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ORIGINAL ARTICLE

Emergency open surgery for aorto-oesophageal and aorto-bronchial fistulae after thoracic endovascular aortic repair: a single-centre experience[†]

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Abstract

OBJECTIVES: Severe complications after thoracic endovascular aortic repair (TEVAR), such as secondary aorto-oesophageal (AOF) or aorto-bronchial fistulae (ABF), are most likely under-reported; however, once detected, emergent surgery becomes necessary.

METHODS: Between June 2002 and September 2013, 10 (2.6%) of 374 patients (8 males; mean age 68 years, range: 49–77) were admitted with AOF ($n = 8$) or ABF ($n = 2$) post-TEVAR during follow-up (mean 12.9 months, range 0.2–48.1). The respective Ishimaru landing zones were 0 ($n = 1$), 2 ($n = 3$), 3 ($n = 4$) and 4 ($n = 2$). Median interval between TEVAR and AOF/ABF formation was 18.1 months (range 0.1–65.1). Symptoms on admission included haematemesis ($n = 4$), haemoptysis ($n = 2$), melena ($n = 1$), elevated C-reactive protein ($n = 10$), new-onset fever ($n = 3$), positive blood cultures ($n = 8$), dysphagia ($n = 1$), chest pain ($n = 4$), previous syncope ($n = 1$) and vertigo ($n = 1$). In 6 patients with AOF, stent graft removal required ascending aortic ($n = 1$), aortic arch ($n = 1$), left hemiarch ($n = 2$) and descending aortic ($n = 6$) replacement with concomitant oesophagectomy ($n = 4$) and cervical oesophagostomy ($n = 1$) or oesophageal repair ($n = 2$); another patient with AOF underwent oesophagectomy and cervical oesophagostomy via posterolateral thoracotomy without stent graft removal as a first-stage operation. One patient with ABF was treated by stent graft removal, aortic arch and descending aortic replacement in combination with bronchial repair. Two patients were deemed inoperable and treated conservatively.

RESULTS: All patients survived the operation. Reoperation due to postoperative mediastinitis, haemorrhage, pericardial tamponade and wound infection was required in 4 (50%, 95% confidence interval [CI] [22, 78]) patients. In-hospital mortality was 25% ($n = 2$; 95% CI [7, 59]) due to mediastinitis with resulting multiorgan failure ($n = 1$) and aortic rupture with haemorrhagic shock ($n = 1$). One patient died due to unknown cause on postoperative day 158. No neurological complications occurred postoperatively. Postoperative complications comprised acute renal failure with temporary dependence on haemodialysis ($n = 2$) and respiratory insufficiency ($n = 4$) requiring percutaneous tracheostomy ($n = 2$). Both patients treated conservatively died after 4 and 81 days due to pulmonary haemorrhage and fulminant mediastinitis, respectively.

CONCLUSIONS: AOF and ABF represent uncommon but fatal complications—if treated conservatively—after TEVAR that may occur during short- and mid-term follow-up. Surgery for AOF/ABF requires early diagnosis and should be performed promptly and in a radical fashion to totally excise all infected tissues in these high-risk patients.

Keywords: Aorto-oesophageal fistula • Aorto-bronchial fistula • Thoracic endovascular aortic repair • Stent graft infection • Aortic erosion • Postinterventional complication

INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) has been clinically introduced in the mid-90s and is now increasingly advocated by many surgeons and interventionalists as the method of choice to treat thoracic aortic disease [1]. However, despite a reported low early postoperative mortality, stent grafts—if compared with open aortic surgery—may result in a higher incidence of long-term complications [2], potentially causing severe collateral damage to adjacent mediastinal structures [3], while associated with an equally increased risk of postoperative paraplegia [4].

Secondary aorto-oesophageal (AOF) and aorto-bronchial (ABF) fistulae have been known to be uncommon but fatal complications after open thoracic and thoracoabdominal aortic surgery [5].

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More recently, the incidence of AOF and ABF post-TEVAR has been described to be 1.5–1.9% [5–7]. However, the incidence of secondary AOF and ABF is most likely under-reported due to patients that are lost during follow-up and might even increase in the future, since TEVAR is nowadays not exclusively used in aortic emergencies or elderly high-risk patients [2, 3].

Since secondary AOF and ABF are uncommon and optimal treatment remains controversial, the purpose of this study was to report on the incidence, clinical presentation and outcomes after radical surgery in this high-risk cohort of post-TEVAR patients.

PATIENTS AND METHODS

A total of 374 patients underwent TEVAR at our institution between June 2002 and September 2013. We retrospectively identified 10 patients who were admitted either due to AOF ($n = 8$) or due to ABF ($n = 2$). The mean patient age was 67.6 ± 8.1 years (range 49–77) and 8 (80%, 95% confidence interval (CI) [49, 94]) were males. Follow-up post-TEVAR was 100% complete (mean 12.9 months; range 0.2–48.1). The patients' demographics and comorbidities are given in Table 1.

Endovascular procedures

The indications for TEVAR in the 10 patients were descending aortic aneurysm ($n = 5$), chronic ($n = 2$) or acute ($n = 1$) type B aortic dissection (TBAD), penetrating atherosclerotic ulcer (PAU; $n = 1$) and aberrant right subclavian artery aneurysm with aortic arch involvement ($n = 1$). Three different endovascular stent graft systems were used: Valiant (Medtronic Vascular, Santa Rosa, CA, USA) in 7 patients, Excluder (TAG; W.L. Gore and Associates, Inc., Flagstaff, AZ, USA) in 2 patients and Talent (Medtronic Vascular) in 1 patient. Retrograde stent graft deployment via the femoral artery ($n = 10$) was performed in the ascending aorta after complete supra-aortic debranching ($n = 1$), the aortic arch ($n = 3$) and the descending aorta ($n = 6$); the respective Ishimaru landing zones were 0 ($n = 1$), 2 ($n = 3$), 3 ($n = 4$) and 4 ($n = 2$). The single patient with stent graft deployment in landing zone 0 had received supra-aortic debranching prior to TEVAR. In 3 patients with an Ishimaru landing zone 2, intentional left subclavian artery (LSA) overstenting was performed; 1 of the 3 patients initially received left common carotid to LSA bypass before TEVAR. Another patient was initially treated with 1 stent graft for successful exclusion of a large descending aortic aneurysm but he required stent graft extension 5 years later due to aneurysmal progression of the distal landing zone. No endoleaks were noted during post-procedural angiography; post-deployment ballooning with stent graft oversizing of > 20%, 10–19% and 0–9% was performed in 5, 2 and 3 patients, respectively.

