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Increasing Incidence of Thoracic Aortic Aneurysm Repair in Germany in the Endovascular Era: Secondary Data Analysis of the Nationwide German DRG Microdata

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WHAT THIS PAPER ADDS

This analysis reveals important data on outcomes after surgical repair of an unselected nationwide descending thoracic aortic (DTA) aneurysm cohort undergoing any kind of surgical treatment in Germany. The number of patients hospitalised for DTA aneurym in Germany increases each year, with more than 80% now being treated endovascularly. Aneurysm rupture, older age, and comorbidity score are independent risk factors of increased mortality. Endovascular DTA aneurym repair was associated with lower peri-operative mortality. Therefore, elective repair should be recommended for individuals with a high risk of rupture who are fit for surgery.

Objectives: Nationwide population based data on epidemiology and surgical treatment of descending thoracic aortic (DTA) aneurysms are not available for Germany. The aim was to assess the in hospital incidence, and to report outcomes of patients who received surgical treatment.

Methods: Data were acquired by analysing the diagnosis related group (DRG) statistics of the German Federal Statistical Office. All inpatient cases of ruptured (rDTA aneurysm, ICD Code I71.1) or non-ruptured DTA aneurysm (nrDTA aneurysm; I71.2) who received thoracic endovascular (TEVAR; OPS procedure code 5-38a.7/70/8/80) or open aortic repair (OAR; OPS 5—384.3) between 2005 and 2014 were included. To adjust for sex, age, medical risk (Elixhauser comorbidity score), type of procedure, and type of admission, a multilevel multivariable regression model with robust error variance was applied. The primary outcome was in hospital mortality; secondary outcomes were organ complications. A volume outcome analysis was performed.

Results: A total of 48,098 cases of DTA aneurysm (5,848, 12.2% rDTA aneurysm) were identified. The average age was 69 ± 12 years. 65.2% were male. Frequent comorbidities were hypertension (74.9%), peripheral artery disease (including abdominal aortic aneurysm, 42.6%), other heart diseases (41.6%), coronary heart disease (26.2%), and renal failure (22.5%). Surgical treatment was received by 4969 patients (10.3%): 4057 TEVAR (81.6%) and 912 OAR (18.4%) procedures. Mortality for rDTA aneurysm was 42.9% (OAR) and 22.3% (TEVAR). It was 10.5% and 3.7% for DTA aneurysm, respectively. Rupture, increasing age, and higher comorbidity score were significantly associated with higher mortality (RR 6.66, 5.33—8.25; 1.28, 1.17—1.40; and 1.06, 1.05—1.08, respectively). Endovascular treatment was associated with lower mortality (RR 0.31, 0.23—0.41). Hospital volume was not significantly associated with in hospital mortality.

Conclusions: Eighty per cent of patients treated surgically for a DTA aneurysm receive endovascular therapy, with low peri-operative mortality in non-ruptured cases. Elective endovascular repair should be considered for individuals at a high risk of rupture who are fit for surgery. Open repair, increased age, and a high comorbidity score are associated with higher mortality.

Keywords: Thoracic aortic aneurysm, In hospital mortality, Hospital incidence, TEVAR, Secondary data analysis, Germany
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INTRODUCTION

In contrast to abdominal aortic aneurysms (AAAs), little is known about the incidence of descending thoracic aortic (DTA) aneurysms, particularly as reports often include patients with aneurysms of the ascending thoracic aorta, aortic dissections, or even thoraco-abdominal pathologies.[1]

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Nationwide population based data on epidemiology and surgical treatment of DTA aneurysm are not available for Germany.

Predisposing risk factors for any kind of aortic disease are male sex and increasing age, as well as the presence of hypertension, history of or current smoking, chronic obstructive pulmonary disease, obesity, and dyslipidaemia.[2] The majority of aneurysms, approximately 80%, are associated with atherosclerosis.[3,4] In around 20%, a chronic type B dissection is the underlying pathology when it comes to secondary expansion.[4,5] Connective tissue diseases such as Marfan or Ehlers—Danlos syndromes, trauma, inflammation, or infection are rare causes and affect the treatment strategy.[1,4]

Several studies report outcomes after open aortic repair (OAR) or thoracic endovascular aortic repair (TEVAR) of such pathologies, with 30 day mortality rates between 3% and 10%. Reduced mortality rates were observed for endovascular repair compared with OAR.[6—11] However, most reports represent results from experienced surgical centres with small, heterogeneous, and highly selected patient cohorts, including more extensive repairs (i.e., thoracoabdominal aortic aneurysms).[12] To date, no prospective randomised controlled trial comparing outcomes after endovascular and open repair exists.

Therefore, this analysis aims to assess the in hospital incidence and outcomes of an unselected nationwide DTA aneurysm cohort undergoing surgical treatment in Germany.

