arrest, respiratory or hemodynamic instability, non compliance of the patient, or patient's will.

The operation room is equipped with fluoroscopic and angiographic capabilities (Series 9800; OEC Medical Systems, Inc, Salt Lake City, Utah until April 2007, after that Axiom U, Siemens, Forchheim, Germany) and a carbon fiber operating table. The procedure protocol has been published before.[3] Transfemoral surgical access was used in 16 (64%) patients. Six patients needed an iliac conduit graft due to small (<8 mm) femoral access arteries. In one patient, the right limb of a previously implanted aorto-biiliac bifurcated prosthesis had to be used for stent graft deployment. Extension of the proximal landing zone by covering the left subclavian artery was performed in five patients (22%). For exact positioning of the stentgraft in the aortic arch, adenosine-induced cardiac arrest was used in seven patients. During stent graft deployment, we experienced proximal displacement of the prosthesis with unintended coverage of the left carotid artery in one patient. An immediate carotid-carotid cross-over bypass was performed. The 85-year-old, highly comorbid patient died on the first postoperative day of a multiorgan failure (renal failure and pulmonary failure caused by a tracheomalacia as a result of aneurysm compression) before CTA control or neurological reevaluation could be performed. A total of 42 stentgrafts were implanted, with 14 patients (61%) receiving more than one stentgraft. Three types of devices were implanted: 12x Talent/Valiant (Medtronic Vascular, Santa Rosa, Calif), 9x TAG (W.L. Gore & Associates, Flagstaff, Ariz), and 2x Zenith (Cook Inc, Bloomington, Ind).

**Mortality and morbidity.** Technical success was achieved in 20/23 patients (87%), as three patients showed relevant (type I or III) primary endoleaks (reinterventions; see below).

The overall in hospital mortality was 48% (Table III). Causes of death in these 11 patients were cardiac complications in seven patients, multiorgan failure in three, and pulmonary embolism in one. Postoperative complications occurred in 14 patients (61%), which included seven patients with cardiac complications (five patients with perioperative myocardial infarction and two patients with hemodynamic relevant arrhythmia). Six patients with preoperative impaired renal function showed an acute or chronic renal failure and required postoperative hemodialysis. One patient experienced a groin wound infection and one pa-

**Table III.** Operative results

| | |
|---|---|
| In hospital mortality | 11 (48) |
| Perioperative morbidity | 14 (61) |
| Stroke/TIA | 2 (9) |
| Paraplegia | 1 (4) |
| Cardiac complications | 7 (36) |
| Respiratory failure | 6 (26) |
| Renal failure | 6 (26) |
| Groin wound infection | 1 (4) |
| Bleeding | 1 (4) |
| Open conversion | |
| Early | 2 (9) |
| Late | 0 (0) |
| Primary endoleak | 4 (17) |
| Type I | 2 (9) |
| Type II | 1 (4) |
| Type III | 1 (4) |
| Late endoleak | 0 (0) |
| Reintervention | 4 (17) |

*TIA,* Transient ischemic attack.
Values are presented as n (%).

tient needed operative revision due to a postoperative bleeding at the access site.

**Neurological complications.** One patient suffered from an ischemic stroke with a left sided hemipareses on the third postoperative day. Control CTA showed the stent graft in the exact position with intended coverage of the left subclavian artery. The actual cause remained unclear, but the patient recovered completely and is currently, 6.8 years after the operation, alive without further event. A second patient showed a transient ischemic attack with aphasia and right-sided hemipareses of unknown origin on the third postoperative day. No residual neurological damage remained.

No paraplegia was observed after TEVAR procedures, but one patient showed a postoperative paraplegia after requiring open conversion due to a de novo aorto-esophageal fistula four weeks after stent graft repair (see below).

**Primary endoleaks.** Primary endoleaks were seen in four of 25 patients (16%). Two patients showed a proximal type I endoleak in the aortic arch at the first postoperative CTA control. Reintervention with complete supraaortic debranching and proximal stent graft extension, which excluded the endoleak in both cases, was performed. One patient had a type II endoleak via a retrograde perfused left subclavian artery, which sealed spontaneously during follow up. The fourth patient showed a small endoleak type III at the overlapping zone of two stentgrafts in the first postoperative control CTA. The patient died on the second postoperative day due to a multiorgan failure before further reintervention.