Table 1: Preoperative comorbidities and intraoperative data

Characteristics	Number of patients (% [95% CI])
Overall	10
Age (years, mean ± SD)	67.6 ± 8.1
Gender (male)	9 (90 [60, 99.5])
Hypertension	9 (90 [60, 99.5])
Coronary artery disease	4 (40 [17, 69])
Cardiomyopathy (EF < 30%)	2 (20 [6, 51])
Chronic obstructive pulmonary disease (COPD)	3 (30 [11, 60])
Previous pneumonia	4 (40 [17, 69])
Renal insufficiency	3 (30 [11, 60])
Diabetes mellitus	6 (60 [31, 83])
Obesity	4 (40 [17, 69])
Hyperlipidaemia	3 (30 [11, 60])
Peripheral vascular disease	3 (30 [11, 60])
Previous cardiac surgery	2 (20 [6, 51])
Previous cerebral infarction	1 (10 [0.5, 40])
Intraoperative data; patients ($n = 8$)	
CPB time, mean ± SD (range)	175 ± 77.7 min (117–220)
Femoral artery cannulation, *n* (% [95% CI])	7 (88 [53, 99.4])
Axillary artery cannulation, *n* (% [95% CI])	2 (25 [7, 59])
SCP, *n* (% [95% CI])	3 (38 [14, 69])
Distal aortic perfusion, *n* (% [95% CI])	6 (75 [31, 83])
Overall HCA temperature, mean (range)	26.1°C (21–32)
Deep-to-moderate HCA, mean (range)	22.2°C (21–24)
Mild HCA, mean (range)	31.3°C (30–32)
HCA time, mean ± SD (range)	13.5 ± 6.3 min (3–22)

CPB: cardiopulmonary bypass; SCP: selective cerebral perfusion; HCA: hypothermic circulatory arrest; CI: confidence interval.

Surgical procedures

All patients diagnosed with AOF or ABF were generally classified as surgical emergencies. The optimal treatment strategy was discussed on an individual basis by an interdisciplinary team including a cardiovascular surgeon, a general/visceral surgeon, a vascular interventionalist and a radiologist. However, re-TEVAR was not considered as a potential treatment option in these patients due to the underlying infectious process of the mediastinum with involvement of the previously implanted endovascular prostheses. Two patients were deemed inoperable and treated conservatively.

The details of our institutional surgical technique to address secondary surgical procedures after TEVAR have been described elsewhere [8, 9]. In brief, surgical access was achieved via a left-sited posterolateral thoracotomy ($n = 6$) or in combination with a full sternotomy ($n = 2$). Arterial cannulation for cardiopulmonary bypass (CPB; $n = 7$) was performed via the femoral ($n = 5$), the axillary artery ($n = 1$) or both ($n = 1$). The right axillary artery was cannulated to allow selective cerebral perfusion (SCP) along with direct cannulation of the right atrium for venous drainage ($n = 2$). Median CPB time was 17 5 ± 77.7 min (range 117–220).

Hypothermic circulatory arrest (HCA) was induced at deep-to-moderate hypothermia of 21–24°C ($n = 4$) by cross-clamping the lower descending aortic segment. However, intraoperative body core temperatures for hypothermic circulatory arrest (HCA) have been gradually increased to mild hypothermic conditions (30–33°C; $n = 3$) in the past few years. HCA without SCP was utilized in 5 patients (mean HCA duration 13.5 min; range 3–22). The head was packed externally in ice during HCA.

In all patients with aortic replacement—except 1 patient who was operated on at deep-to-moderate HCA of 22°C in combination with SCP—moderate distal aortic perfusion (25–32°C; 3 l/min) was performed retrogradely via the femoral artery ($n = 6$) for adequate visceral and spinal cord protection during the entire procedure. Perioperative cerebrospinal fluid (CSF) drainage as an additional measure to minimize the risk of paraplegia was used up to 72 h postoperatively. Intraoperative perfusion data are summarized in Table 1.

In 6 patients with AOF, stent graft removal required ascending aortic ($n = 1$), aortic arch ($n = 1$), left hemiarch ($n = 2$) and descending aortic ($n = 6$) replacement with concomitant oesophagectomy ($n = 4$) and cervical oesophagostomy ($n = 1$) or oesophageal repair by suture ($n = 2$) (Fig. 1); 2 of the 6 patients underwent a staged procedure: primary oesophagoectomy with cervical oesophagostomy via a left-sited posterolateral thoracotomy followed by aortic replacement in a second procedure ($n = 1$) and vice versa ($n = 1$). One patient with AOF—initially treated by supra-aortic debranching prior to TEVAR—who had been diagnosed with severe mediastinitis and several oesophageal abscesses underwent oesophagectomy and cervical oesophagostomy via a left-sited posterolateral thoracotomy without stent graft removal as a first-stage operation. Four AOF patients also received a percutaneous endoscopic gastrostomy tube to allow enteral nutrition postoperatively. The single patient with ABF underwent aortic arch and descending aortic replacement due to extensive aneurysm progression with bronchial repair. Table 2 gives an overview of the performed operative procedures.

Smear tests of the mediastinum and the infected prostheses were performed in all cases. All patients were treated either with broad-spectrum antibiotics (institutional protocol) or calculated antibiotic therapy with regard to previously isolated bacteria from the individual patient's blood cultures.

Study variables and definitions

The operative reports and clinical charts of all patients were retrospectively reviewed. The local ethics committee did not require additional patient consent.

Definite diagnosis of AOF or ABF fistula was defined as documented imaging results by endoscopy, CT, oesophagography or bronchioscopy.

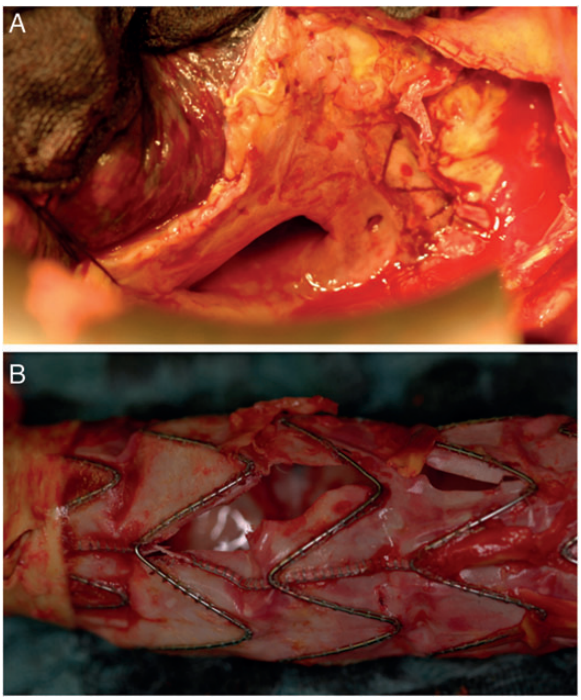

Figure 1: Intraoperative exposure of an aorto-oesophageal fistula after stent graft removal (**A**). Explanted endovascular stent graft; the prosthetic material has been dissolved by the infectious process (**B**).

HCA was defined as time of complete circulatory arrest (without SCP or distal aortic perfusion).

Renal failure was defined as an increase in serum creatinine of >1.5 mg/dl and temporary (resolved by the time of discharge) or permanent need for haemodialysis. Respiratory insufficiency was defined as weaning failure from mechanical ventilation by means of prolonged ventilation (>7 days) or requirement of reintubation or tracheostomy. Hospital mortality was defined according to current guidelines as death in hospital prior to discharge or within 30 days of surgery (regardless of location).

Follow-up was 100% complete with a mean follow-up time of 12.9 months (range 0.2–48.1). Follow-up was ascertained by a mailed paper questionnaire or a phone call to the patient or family members, or by contact with the family physician. It was performed by study personnel and consisted of information on patient vital status, symptomatology, and reoperations or hospitalisations. Supplemental information on CT or endoscopy findings was obtained when possible.

Statistical methods

Categorical data are reported as frequencies (percentages) and continuous variables as mean (range). 95% CIs were calculated following the method of Wilson by means of the R package binom.