METHODS

Data source

The methods used have already been described elsewhere.[13—18] In short, data were extracted from diagnosis related group (DRG) statistics provided by the research data centres of the German Federal Statistical Office,[19] which covers all inpatient cases (except psychiatry and special services) from 2005 to 2014. Data are regulated by law and all inpatient data need to be reported anonymously to the Institute for the Hospital Remuneration System (Institut für das Entgeltsystem im Krankenhaus). It is then transferred to the German Federal Statistical Office (GFSO) according to §21 of the Hospital Reimbursement Act (Krankenhausentgeldgesetz). Data are saved on servers of the German Federal Statistical Office and individual patient data or institutional identifiers for hospitals were not available to the authors. The data were accessed using so called remote controlled data processing. The analysis was conducted following Good Practice of Secondary Data Analysis guidelines[20] and data reporting follows the STROSA2 guidelines.[21,22] Study ethics were approved by the local Ethics Committee of the Medical Faculty, Technical University of Munich (Reference 21/16 S). A protocol for the study was submitted to the German Federal Statistical Office during the application process (not published separately). This research did not receive any specific grant from funding agencies in the public, commercial, or not for profit sectors.

Study population

"In hospital" is defined as the episode from admission to discharge. Since the record does not include patient identifiers, cases rather than patients are referred to in this study. Owing to German data protection law, separate hospital episodes of the same patient could not be linked. Therefore, patients who received specific treatment while having a specific diagnosis are included. It was assumed that combining the diagnosis code and the procedure code reduces the risk of double counting as far as possible. All cases with a diagnosis of ruptured and non-ruptured DTA aneurysm (ICD-10 I71.1, I 71.2) and procedure codes (OPS 2005—2014) for endovascular or open repair of the descending thoracic aorta (TEVAR (5—38.a.7/70/8/80) or OAR (5—384.3, please see Table S1 for details) treated from 2005 to 2014 were included. Patients with procedural codes for fenestrated or branched prosthesis and/or cervical debranching were excluded. Baseline data of patients not undergoing surgery were not added, because this patient cohort would also include patients with an aneurysm of the ascending aorta (AA) and arch. It cannot be excluded that patients received operative treatment in more than one hospital, but the number of cases is considered insignificant. Patients of unknown or foreign domicile were also excluded from the analysis. In order to achieve comparability with international studies and to account for changes in age/sex structure, incidence rates were directly standardised using the European Standard Population 2013.[23]

Age, sex, type of admission (referred by a physician, without referral/emergency, or transferred from another hospital), and type of surgery (TEVAR vs. OAR) were identified for all patients. To scan for comorbidities in the administrative database, definitions established as in the Elixhauser comorbidity score were used for hypertension, chronic pulmonary disease, and coagulopathy, and as in the Charlson comorbidity score for peripheral vascular disease (PVD), diabetes, renal disease, and malignant disease.[24] As a measure of comorbidity, the modified Elixhauser score was calculated.[25] The definition of comorbidity is based on DRG coding and relates only to the same hospital episode. Medication is not documented by the hospitals.

The primary outcome was in hospital death. As follow up ends on hospital discharge, death occurring after discharge could not be documented. In hospital mortality refers to the hospital in which the procedure took place. Secondary outcomes were need for prolonged ventilation, blood transfusion (none, 1—5 units, and >5 units), platelet transfusion, acute myocardial infarction, peripheral arterial thrombosis and embolism, mesenteric thrombosis and embolism, renal artery thrombosis and embolism, as well as the necessity for bowel resection or major amputation of lower limbs, and length of hospital stay. Outcomes were analysed according to type of aneurysm (ruptured or non-ruptured) and type of treatment (TEVAR or OAR). Mortality rates were standardised for sex, age, and medical risk (using the Elixhauser score) by applying an indirect standardisation approach.[13]

To compare age dependendent outcomes, five age groups were arbitrarily set in order to facilitate comparability with other reports (age $<$ 65 years, 65—69 years, 70—74 years, 75—79 years, and $\geq$80 years). A sub-analysis on outcome of octogenarians (patients aged 80—89 years) was performed.

DTA aneurysm is defined as an aneurysm of the descending thoracic aorta only. The ICD code for dissection is different from DTA aneurysm, which makes it possible to exclude dissections only. However, an aneurysm associated with aortic dissection could still be included in this analysis.

Hospital volume

For analysing a volume—outcome effect, each year hospitals have been grouped using the *k*-means clustering algorithm[26] into low, medium, and high volume facilities subject to their annual DTA aneurysm procedures. This was done in order to avoid arbitrary categorisation, and to arrange homogeneous clusters based on empirical data. Allowing for a diminishing marginal utility effect on the experience growth by an additional procedure, the clustering algorithm used the logarithmised annual volume as separating variable. Additionally, a multivariable regression model has been used to analyse the continuous volume—outcome effect while adjusting for sex, age, type of treatment, and comorbidity burden.

Statistical analysis

Categorical variables are presented as absolute numbers and percentages. Continuous, non-normal variables are presented as the median with the first (Q_1) and third (Q_3) quartiles. To adjust for confounding, a multilevel multivariable regression model (generalised linear mixed model, GLMM) was applied. Age, sex, treatment modality, and Elixhauser score were entered into the model as fixed effects. Additionally, unique centre ID and geo-coordinates were entered as random effects in order to take clustering of patients within centres and spatial autocorrelation of outcomes into account. For remote data processing and statistical analysis, SAS software (version 9.2 for Microsoft Windows, 2015 SAS Institute Inc., Cary, NC, USA) was used. Processing of secondary diagnoses and procedural codes were performed using the NewVar-Macro provided by the Federal Statistical Office (Statistisches Bundeamt, StBA, version 1.2, April 2017).