**Early conversion.** Early conversion was necessary in two patients. One patient presented with an rTAA and an additional aortoesophageal fistula. Initially, the patient received an endovascular bridging manoeuver. Six days later a staged, planned conversion using a silver Dacron prosthesis was performed, but the patient died one month postoperatively at the intensive care unit of a myocardial infarction.

**Table IV.** Risk factor analysis regarding perioperative death

| *Variable* | *Hazard ratio* | *95% CI* | P *value* |
|---|---|---|---|
| Renal insufficiency | 5.85 | 1.617-21.153 | .0073 |
| COPD | 1.23 | 0.331-4.639 | .7511 |
| CHD | 0.39 | 0.092-1.725 | .2211 |
| Hemodynamic status | 3.12 | 0.837-11.631 | .0916 |

*CHD,* Coronary heart disease; *COPD,* chronic obstructive pulmonary disease.

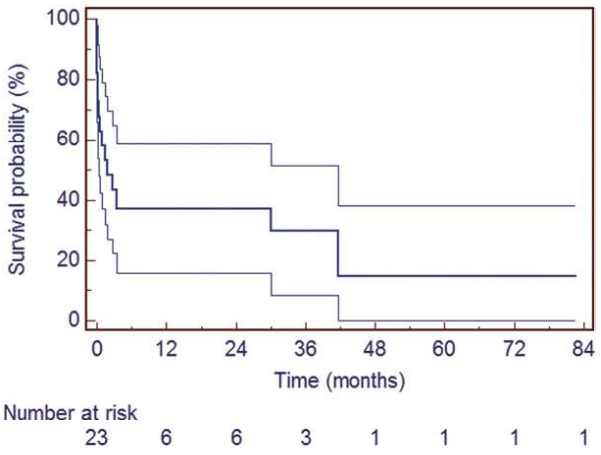


**Fig 3.** Kaplan-Meier estimate of actuarial survival (including 95% CI) in all patients (n = 23) treated with TEVAR for rTAA. *CI,* Confidence interval; *rTAA,* ruptured thoracic aortic aneurysm; *TEVAR,* thoracic endovascular aortic repair.

The second patient showed an aorto-esophageal fistula after successful TEVAR for rTAA. The initial postoperative course after TEVAR was uneventful. Three weeks postoperatively, the patient suddenly developed hematemesis with signs of a new aorto-esophageal fistula in the CTA control. Immediate conversion using distal perfusion via an axillo-femoral bypass graft and additional resection of the esophagus was performed. The intraoperative course was uneventful but the patient developed a paraplegia, which persisted despite cerebrospinal fluid drainage. The patient is currently three months postoperatively alive.

**Risk factor analysis.** Cox regression analysis revealed renal insufficiency (HR 5.85, $P = .007$) as independent predictor of perioperative death. A hemodynamic unstable status (HR 3.12, $P = .091$), chronic obstructive pulmonary disease (COPD; HR 1.23, $P = .751$), and coronary heart disease did not influence perioperative outcome (Table IV).

**Midterm results.** The actuarial survival estimates at one and three years were 37.3% and 29.9% (Fig 3).

The causes of late death were cardiac failure during coronary artery bypass grafting with aortic valve replacement in one patient, lung cancer in one patient, and pneumonia in a 76-year-old patient three and a half years postoperatively. There was no aortic related death during follow up. No late endoleak was observed.

Early or late reintervention was necessary in four of 25 patients (16%). These patients have already been discussed above.

## DISCUSSION

The present series underlines the technical feasibility of TEVAR in an emergency setting with patients presenting with ruptured TAAs. Furthermore, it shows a high, non-procedure related, perioperative mortality and morbidity rate combined with poor midterm survival. Risk factor analysis revealed renal insufficiency as an independent predictor of perioperative death. There was a tendency towards a worse perioperative outcome in hemodynamic unstable patients (HR 3.12; $P = .091$), which did just not reach statistical significance in risk factor analysis, likely caused by the small patient cohort (only six of 23 patients considered hemodynamic unstable). To our knowledge, no other series exist focusing on risk factor analysis regarding endovascular treatment of rTAA.