RESULTS

Incidence and clinical presentation

Among the 374 patients treated by TEVAR between January 2002 and February 2013, the overall incidence of either AOF or ABF was 2.6% ($n = 10$); the respective incidence of AOF and ABF were 2.1%, 95% CI [1.1, 4.2]% ($n = 8$) and 0.5%, 95% CI [0.15, 1.9]% ($n = 2$).

Mean interval between TEVAR and development of AOF/ABF was 18.1 ± 24.8 months (range 0.1–65.1). Clinical symptoms on admission included haematemesis ($n = 4$), melena ($n = 1$) or haemoptysis ($n = 2$) with haemorrhagic shock ($n = 4$), new-onset fever ($n = 3$), elevated inflammatory laboratory parameters ($n = 10$), dysphagia ($n = 1$), dyspnea ($n = 1$), chest pain ($n = 4$), vertigo ($n = 1$) and previous syncope ($n = 1$).

At the time of admission, 8 (80%) patients were found to have positive blood cultures with bacteria. Mediastinal smear tests were positive in 6 cases. Antibiotics were continued for at least 3 months postoperatively. Table 3 gives an overview of the obtained microbiological data.

The initial diagnosis of AOF/ABF was performed via endoscopy ($n = 7$), CT ($n = 4$), bronchoscopy ($n = 1$) or oesophagography ($n = 1$) (Fig. 2). However, all patients received a CT of the thoracic and thoracoabdominal aorta (aortic protocol) prior to surgery; 1 patient had developed a type I endoleak and 4 patients were diagnosed with an endoleak type II fed by the LSA ($n = 3$) or a thoracic aortic segmental artery ($n = 1$) prior to open surgery.

Clinical symptoms of all patients at the time of admission for AOF/ABF are summarized in Table 4.

Hospital mortality and longevity

The respective in-hospital, 6-month mortality and 1-year mortality rates were 25% ($n = 2$), 37.5% ($n = 3$) and 37.5% ($n = 3$) for operated and 50% ($n = 1$), 100% ($n = 2$), 100% ($n = 2$) for conservatively

Table 2: Aetiologies, procedures and complications

Patient, age (yrs)	Aetiology	Previous TEVAR stent graft (*n*), length (mm)	Prox. LZ/ oversizing (%)	Type of fistula (length)/ Incidence of Endoleak	Operation aortic replacement; AOF or ABF repair	Postoperative complications	Hospital mortality
#1, 61	Acute TBAD	Valiant (1), 28 × 157	Z3/21	AOF (5 cm)/yes	DA replacement; oesophagectomy	–/–	No
#2, 71	DAA	Talent (1), 42 × 114	Z2/0	AOF (1.5 × 1.5 cm)/yes	Asc Ao, AA, DA replacement; oesophageal repair/staged cervical oesophagostomy	Rethoracotomy: mediastinitis, PE; Pneumonia, temp. dialysis, multi-organ failure	Yes
#3, 75	DAA	Valiant (1), 32–36 × 150	Z4/11	AOF (3 × 4 cm)/ no	DA replacement; oesophagectomy	Tracheostomy	No
#4, 49	PAU	Gore TAG (1), 31 × 100	Z2/26	AOF (5 × 2 cm)/ no	Left hemiarch, DA replacement; oesophagectomy/staged cervical oesophagostomy	Rethoracotomy: haemorrhage, PE, mediastinitis; Resp. insufficiency, wound infection	No
#5, 70	DAA	Gore TAG (1), 34 × 200; Talent (1) 34 × 114	Z4/21	AOF (0.5 cm)/no	DA, upper TAA replacement; oesophageal repair	Rethoracotomy: wound infection; Temp. dialysis	No
#6, 73	Aberrant RSAA	Valiant (1), 38 × 200	Z0/21	AOF (2 cm)/yes	-/Oesophagectomy and cervical oesophagostomy	Rethoracotomy: haemorrhage (x2)	Yes
#7, 66	Chronic TBAD	Valiant (1), 46 × 150	Z2/9	ABF (N.A.)/no	AA, DA replacement/bronchial repair	Splenectomy	No
#8, 74	DAA	Valiant (1), 34 × 160	Z3/18	AOF (6 cm)/yes	Oesophagectomy and cervical oesophagostomy/staged left hemiarch, DA replacement	Tracheostomy, pneumonia	No
#9, 77	DAA	Valiant (1), 44 × 200	Z3/21	AOF (5 cm)/no	–/–	–/–	–/–
#10, 59	Chronic TBAD	Valiant (1), 32 × 32 × 150	Z3/9	ABF (N.A.)/yes	–/–	–/–	–/–

TEVAR: throacic endovascular arotic repair; LZ: landing zone; AOF: aorto-oesophageal fistula; ABF: aorto-bronchial fistula; TBAD: type B aortic dissection; DAA: desecening aortic aneurysm; RSAA: right subclavian artery aneurysm; AscAo: ascending aorta; AA: aortic arch; DA: descending aorta; TAA: thoracoabdominal aorta; PE: pericardial effusion; N.A.: not available.

Table 3: Laboratory and microbiological data

Patient	C-reactive protein (CRP) mg/l	Leucocytes per microliter	New-onset fever	Blood cultures	Mediastinal smear test
#1	102	10200	Yes	Staphylococcus aureus	Staphylococcus aureus
#2	231	22200	Yes	No growth	No growth
#3	65	7080	No	Citrobacter freundii (ESBL)	Staphylococcus epidermidis, Proteus mirabilis, Citrobacter freundii, Steptococcus mitis, Prevotella oralis
#4	232	14400	Yes	Staphylococcus aureus	Staphylococcus aureus, Streptococcus mitis/oralis, Prevotella oralis (Bacteroides oralis), Candida albicans
#5	291	15100	No	No growth	Candida glabrata (Torulopsis glabrata), Propionibacterium acnes
#6	198	6160	No	Streptococcus anginosus	Streptococcus anginosus
#7	40	9660	No	Staphylococcus epidermidis	No growth
#8	29	8550	No	Staphylococcus anginosus, Escherichia coli (ESBL)	Streptococcus anginosus, Escherichia coli (ESBL) extended spectrum ß-lactamase
#9	404	9800	No	Lactobacillus species	–
#10	70	9660	No	Salmonella enteritis, Staphylococcus epidermidis	–