RESULTS

Patient characteristics and comorbidities

During one decade of data collection (2005—2014), 48,098 cases of DTA aneurysm (5848 rDTA aneurysm, ICD I71.1 and 42 250 nrDTA aneurysm, ICD I71.2 as the principal diagnosis) were identified. Surgical aneurysm treatment was received by 4969 patients (10.3%), who were thus included in the final analysis. Of these patients, 1161 had rDTA aneurysm and 3808 nrDTA aneurysm (Fig. 1).

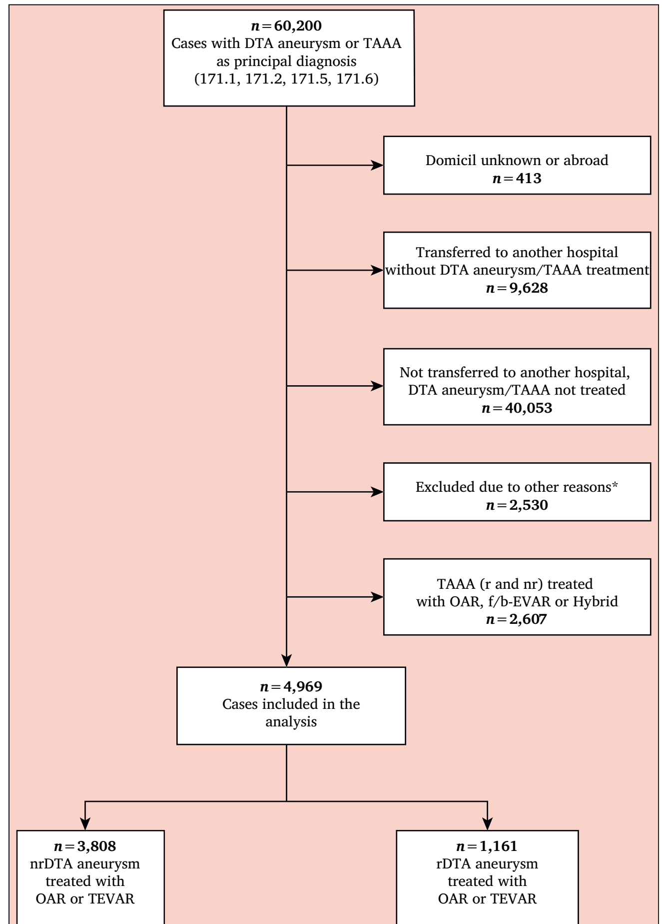

Figure 1. Patient flowchart. DTA = descending thoracic aorta; TAAA thoracic-abdominal aortic aneurysm; r = ruptured; nr = non-ruptured (intact); TEVAR = thoracic endovascular aortic repair; EVAR = endovascular aortic repair; f/b- = fenestrated/branched; OAR = open aortic repair. * Patients with DTA aneurysm treated with f/b-EVAR or hybrid procedure (*n* = 402), patients with TAAA treated with TEVAR (*n* = 1,479), and patients receiving cervical debranching procedures (*n* = 649).

The average age of patients was 69 years (standard deviation 12 years), and this increased each year. Overall, women tended to be older at the time of treatment. Of all patients, 65.2% were male. Hypertension (74.9%), peripheral artery disease (including AAA, 42.6%), other heart diseases (41.6%), coronary heart disease (26.2%), and renal failure (22.5%) were frequent comorbidities. The Elixhauser comorbidity measure for risk adjustment showed higher scores in patients with rDTA aneurysm than in patients with nrDTA aneurysm (7 vs. 5; Table 1).

Treatment of DTA aneurysm over time

The number of hospitals treating DTA aneurysm doubled in the decade commencing in 2005 (2005, *n* = 89; 2014, *n* = 187). There was an increase in the number of cases each year, although the median number of cases per hospital remained stable at three (Q_1, 1; Q_3, 7; Fig. 2).

The in hospital incidence ranged between 0.67 (2006) and 1.14 per 100,000 inhabitants (2014) (Fig. 3A and B). In total, 81.6% of patients with DTA aneurysm were treated endovascularly. TEVAR was performed in more than half of the patients in 2005. This number increased over time: in 2014, 88% of nrTAAs and 89% of rDTA aneurysms were treated endovascularly (Fig. 3C).

Table 1. Baseline characteristics of 4969 patients with DTA aneurysm

	Total (n = 4,969)	Ruptured (n = 1,161, 23%)	Non-ruptured (n = 3,808, 77%)
Age, years	69 ± 12	71 ± 13	68 ± 12
Male	3238 (65.2)	710 (61.2)	2528 (66.5)
Median Elixhauser score (Q_1–Q_3)	*n/a*	7 (2–13)	5 (2–11)
Coded comorbidities[a]			
Coronary heart disease	1300 (26.2)	229 (19.7)	1071 (28.1)
Other heart diseases[b]	2069 (41.6)	496 (42.7)	1573 (41.3)
Cerebrovascular disease	542 (10.9)	141 (12.1)	401 (10.5)
PAD incl. AAA	2117 (42.6)	446 (38.4)	1671 (43.9)
Hypertension	3721 (74.9)	762 (65.6)	2959 (77.7)
COPD	916 (18.4)	188 (16.2)	728 (19.1)
Diabetes	771 (15.5)	204 (17.6)	567 (14.9)
Malignancy	131 (2.6)	36 (3.1)	95 (2.5)
Obesity	523 (10.5)	81 (7)	442 (11.6)

Data are presented as n (%) or mean ± standard deviation, unless stated otherwise. PAD = peripheral artery disease, AAA = abdominal aortic aneurysm, COPD = chronic obstructive pulmonary disease, $Q_1 - Q_3$ = interquartile range, n/a = not available; DTA = descending thoracic aorta.