Mortality rates after TEVAR for acute descending aortic rupture vary between 0% and 17% in the few available series, which seems relatively low compared with our in-hospital mortality rate of 48%[11,12,16] This might be explicable as all these series contain a variety of aortic pathologies (rTAA, ruptured penetrating aortic ulcers, ruptured acute aortic dissections, and traumatic aortic transections). These entities all vary in outcome, pathology and procedure-specific complications and should therefore not be compared with this series. Especially the large proportion of patients with traumatic transection (15%-68%) in these studies, which have been excluded in our analysis, warrants consideration as these patients are usually young, "healthy" trauma victims and show favorable mortality and morbidity rates after TEVAR as proved in various single center series and meta analysis.[8-10] In opposition to that, this series represents a rather old (median age, 75 years), highly comorbid (83% patients with coronary heart disease, 43% patients with renal insufficiency, and 30% patients with COPD) patient cohort, resulting in high cardio-pulmonary and renal complications with consecutive perioperative death. Midterm survival is influenced by these parameters. Therefore, our three-year survival estimate of 30% is not comparable to the only other reported midterm survival of 68% after two years by Morishita et al.[16]

In our series, two patients (9%) experienced a postoperative stroke or transient ischemic attack (TIA), which is in line with Scheinert et al, who report a stroke rate of 9.5% in their series of 21 patients with acute rupture of the descending aorta.[13] Although the cause in our two patients remained unclear, procedure associated factors, like embolization due to wire or nose cone manipulation in the aortic arch could be possible explanations, but seem unlikely since both events occurred on the third postoperative day. In our series, no patient experienced paraplegia after TEVAR, which is in line with the few reported literature on descending aortic rupture and is most likely due to the small amount of patients in all series.[13,17] Paraplegia after TEVAR in elective cases can be expected in 1%-3% of all cases, with coverage of the left subclavian artery and previous aortic surgery as independent predictors.[18,19]

Small access vessel diameters caused by shock and/or heavily calcified femoral or iliac arteries can make TEVAR in patients with rTAA technically challenging procedures. In this series, only 70% of all patients could be managed with a femoral cut down, which emphasizes adequate preoperative access planning to avoid potentially lethal, unnecessary time delay during the operation. Although stentgraft application was possible in all cases, technical success could only be achieved in 87% of our patients as three patients showed type I or III endoleaks. Both patients with proximal type I endoleak underwent complete arch debranching to extend the proximal landing zone and received successful proximal stent graft extension sealing the endoleak. In retrospective analysis, both patients showed a very short (approx. 1 cm) proximal landing zone, which was chosen as a compromise to avoid sternotomy with complete debranching and thereby minimizing operative trauma in the emergency setting. In general, one would aim for a proximal landing zone $> 2$ cm and deliberately cover the left subclavian artery (LSA, 22% in this series) to achieve a sufficient sealing zone and perform staged revascularization of the LSA if necessary (none in this series). Whether primary revascularization or secondary transposition after the development of symptoms in order to avoid type II endoleaks and to reduce the risk of paraplegia is advocated still remains debatable.[18,20,21]

**Limitations.** Limitations of this study certainly include the relatively small amount of patients and its retrospective design. However, only a few patients with ruptured thoracic aortic aneurysms reach the hospital alive and this represents, to our knowledge, the largest single center study population.

## CONCLUSIONS

The endovascular treatment of ruptured thoracic aortic aneurysms is associated with a high perioperative mortality and morbidity as well as poor midterm survival. Renal insufficency proved as an independend risk factor for perioperative death.

## AUTHOR CONTRIBUTIONS

Conception and design: PG, DB
Analysis and interpretation: PG, DB, AD
Data collection: DK, TW, AD
Writing the article: PG, DB
Critical revision of the article: DB, DK
Final approval of the article: PG, DB
Statistical analysis: PG
Obtained funding: N/A
Overall responsibility: DB, PG

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