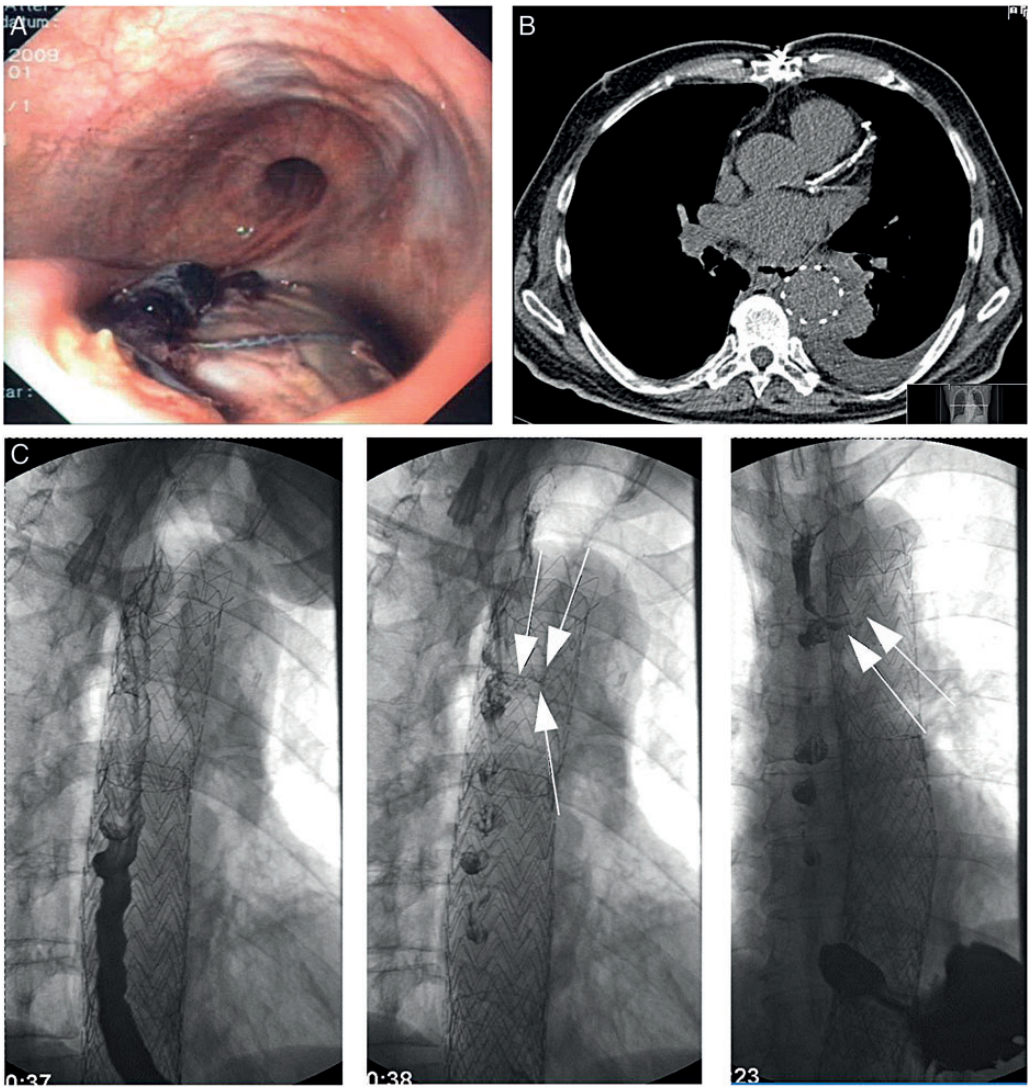

Figure 2: Diagnosis of aorto-oesophageal fistulae by endoscopy (**A**), computed tomography (**B**) or oesophagography (white arrows) (**C**).

treated patients. Postoperative follow-up was available for all patients and 100% complete. After a mean period of 12.9 months, 5 (62.5%) patients were still alive.

All initial open surgical procedures for stent graft removal and/or oesophageal resection were technically successful. However, 2 patients died within 40 days, resulting in an in-hospital mortality of 25%.

The first patient had been admitted in septic shock due to fulminant mediastinitis caused by AOF 4 months post-TEVAR (Fig. 3). He underwent oesophagectomy and cervical oesophagostomy via left posterolateral thoracotomy and secondary aortic surgery was planned after clinical stabilization. Six days later, he developed right-sited haemothorax with acute rupture of the ascending aorta and died as a result of hypovolemic shock in the operating theatre.

The second patient had been admitted due to AOF and was treated by aortic replacement with oesophageal repair and subsequent coverage by a pericardial patch. Postoperatively, the patient required prolonged mechanical ventilation. On postoperative day (POD) 14 the patient became septic and haemodynamically instable. Chest CT revealed a pneumomediastinum and reoccurrence of the AOF and pericardial effusion. After pericardial drainage, the patient successfully underwent oesophagoectomy with cervical oesophagostomy. However, the patient ultimately developed multiorgan failure during the following clinical course and died on POD 40.

Postoperative complications

Complications leading to rethoracotomy occurred in 4 (50%) patients and were in detail: mediastinitis ($n = 2$), postoperative haemorrhage ($n = 2$), pericardial tamponade ($n = 2$) and wound infection ($n = 2$). Another patient with chronic TBAD required splenectomy via a left-sited laparotomy due to preoperative infarction of the spleen.

Four patients—including 2 individuals with chronic obstructive pulmonary disease—developed respiratory insufficiency. Percutaneous tracheostomy was required in 1 patient with COPD and 1 patient due to postoperative pneumonia in order to be weaned from the ventilator. Temporary dialysis due to acute renal failure occurred in 2 (25%) patients—with 1 of them developing

Table 4: Patient presentation and diagnostics

Incidence of AOF/ABF; patients (n = 10)	
Overall, n (% [95% CI])	10 (2.7 [1.5, 4.9])
AOF, n (% [95% CI])	8 (2.1 [1.1, 4.2])
ABF, n (% [95% CI])	2 (0.5 [0.15, 1.9])
Timing	
Months since TEVAR, mean ± SD (range)	18.1 ± 24.8 (0.1–65.1)
Clinical symptoms	
Elevated C-reactive protein, mg/ l ± SD (range)	166.2 ± 118.3 (29–404)
New-onset fever, n (% [95% CI])	3 (30 [11, 60])
Positive blood cultures, n (% [95% CI])	8 (80 [49, 94])
Haematemesis, n (% [95% CI])	4 (40 [17, 69])
Haemoptysis, n (% [95% CI])	2 (20 [6, 51])
Melena, n (% [95% CI])	1 (10 [0.5, 40])
Haemorrhagic shock, n (% [95% CI])	4 (40 [17, 69])
Chest pain, n (% [95% CI])	4 (40 [17, 69])
Dysphagia, n (% [95% CI])	1 (10 [0.5, 40])
Dyspnoea, n (% [95% CI])	1 (10 [0.5, 40])
Vertigo, n (% [95% CI])	1 (10 [0.5, 40])
Syncope, n (% [95% CI])	1 (10 [0.5, 40])
Exhaustion, n (% [95% CI])	1 (10 [0.5, 40])
Evidentiary preoperative diagnostics	
Computed tomography, n (% [95% CI])	4 (40 [17, 69])
Endoscopy, n (% [95% CI])	7 (70 [40, 89])
Oesophagography, n (% [95% CI])	1 (10 [0.5, 40])
Bronchoscopy, n (% [95% CI])	1 (10 [0.5, 40])

TEVAR: thoracic endovascular aortic repair; AOF: aorto-oesophageal fistula; ABF: aorto-bronchial fistula; CI: confidence interval.

multiorgan failure during his clinical course. No new neurological complications occurred postoperatively.

Overall mean time to hospital discharge was 30 ± 21.4 days (range 3–68). Postoperative complications are listed in Table 2.

Non-surgical treatment

Two patients with AOF (n = 1) and ABF (n = 1) were deemed inoperable at the time of diagnosis, and therefore were treated conservatively.

The first patient had successfully undergone emergency TEVAR for chronic TBAD with covered aortic rupture. On POD 5 surveillance CT of the chest revealed an endoleak type I that was treated by intra-aortic angioplasty with ballooning at the proximal and distal end of the prosthesis on the same day; postinterventional angiography showed no persisting endoleak. However, on the next day, he developed haemoptysis and was transferred to the ICU due to haemodynamic instability. Chest CT revealed an ABF of the left main bronchus (Fig. 4). On POD 7, he acutely developed massive haemoptysis—including small parts of lung tissue—requiring reintubation with a double lumen endotracheal tube and cardiopulmonary resuscitation. However, the patient died shortly after successful CPR due to significant pulmonary bleeding and subsequent haemorrhagic shock.