[a] Coded comorbidities were assumed to be pre-existing.

[b] Other heart diseases = heart failure, arrhythmia, valvular heart disease.

Outcomes

The mortality for rDTA aneurysm was 25.2% and for nrDTA aneurysm 5%. Table 2 shows that younger patients fared better and mortality constantly increased with every 5 year age increase. In hospital mortality was higher following open repair than endovascular repair (42.9% vs. 22.3% for rDTA aneurysm and 10.5% vs. 3.7% for nrDTA aneurysm, respectively). There was no clinically significant difference in mortality rates for women and men. Mortality after elective repair was 9.6% in 2005 and 4.2% in 2015, with a constant decrease over the years. For ruptured aneurysms, mortality ranged between 20.9 (2011) and 34.7% (2007) and did not decrease over time (Fig. 4).

The multilevel multivariable regression analysis revealed that rupture, increasing age, and higher comorbidity score were significantly associated with higher mortality (risk ratio [RR] 6.66, 5.33–8.25; 1.28, 1.17–1.40; and 1.06, 1.05–1.08, respectively). Endovascular treatment was associated with lower mortality (RR 0.31 [0.23–0.41]; Fig. 5). Overall, there were more documented cases of acute mesenteric infarction (1.5 vs. 0.7%), bowel resection (1.3 vs. 0.7%), acute paraplegia/spinal infarction (1.5 v. 1.1%), and dialysis (14.8 versus 6%) following open aortic repair. Acute/recurrent myocardial infarction (1.7 vs. 1.3%) and acute peripheral limb ischaemia (3.3 vs. 2.3%) were more frequent after TEVAR. Stroke rate was 0.4% (15/4057 patients) for TEVAR and 0.8% (7/912 patients) following OAR (Table 3).

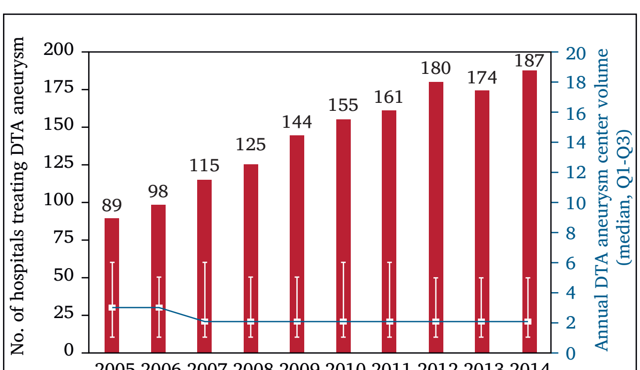

Figure 2. Number of hospitals treating thoracic aortic aneurysms including median annual centre caseload (white squares with bars representing the interquartile range). DTA = descending thoracic aorta.

Ventilation time, and length of hospital stay were longer after OAR. Also, the need for transfusion of red blood cells and platelets was higher after OAR. More computed tomography scans are performed after TEVAR. Discharge data are incomplete, but rehabilitation seems to be more common after open repair, whereas regular discharge (home after discharge) is frequent after TEVAR. Please see Table S2 for further details on management and complications with regard to treatment modality.

Of the patients investigated, 14.9% were aged 80–89 years. In octogenarians, the overall mortality was 13.9% and higher following OAR (29.8%; 12.8% for TEVAR). Fifty-five per cent of patients were male, and 63% had a non-ruptured aneurysm. The overall median Elixhauser Score was 8 (3–13) and higher in patients who received open aortic repair 12 (4–17). Complications were reported for all patients, but cannot be provided for OAR and TEVAR separately because of small numbers (censored by the German Federal Statistical Office). Dialysis was more frequent in patients who received OAR (31.9%) than in those who were treated by TEVAR (6.3%). Characteristics and outcome of this patient cohort is summarised in Table 4.

Volume outcome analysis

The number of cases per hospital per year was one to two for low volume hospitals (n = 770), three to eight for medium volume hospitals (n = 460), and nine or more for high volume hospitals (n = 143, 95% CI 9–21). More patients (2,098, 42.2%) were treated in medium volume centres, 20.5% and 37.3% in low and high volume centres, respectively. The percentage of TEVAR treated patients was slightly higher in