The second patient had been initially treated endovascularly for acute rupture of her descending aortic aneurysm but returned 42 days post-TEVAR due to development of an AOF. Patient history revealed chest pain and haematemesis prior to syncope. On admission, the patient was already intubated and sedated. Endoscopy revealed a large AOF (length: 5 cm) located in the mid-oesophagus without an active bleeding source. Due to various other comorbidities, including ongoing left-sited pneumonia and urinary tract infection, the patient was treated medically and died after 81 days due to fulminant mediastinitis.

DISCUSSION

Described for the first time by Dubrueil in 1818 and Girardet in 1914, primary AOF and ABF have been known to be extremely rare but lethal clinical entities [10, 11]. Secondary AOF/ABF after open thoracic aortic surgery occur with an increased incidence in up to 1.7% of patients following open thoracic aortic surgery [5].

Although long-term outcomes (>10 years) after stent grafting of the thoracic aorta are still unknown, TEVAR is now being proclaimed by many interventionalists as the method of choice to address thoracic aortic pathologies [2]. With increased use of TEVAR, formerly unknown complications such as retrograde aortic dissection [12] and other uncommon severe complications have been described [4, 6]. In this context, the clinical incidence of secondary AOF and ABF post-TEVAR is currently reported to be 1.5–1.9% [5–7].

We report an overall incidence of AOF/ABF of 2.6% in a consecutive patient cohort of 374 patients over a period of more than 10 years as a single-centre experience—with a respective incidence of AOF and ABF of 2.1 and 0.5%.

The mean time interval between TEVAR and AOF/ABF development was 18 months, with 7 (70%) patients being readmitted within the first year after treatment (< 12 months). In 2009, Chiesa *et al*. reported a mean interval to AOF (68%), ABF (5%) or combined AOF/ABF (26%) after thoracic stent grafting of 11 months (10.9 ± 15.4 months). Most recently, data by the European Registry of Endovascular Aortic Repair Complications (EuREC) showed a median TEVAR-to-AOF time of ∼3 months (90 days) [6]. However, the underlying mechanisms of secondary AOF and ABF development post-TEVAR are still unknown.

Czerny *et al*. [6] hypothesized that AOF development may be associated with the need for an emergency procedure and the presence of mediastinal haematoma prior to TEVAR. Secondary oesophageal ischaemia may be the result of elevated pressures within the posterior mediastinum, ultimately leading to AOF formation. Similarly, ABF may occur if the bronchial artery is completely excluded during TEVAR, resulting in bronchopulmonary ischaemia [13]. Chronic inflammation—due to resorption of the haematoma or aortic compression and erosion by the implanted stent graft—is another theory of AOF/ABF development [5, 6].

Endoleaks after endovascular stent grafting during follow-up have also been reported to represent a potential cause of AOF/ABF development [7, 8]. In our series, 5 of 10 patients (50%) with AOF/ABF developed an endoleak (type I: n = 1, type II: n = 4), including 2 patients with intentional LSA coverage. Although intentional LSA coverage may be performed safely to achieve an adequate proximal landing zone, this strategy may increase the risk of a persisting endoleak type II and possible AOF/ABF formation. LSA transposition, ligation with left common carotid artery to LSA bypass or LSA embolization post-TEVAR could prevent potential type II endoleaks (risk for steal from the left vertebral artery) or neurological complications in cases with a proximal Ishimaru landing zone within the arch 0–2 [14]. Type II endoleak post-TEVAR also occurred in 1 patient due to back bleeding from a prominent thoracic aortic segmental artery; this represents

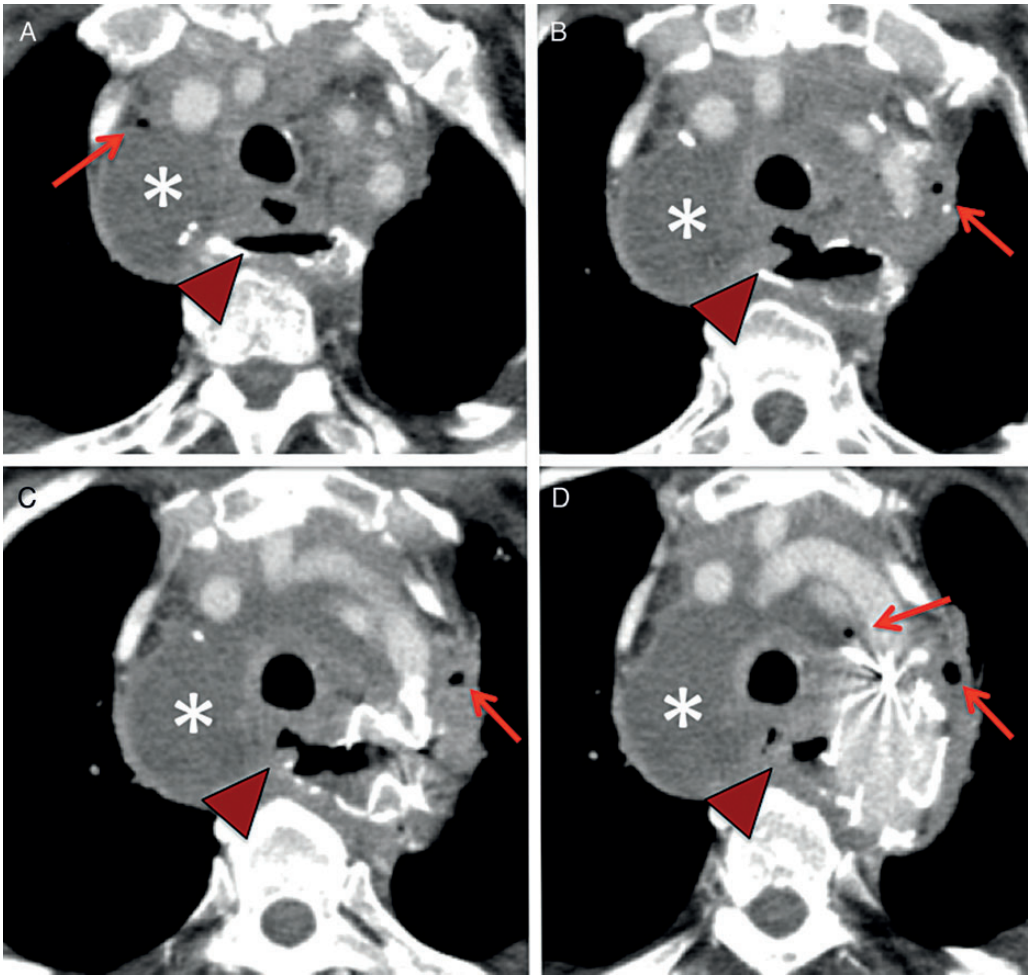

Figure 3: Computed tomography after readmission showing mediastinits (asterisk) and an aorto-oesophageal fistula (dark red arrow heads) after TEVAR at the level of the transverse arch (**A–D**). Ectopic gas can be found within the mediastinum (red arrows).

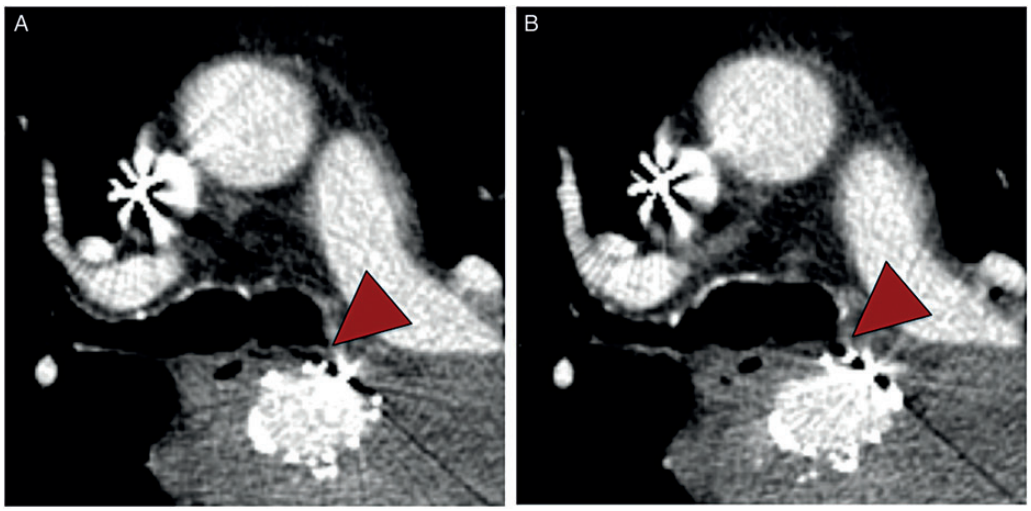

Figure 4: Computed tomography of the chest showing an aorto-bronchial fistula with a communication between the left main bronchus and the stent graft at the level of the descending aorta (dark red arrow heads; **A** and **B**).

another unsolved problem of TEVAR, especially after extensive endovascular thoracic and thoracoabdominal aortic coverage. New innovative strategies, such as segmental artery coil embolization prior to TEVAR, are currently under investigation to address this issue [15].

During stent graft deployment, oversizing may be necessary to achieve an optimal result on post-procedural angiography. However, oversizing may increase the risk of aortic wall deterioration and fistula formation [5, 12]. Stent graft oversizing was performed in almost all patients of our series ($n = 9$; Table 2), including 5 (50%) patients with an intra-procedural oversizing of >20%. We can conclude that oversizing of more than 20% should be avoided if possible during TEVAR [5].

Recently, the use of stent grafts with rigid, proximal bare springs has also been noted to bare a potential risk of aortic intimal erosion, retrograde aortic dissection, free rupture and/or aortic penetration with damage to adjacent mediastinal structures causing a state of chronic inflammation [3, 6, 12, 16]. We have previously demonstrated that proximal bare springs may increase the risk for aortic intimal damage—and potential AOF/ABF formation—in patients with an ectatic/dilated native thoracic aorta [12] (Fig. 3).

Patients with AOF/ABF present with a variety of clinical symptoms, which may lead to a significant delay in diagnosis and treatment. Patients frequently have a history of self-limited haematemesis or haemoptysis ('sentinel' or 'herald bleedings', Table 4) with no significant decrease in haemoglobin [5, 7, 17]. At the time of bleeding recurrence, patients often present with haemorrhagic shock requiring emergent surgical treatment [8]. Therefore, a history of bleeding (haematemesis, haempotysis, melena, etc.) should raise the suspicion of secondary fistula formation after TEVAR and further diagnostics such as CT, endoscopy and/or bronchioscopy should be performed promptly.

Of note, only 3 patients in this series presented with new-onset fever but all ($n = 10$; 100%) were found to have elevated inflammatory laboratory parameters and positive blood cultures with bacteria ($n = 8$; 80%) at the time of AOF/ABF diagnosis. Intraoperative mediastinal smear tests detected bacteria ($n = 6$; 75%) or fungi ($n = 2$; 25%) in 6 of 8 patients (see Table 3).

One of our patients presented with nonspecific symptoms (i.e. vertigo and chest pain) and the diagnosis of AOF was made only after CT imaging (Fig. 2). Other nonspecific symptoms—such as dyspnea, dysphagia, previous syncope, new onset fever or exhaustion—were always accompanied by more definite symptoms suggestive of AOF or ABF (i.e. haemoptysis or haematemesis). We therefore suggest to closely follow all patients post-TEVAR and to expect late complications after endovascular treatment even if patients present with uncommon or unspecific clinical symptoms.

The optimal treatment for secondary AOF/ABF has been discussed controversially in the literature. Medical treatment alone is known to be inadequate with a mortality rate of 100% [5–7, 18].

Re-TEVAR as a treatment option for AOF/ABF has been reported by some investigators [19, 20], but seems very questionable since the infected prosthesis remains in place and debridement of infected tissue cannot be performed [20, 21]. Moreover, life-long antibiotic therapy would be necessary in these high-risk patients. We believe that emergency TEVAR for AOF should only be used as a 'bridge-to-surgery' in haemodynamically unstable patients [9, 22].

It has been suggested that open surgery offers the best outcome in the treatment of primary and secondary AOF/ABF, but no consensus about the optimal surgical strategy exists [6, 18]. Mortality after open repair for AOF/ABF has been reported to be 64% [5] with a 1-year survival between 16 and 57% [5, 6].

Extra-anatomic aortic bypass has been initially reported by Yonago *et al*. [17] in 1969 and is still considered an alternative surgical strategy to manage a primary or secondary AOF/ABF. An omental flap has been reported for patients with aorto-enteric fistula [23]. Most recently, Okita *et al*. presented their results for open surgery of primary and secondary AOF (post-TEVAR patients: $n = 4$) at the 27th EACTS Annual Meeting in Vienna and reported a low hospital mortality rate of 26.7%. Their surgical strategy comprised simultaneous resection of the aorta and the oesophagus followed by *in situ* reconstruction of the descending aorta using a rifampicin-soaked Dacron graft with additional coverage of an omental (or intercostal muscle) flap [22].

Others investigators favour the use of cryopreserved aortic allografts (homografts) and have achieved similar results with an equally low mortality rate of 27% [24]. However, homografts may not always be available at a time and usually tend to be too short and of a small diameter to allow aortic replacement in AOF/ABF cases. A promising alternative could be the use of 2–3 self-made pericardial tubes, e.g. by wrapping around a conventional 15 × 10 cm pericardial patch to get a 3.5 cm tube.

Canaud *et al*. [25] most recently reported on their results after secondary open surgery in a heterogeneous post-TEVAR cohort of 14 of 236 patients and reported an extraordinary low hospital mortality of 14.3% with a 2-year survival rate of 87.7%. However, their surgical series of 14 patients included only 7 patients (50%) with AOF ($n = 1$) and ABF ($n = 6$).

We are convinced that prompt and radical surgical therapy represents the treatment of choice in patients with post-TEVAR complications [8, 9]. In AOF patients, we perform a staged surgical approach: oesophagectomy (with or without oesophagostomy) with radical excision of all infected tissue, stent graft removal and aortic replacement followed by second-stage oesophageal reconstruction, e.g. gastric pull-up operation. For patients with ABF, we perform a similar approach to the aorta/stent along with appropriate bronchial repair, e.g. flap coverage or lobectomy.

CONCLUSIONS

AOF and ABF represent uncommon but fatal complications after TEVAR that may occur during short- and mid-term follow-up. Surgery for AOF/ABF requires detailed planning and should be performed promptly and in a radical fashion to excise all infected tissues. However, more data is required on the surgical outcome of patients with fistula formation after TEVAR in order to determine the optimal surgical strategy of these challenging patients.