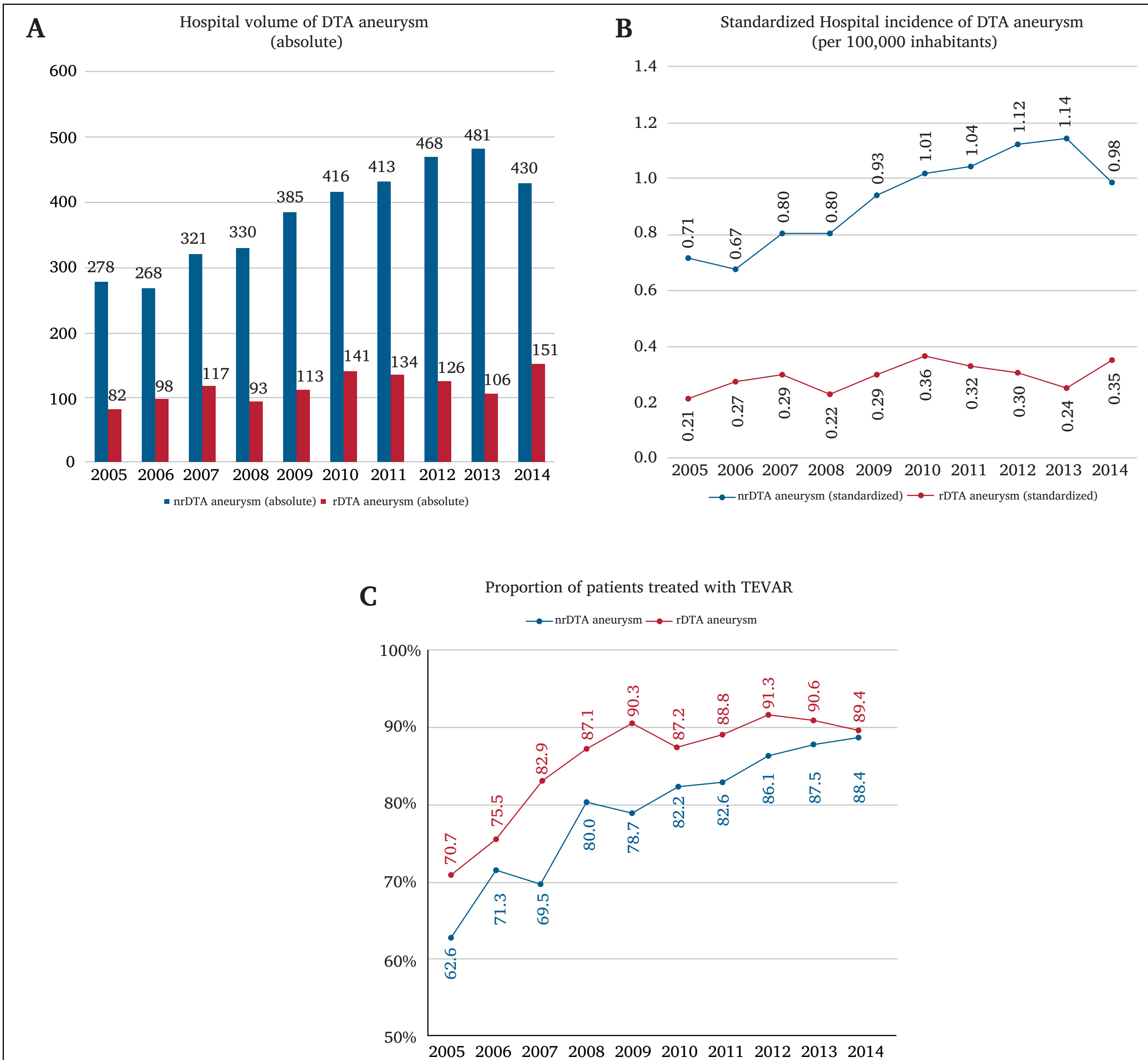

Figure 3. Absolute hospital volume of DTA aneurysm per year (A), standardised (direct standardisation using European Standard Population 2013) hospital incidence of DTA aneurysm per 100,000 inhabitants (B), and proportion of patients treated by TEVAR from 2005 to 2014 (C). DTA = descending thoracic aorta; r = ruptured; nr = non-ruptured (intact); TEVAR = thoracic endovascular aortic repair.

low volume hospitals (91.4%, 79.5%, and 79.2% for low, medium, and high volume). Multivariable regression analysis revealed that hospital volume (as a continuous variable) was not associated with in hospital mortality (RR 0.95, 95%-CI 0.88—1.03 for an increase of five cases per year; $p = .21$). The volume outcome analysis is summarised in Table 5. For the purpose of illustration, the relationship of hospital volume and in hospital mortality for patients with an age of 71 years (empirical mean) and an Elixhauser Score of 6 (empirical median) is demonstrated in Fig. S1.

DISCUSSION

The incidence of thoracic aortic disease (including aortic dissections, aneurysms of the ascending thoracic aorta or arch) is reported to be between five and 10 per 100,000 inhabitants;[27,28] it is higher in men than in women[29] and increasing over time. A population based study in England and Wales covering the time period from 1999 to 2010 reported a steady increase of hospital admission rates for DTA aneurysm.[30] Demographic changes, including the increasing elderly population and improvements in diagnostics, are possible reasons to explain this increased incidence, but it is also possible that there is a real increase in prevalence.[31] Based on the data, the in hospital incidence ranged from 0.71 to 1.14 per 100,000 inhabitants for nrDTA aneurysm, and from 0.21 to 0.36 per 100,000 inhabitants in Germany for rDTA aneurysm between 2005 and 2014. This discrepancy might be caused by different definitions of DTA aneurysm. As previously mentioned, most reports include type B dissections or even

Table 2. In hospital mortality of DTA aneurysm management (primary study outcome)

	Ruptured (n = 1,161)	Non-ruptured (n = 3,808)
Overall mortality	292/1161 (25.2)	191/3808 (5)
By sex		
Men	181/710 (25.5)	113/2528 (4.7)
Women	111/451 (24.6)	78/1280 (6.1)
By age group		
< 65 years	54/281 (19.2)	34/1040 (3.3)
65–69 years	29/137 (21.2)	28/632 (4.4)
70–74 years	55/208 (26.4)	48/871 (5.5)
75–79 years	76/251 (30.3)	51/793 (6.4)
≥ 80 years	78/284 (27.5)	30/472 (6.4)
By treatment		
Open aortic repair	67/161 (42.9)	79/751 (10.5)
Endovascular repair	233/1000 (22.3)	112/3057 (3.7)

Data are presented as absolute numbers and proportions of subgroups, n/subgroup (%). DTA = descending thoracic aorta.

aneurysms of the ascending aorta, and refer to an incidence of "thoracic aortic disease." The current analysis is strictly limited to patients who received surgical treatment of their descending DTA aneurysm and therefore does not reflect the entire cohort of individuals suffering from this disease: unfortunately, no further information is available for patients not undergoing surgery. Finally, the current results are age standardised, which has an impact on comparability since degenerative aortic disease is more frequent in the elderly population: in this cohort 14.7% of patients were aged 80–89 years.

In addition to an increase in per-hospital incidence in Germany, the total number of hospitals treating these complex pathologies doubled within almost 10 years. As a consequence, approximately half of the hospitals treat less than three cases per year (median 3 cases/hospital/year). Endovascular repair was the treatment of choice for more than half of the patients presenting with an aneurysm located in the descending thoracic aorta for almost more than a decade, a trend that is clearly proven by the present data and reflects the recommendation of the ESVS guidelines for Management of Descending Thoracic Aorta Diseases.[1,32] Between 2005 and 2014, 93.6% of octogenarians were treated endovascularly. Interestingly, the Elixhauser comorbidity score was higher in the remaining 6.4% of elderly patients that received open aortic repair, most probably caused by comorbidities and complications that occurred post-operatively. Particularly when rupture occurs, TEVAR represents a fast and readily available alternative to open surgery. A retrospective analysis of a large national inpatient sample of 12,399 patients treated between 1993 and 2012 for rDTA aneurysm shows that TEVAR is the preferred treatment option in almost half of the patients (43% in 2011–2012 vs. 2% in 2003–2004). Following the implementation of TEVAR, mortality decreased by 10% (from 36% to 27%).[33] The current analysis reveals that in hospital mortality after rDTA aneurysm repair shows a high variability over time, and ranges between 34.7% and 20.2%. In contrast, mortality rates for nrDTA aneurysm cases are bisected (9.4% in 2005 down to 4.2% in 2014). As a surprising finding, the in hospital mortality rates are comparable to those reported in the literature for elective repair, despite the fact that many low volume centres are included in this analysis. Low volume centres with a case load of one to two cases per year treated 20.5% of the patients. Mortality rates were similar to high volume centres (8.8% vs. 8.6%). Ultimately, the volume outcome analysis revealed, that low hospital volume was not associated with an increased mortality (p = .21).

These data confirm that DTA aneurysms can be treated with an overall mortality risk of 5% in a non-emergency setting and even in elderly patients. However, von Allmen et al.[34] reported different outcomes with similar mortality rates for TEVAR and OAR for nrDTA aneurysm and concluded based on their data, that it is not justified to favour endovascular repair. Consistent with the results of most existing reports, in this analysis endovascular repair was significantly associated with lower mortality for the entire patient cohort and for octogenarians (3.7% for TEVAR vs. 10.5% for OAR in patients with nrDTA aneurysm, 12.8% for TEVAR and 29.8% for OAR in octogenarians). One reason might be that endovascular repair of the thoracic aorta (TEVAR) is already routine clinical practice and can be safely performed by many surgeons. With increasing surgical experience as well as constantly evolving endovascular devices, implanting techniques, and imaging tools in a hybrid operating room, not only DTA aneurysms but also acute or chronic type B aortic dissections, aortic rupture, or aortic ulcers can be treated with minor trauma. A recently published study by Hu et al.[32] identified age and emergency procedure as risk factors for increased 30 day mortality. In the current analysis,

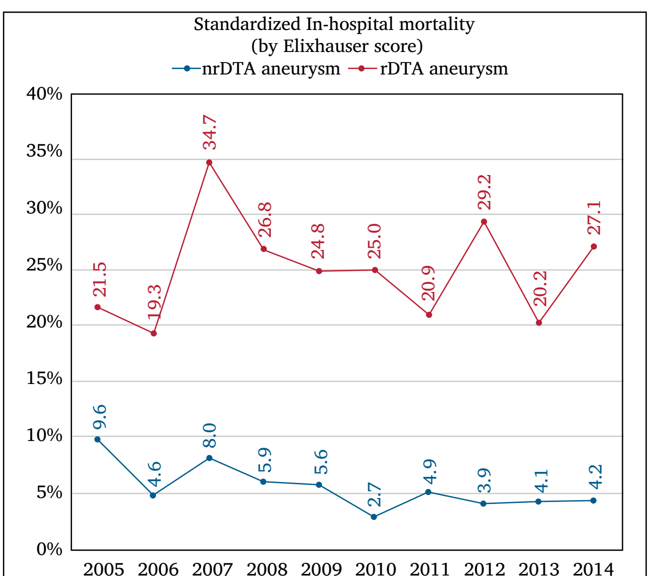

Figure 4. Nationwide in-hospital mortality for nrDTA aneurysm (blue) and rDTA aneurysm (red) from 2005 to 2014. Mortality was standardised for age, sex, and comorbidity (using Elixhauser score). DTA = descending thoracic aorta; r = ruptured; nr = non-ruptured (intact).