Conflict of interest: none declared.

REFERENCES

[1] Grabenwoger M, Alfonso F, Bachet J, Bonser R, Czerny M, Eggebrecht H *et al*. Thoracic Endovascular Aortic Repair (TEVAR) for the treatment of aortic diseases: a position statement from the European Association for Cardio-Thoracic Surgery (EACTS) and the European Society of Cardiology (ESC), in collaboration with the European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur J Cardiothorac Surg 2012;42: 17–24.

[2] Svensson LG, Kouchoukos NT, Miller DC, Bavaria JE, Coselli JS, Curi MA *et al.* Expert consensus document on the treatment of descending thoracic aortic disease using endovascular stent-grafts. Ann Thorac Surg 2008;85: S1–41.
[3] Luehr M, Etz CD, Lehmkuhl L, Mohr FW. Vertebral body erosion in a 27-year-old woman 12 years after thoracic endovascular aortic repair. Circulation 2013;128:2420–1.
[4] Czerny M, Eggebrecht H, Sodeck G, Verzini F, Cao P, Maritati G *et al.* Mechanisms of symptomatic spinal cord ischemia after TEVAR: insights from the European Registry of Endovascular Aortic Repair Complications (EuREC). J Endovasc Ther 2012;19:37–43.
[5] Chiesa R, Melissano G, Marone EM, Marrocco-Trischitta MM, Kahlberg A. Aorto-oesophageal and aortobronchial fistulae following thoracic endovascular aortic repair: a national survey. Eur J Vasc Endovasc Surg 2010;39: 273–9.
[6] Czerny M, Eggebrecht H, Sodeck G, Weigang E, Livi U, Verzini F *et al.* New insights regarding the incidence, presentation and treatment options of aorto-oesophageal fistulation after thoracic endovascular aortic repair: the European Registry of Endovascular Aortic Repair Complications. Eur J Cardiothorac Surg 2014;45:452–7.
[7] Eggebrecht H, Mehta RH, Dechene A, Tsagakis K, Kuhl H, Huptas S *et al.* Aortoesophageal fistula after thoracic aortic stent-graft placement: a rare but catastrophic complication of a novel emerging technique. JACC Cardiovasc Interv 2009;2:570–6.
[8] Girdauskas E, Falk V, Kuntze T, Borger MA, Schmidt A, Scheinert D *et al.* Secondary surgical procedures after endovascular stent grafting of the thoracic aorta: successful approaches to a challenging clinical problem. J Thorac Cardiovasc Surg 2008;136:1289–94.
[9] Nozdrzykowski M, Etz CD, Luehr M, Garbade J, Misfeld M, Borger MA *et al.* Optimal treatment for patients with chronic Stanford type B aortic dissection: endovascularly, surgically or both? Eur J Cardiothorac Surg 2013;44:e165–74.
[10] Dubrueil J-M. Observation sur la perforation de l'oesophage et de l'aorte thoracique par une portion d'os avalé, avec des reflexions. J Univ Sci Med 1818;3ème année, T. IX, De Ballard, 1818 (7 p. in 8°).
[11] Girardet A. Doppelte Perforation eines Tuberkelknotens in die Aorta und die Bifurkation der Trachea. Deutsch Med Wochenschor 1914;40:1425–8.
[12] Luehr M, Etz CD, Lehmkuhl L, Schmidt A, Misfeld M, Borger MA *et al.* Surgical management of delayed retrograde type A aortic dissection following complete supra-aortic de-branching and stent-grafting of the transverse arch. Eur J Cardiothorac Surg 2013;44:958–63.
[13] Hino H, Murakawa T, Nagayama K, Nakajima J. Bronchopleural fistula after lower lobectomy of the right lung following thoracic endovascular aortic repair. Interact CardioVasc Thorac Surg 2012;14:655–7.
[14] Weigang E, Luehr M, Harloff A, Euringer W, Etz CD, Szabo G *et al.* Incidence of neurological complications following overstenting of the left subclavian artery. Eur J Cardiothorac Surg 2007;31:628–36.
[15] Luehr M, Salameh A, Haunschild J, Hoyer A, Girrbach FF, Von Aspern K *et al.* Minimal invasive segmental artery coil embolization for preconditioning of the spinal cord collateral network prior to one-stage descending and thoracoabdominal aneurysm repair. Innovations (Phila) 2014;9: 60–5.
[16] Czerny M, Weigang E, Sodeck G, Schmidli J, Antona C, Gelpi G *et al.* Targeting landing zone 0 by total arch rerouting and TEVAR: midterm results of a transcontinental registry. Ann Thorac Surg 2012;94:84–9.
[17] Yonago RH, Iben AB, Mark JB. Aortic bypass in the management of aortoesophageal fistula. Ann Thorac Surg 1969;7:235–7.
[18] Murphy EH, Szeto WY, Herdrich BJ, Jackson BM, Wang GJ, Bavaria JE *et al.* The management of endograft infections following endovascular thoracic and abdominal aneurysm repair. J Vasc Surg 2013;58:1179–85.
[19] Chiesa R, Melissano G, Marone EM, Kahlberg A, Marrocco-Trischitta MM, Tshomba Y. Endovascular treatment of aortoesophageal and aortobronchial fistulae. J Vasc Surg 2010;51:1195–202.
[20] Jonker FH, Schlosser FJ, Moll FL, van Herwaarden JA, Indes JE, Verhagen HJ *et al.* Outcomes of thoracic endovascular aortic repair for aortobronchial and aortoesophageal fistulas. J Endovasc Ther 2009;16:428–40.
[21] Dorweiler B, Weigang E, Duenschede F, Pitton MB, Dueber C, Vahl CF. Strategies for endovascular aortic repair in aortobronchial and aortoesophageal fistulas. Thorac Cardiovasc Surg 2013;61:575–80.
[22] Munakata H, Yamanaka K, Okada K, Okita Y. Successful surgical treatment of aortoesophageal fistula after emergency thoracic endovascular aortic repair: aggressive debridement including esophageal resection and extended aortic replacement. J Thorac Cardiovasc Surg 2013;146:235–7.
[23] Hollander JE, Quick G. Aortoesophageal fistula: a comprehensive review of the literature. Am J Med 1991;91:279–87.
[24] Saito A, Motomura N, Hattori O, Kinoshita O, Shimada S, Saiki Y *et al.* Outcome of surgical repair of aorto-eosophageal fistulas with cryopreserved aortic allografts. Interact CardioVasc Thorac Surg 2011;14:532–7.
[25] Canaud L, Alric P, Gandet T, Ozdemir BA, Albat B, Marty-Ane C. Open surgical secondary procedures after thoracic endovascular aortic repair. Eur J Vasc Endovasc Surg 2013;46:667–74.

APPENDIX. CONFERENCE DISCUSSION

Dr M. Schepens *(Brugge, Belgium)*: I just have a brief question. I didn't notice from your data that you use omentoplasty to treat this kind of severe problem. Do you think it has any place in the treatment?

Dr Etz: I personally think this is an option if the patient presents with severe mediastinitis. In this cohort there was only one patient in whom it was considered, but we would rather go for radical resection right now. Presently, data is scarce and we do not utilize omentoplasty much in Leipzig. In this cohort there was only one patient who had a pericardial patch but there was no one that received an omentoplasty. Nevertheless, I think it is a valid option.