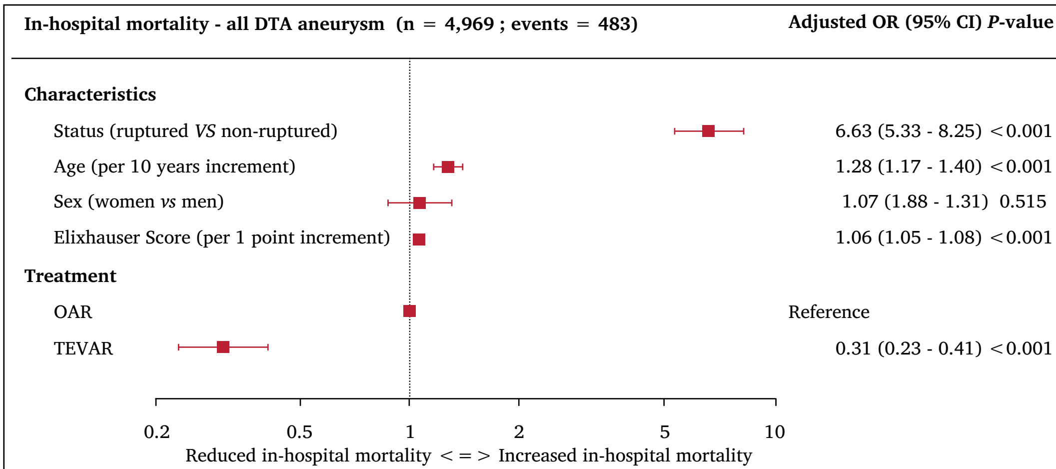

Figure 5. Multilevel multivariable regression analysis of factors associated with in-hospital mortality. Graph represents adjusted odds ratios (OR) with 95% confidence intervals (CI). DTA = descending thoracic aorta; OAR = open aortic anuerysm; TEVAR = thoracic endovascular aortic repair.

rupture, age, and a higher Elixhauser comorbidity score were associated with increased mortality in the multilevel multivariable regression analysis. Patients who experience aneurysm rupture have a six fold increased risk. The data do not support the results of a recently published study by Deery et al.,[35] who identified female sex as an independent predictor of peri-operative mortality following TEVAR for non-ruptured DTA aneurysm. Although women tended to be older at time of treatment, mortality rates for women, and men were similar in this analysis.

Table 3. Type of intervention, perioperative management and secondary study outcomes of 4,969 patients with DTA aneurysm

	Ruptured (n = 1,161, 23%)	Non-ruptured (n = 3,808, 76.6%)
TEVAR	1000 (86)	3057 (80.3)
OAR	161 (13.9)	751 (19.7)
Perioperative management		
ICU stay (yes)	530 (45.7)	1307 (34.3)
Monitoring of motor evoked potentials	3 (0.3)	45 (1.2)
Cerebrospinal fluid drainage	17 (1.5)	166 (4.4)
Ventilation (yes)	534 (46)	870 (24.8)
Median ventilation duration (Q1 − Q3), hours	140 (40–414)	88 (29–348)
Packed red blood cell transfusion (1–5 units)	378 (32.6)	745 (19.6)
Packed red blood cell transfusion (>5 units)	387 (33.3)	608 (16)
Platelet concentrate (1–5 units)	167 (14.4)	446 (11.7)
Platelet concentrate (>5 units)	48 (4.1)	115 (3)
Cell saver auto-transfusion	78 (6.2)	276 (7)
Heart lung machine use	138 (11.9)	107 (2.8)
Median length of stay (Q1 − Q3), days	12 (6–22)	11 (7–18)
CT with contrast performed	823 (41.1)	2230 (58.6)
Type of discharge		
Regular discharge	440 (37.9)	2717 (71.3)
Rehabilitation	140 (12.1)	381 (10)
Other hospital	267 (23)	479 (12.6)
In-hospital complications[a]		
Acute/recurrent myocardial infarction	29 (2.5)	49 (1.3)
Acute paraplegia/spinal infarction	14 (1.2)	46 (1.2)
Acute peripheral limb ischaemia	55 (4.7)	100 (2.9)
Major amputation lower limb	7 (0.6)	xxx
Acute mesenteric infarction	18 (1.6)	26 (0.7)
Bowel resection	14 (1.2)	25 (0.7)
Acute renal artery infarction	7 (0.6)	14 (0.4)
Renal failure	266 (22.9)	852 (22.4)
Coagulopathy	295 (25.4)	665 (17.5)
Dialysis/haemofiltration	142 (12.2)	237 (6.2)

Data are presented as n (%), unless stated otherwise. CT = computed tomography; TEVAR = thoracic endovascular aortic repair; OAR = open aortic repair; ICU = intensive care unit; $Q_1 - Q_3$ = interquartile range; regular discharge = home after discharge; DTA = descending thoracic aorta; xxx = $n < 3$, not included in analysis.