Dr Schepens: What is your opinion about complete resection of the aneurysmal wall, since the previous speaker really said that it was important to remove the whole aneurysm?

Dr Etz: The way I was trained by Dr Griepp is to remove as much diseased aneurysmal tissue as possible, particularly when you are in doubt. If infection is excluded, I think it's okay to leave aneurysmal wall behind if you have a bleeding issue as a major problem, for instance.

Dr Y. Okita *(Kobe, Japan)*: I have two questions. This is a postop TEVAR experience.

Dr Etz: Right.

Dr Okita: In Leipzig, how many had a primary aorto-oesophageal fistula? If you know, please tell us.

Dr Etz: A primary aneurysm?

Dr Okita: An aorto-oesophageal fistula.

Dr Etz: So primary after TEVAR or primary -

Dr Okita: No, no, before.

Dr Etz: In Leipzig it is very rare that a patient comes with a primary untreated aneurysm that's eroding the oesophagus. The raw numbers do not tell us much about the incidence because we neither know the true denominator nor the number of patients that never reach the hospital because of an acute and fatal haemorrhage after rupture.

Dr Okita: This is rare, right?

Dr Etz: It is rare.

Dr Okita: And the second question. You are comparing the results of aorto-oesophageal and aortobronchial. Can you find any difference regarding the mortality between the two of them?

Dr Etz: With the small numbers we have, there is really no way to tell, particularly with only two patients presenting with an aortobronchial fistula. The way these patients present is often quite dramatic as we all know, sometimes with recurrent haematemesis or haemoptysis as direct heralds of imminent rupture. This is one of the reasons why it's probably an under-reported complication. These patients die a sudden death and you don't see them in the hospital.

Dr Okita: Did you do a lung resection as well?

Dr Etz: No, but if it's necessary, if the aneurysm is eroding the lung for instance, we would.

Dr C. Knosalla *(Berlin, Germany)*: I have three questions. First, I would like to know what your current strategy is when dealing with aorto-oesophageal fistula. In which cases do you try to repair the oesophagus? Or do you immediately resort to oesophagectomy to really eradicate it?

And my second question is, as I did my vascular training with Edouard Kieffer in Paris, where do you see the value of allografts in this indication?

And thirdly, you did these operations over quite a period of time and you said you have 100% follow-up in your hospital. So I would imagine that you can give us some more details about recurrence rates after one year.

Dr Etz: Let's start with the first question, what I think about oesophageal repair as opposed to a staged radical resection. In our experience, there was only one patient that had an oesophageal repair, and his survival was poor. First of all, it is always an individual decision, of course, and there is no large experience that we could base it on. But whenever you have a case that goes wrong and you are in doubt whether oesophageal repair is feasible, then it is probably better to perform radical resection, and since we had an experience with this one case we are hesitant with regard to repair. If it is a very small lesion (and possibly depending on who is on call), I would not categorically declare that it would never undergo repair, but we do not generally recommend it.

Regarding your second question, usually we have a number of proximal homografts available and only a few thoracic homografts. If there's availability and we think that the inflammation is a major problem and that there may be difficulties with the proximal anastomosis, for instance, then we would opt for a homograft, if available, yes. And the last question was, again?

Dr Knosalla: The recurrence rate after one year, because these cases really can have late reinfections, particularly if you use prosthetic grafts.

Dr Etz: I believe, and this is what I was taught by Dr Griepp, in reporting one-year mortality as a measure of operative success: this is the true number; reporting hospital mortality, 60-day, and whatever, is not. These are very extensive surgeries and one-year survival is the true number. So that's what we have been reporting; in our series it was 62.5%. I think this is probably the best you can get at this point with these desperate cases at one year.

And you're absolutely right, the study is over a long time period and some of the patients had been operated on before I joined the Leipzig team. Even so, I think our data are resilient, because we have a lot of research personnel thoroughly questioning not only the patients themselves, but also calling the GPs, and if there is any doubt, then the previous operating surgeon is contacted as well.

Dr A. Apaydin *(Izmir, Turkey)*: The homografts, they have a short-term risk of rupture; I think it's about 11%. So they are not very safe, you should keep it in mind.

Dr J. Bachet *(Paris, France)*: You said one thing that intrigues me. You say, 'of course homografts.' These patients are completely unexpected patients, and I suppose that you don't have homografts on the shelf like we have valves.

Dr Etz: Exactly. What I said is, of course, we consider their use.

Dr Bachet: Well, you can consider everything you like.

Dr Etz: If we have homografts available (and Leipzig is a large institution so we have a little more in stock probably than other institutions), yes, we would consider using them. But I totally share your concern.

Dr Bachet: But I suppose they are not very often available, as you said.

Dr Etz: That's right.

Dr Bachet: On the other hand, what do you think of what Thierry Carrel's group proposed, which is to use systemically preserved pericardium? They have published very good results.

Dr Etz: It is also used, yes, of course. It's a good option, I think.

Dr M. Borger *(Leipzig, Germany)*: Just a comment to Dr Bachet. We only have one descending thoracic aortic homograft at a time in our institution. The other more important problem is that they tend to have quite a small diameter and you can't match the size of the homograft to the size of the native aorta, which is usually dilated. Especially by the time you take out the stent, you are often left with this long segment of dilated aorta that needs to be replaced, which is difficult with a homograft.

Until now, we have performed repair of aorto-oesophageal fistula with a standard prosthetic graft. However, we've used bovine pericardium, as you are referring to, in patients with mycotic aneurysms where the area of involved aortic pathology tends to be much shorter. Since we have been very happy with pericardium for mycotic aneurysms, we will probably start using this technique for oesophageal fistulae. However, one would need to sew together three of these pericardial tubes, in order to achieve the correct length and diameter. That is, you take a 15×10 cm pericardial patch, wrap it around and sew the edges together in order to achieve a 3.5 cm diameter tube and then sew enough of these tubes together in order to replace the affected aorta.

Dr W. Harringer *(Braunschweig, Germany)*: This is an excellent technical explanation of how you do it, especially if you don't have homografts of the appropriate size available. I personally still prefer homografts. We also have some of them on the shelf. But this is clearly an individual situation. If you don't have them, then either (as Professor Okita's group) use soaked Dacron or use pericardium as an alternative to prosthetic material. It's not an invention by the Bern group because it has been done before by others, years before, because they didn't have alternatives. But it seems to be an excellent choice if you don't have other material available in these infective situations.

But let me ask you one more thing. The one-year survival rate came down, of course. How many of these patients died of infection or reinfection? What were the reasons for death, do you know that?

Dr Etz: Two patients that died had been deemed to be inoperable. One was already presenting with signs of infection, so in this case we know the cause. The other one died after fulminant haemorrhage. However, once they are home after surgery, the follow-up on the cause of death is very difficult.

Dr M. Piciché *(Rome, Italy)*: My question is about the interval between the beginning of massive haemoptysis and the operation, because, of course, this requires management. What do you do? Do you use a Carlens tube and occlude one side in order to avoid blood flooding into the other side of the bronchus, in case of aorto-oesophageal fistula?

Dr Etz: Fortunately, sentinel bleeding often occurs, which raises our suspicions. We are very alert in these acute emergencies but we have not routinely used a Sengstaken–Blakemore tube, although we used a bronchus blocker in one case – whatever you need to get the patient alive to the OR suite. There is no protocol as such.