[a] In-hospital complications were based on coded perioperative comorbidities.

Table 4. Baseline characteristics, perioperative management and outcomes of 732 octogenarian patients with DTA aneurysm

	Total (n = 732)	OAR (n = 47, 6%)	TEVAR (n = 685, 94%)
Age, years	83 ± 2	82 ± 2	83 ± 2
Male sex	403 (55)	22 (46.8)	381 (55.6)
Ruptured (I71.5)	270 (36.8)	22 (46.8)	248 (36.2)
Non-ruptured (I71.6)	462 (63)	25 (53.2)	437 (63.8)
In hospital mortality	102 (13.9)	14 (29.8)	88 (12.8)
Coded comorbidities[a]			
Coronary heart disease	211 (28.8)	14 (29.8)	197 (28.8)
Other heart diseases	386 (54.4)	31 (66)	355 (51.8)
Cerebrovascular disease	94 (12.8)	5 (10.6)	89 (13)
PAD including AAA	267 (36.5)	25 (53.2)	242 (35.3)
Hypertension	543 (74.2)	35 (74.5)	508 (74)
COPD	134 (18.3)	4 (8.5)	130 (18.9)
Diabetes	126 (17.2)	6 (12.8)	120 (17.5)
Malignant diseases	21 (2.9)	xxx	xxx
Obesity	36 (4.9)	xxx	xxx
Median Elixhauser score ($Q_1 - Q_3$)	8 (3–13)	12 (4–17)	8 (3–13)
Perioperative management			
ICU stay (yes)	275 (37.6)	18 (38.3)	257 (37.5)
Ventilation (yes)	201 (27.4)	32 (68.1)	169 (24.7)
Median ventilation duration (Q1 − Q3), hours	55 (16–268)	225 (44.5–432)	46 (14–247)
Packed red blood cell transfusion (1–5 units)	207 (28.3)	15 (31.9)	192 (28)
Packed red blood cell transfusion (>5 units)	130 (17.6)	26 (55.3)	104 (15.2)
Heart–lung machine use	30 (4)	xxx	xxx
Median length of stay (Q1 − Q3), days	12 (8–20.5)	18 (9–28)	12 (8–20)
CT with contrast performed	482 (65.8)	20 (42.5)	462 (67.4)
In-hospital complications[b]			
Acute/recurrent myocardial infarction	19 (2.6)	xxx	xxx
Acute paraplegia/spinal infarction	8 (1)	xxx	xxx
Stroke	xxx	xxx	xxx
Acute peripheral limb ischaemia	8 (1)	xxx	xxx
Major amputation lower limb	0	xxx	xxx
Acute mesenteric infarction	6 (0.8)	xxx	xxx
Bowel resection	xxx	xxx	xxx
Acute renal artery infarction	3 (0.4)	xxx	xxx
Renal failure	224 (30.6)	14 (29.8)	210 (30.6)
Coagulopathy	129 (17.6)	23 (49)	106 (15.5)
Dialysis/haemofiltration	58 (7.9)	15 (31.9)	43 (6.3)
Type of discharge			
Regular discharge	402 (54.9)	6 (12.8)	396 (57.8)
Rehabilitation	60 (8.2)	7 (14.9)	53 (7.7)
Other hospital	149 (20.4)	19 (40.4)	130 (19)

Data are presented as n (%), unless stated otherwise. PAD = peripheral artery disease; AAA = abdominal aortic aneurysm; COPD = chronic obstructive pulmonary disease; CT = computed tomography; TEVAR = thoracic endovascular aortic repair; OAR = open aortic repair; ICU = intensive care unit; $Q_1 - Q_3$ = interquartile range; regular discharge = home after discharge; DTA = descending thoracic aorta; xxx = $n < 3$, not included in analysis as censored due to data protection law.

[a] Coded comorbidities were assumed to be pre-existing.

[b] In-hospital complications were based on coded perioperative comorbidities.

This is a record of 48,098 cases with a principal diagnosis ruptured or non-ruptured thoracic aortic aneurysm including pathologies of the entire thoracic aorta and aortic dissections. Only 10.3% received surgical treatment of an aneurysm of the descending thoracic aorta as patients with procedure codes for repair of an ascending aortic aneurysm, arch, and dissections were excluded. Conclusions regarding the clinical practice of surveillance of patients with aortic aneurysms cannot be drawn from these data and no data are available for a large fraction of patients that did not receive operative treatment. It remains unclear whether individuals with a ruptured aortic aneurysm represent a fraction of those being followed or whether these patients were never previously diagnosed as having such.

Strengths and limitations

This study has several limitations that have been discussed in detail elsewhere.[13] In short, the results are based on administrative data that describe associations rather than draw causal relationships. The documentation of diagnosis, comorbidities and procedure codes is routinely controlled by the Health Insurance Medical Service (Medizinischer Dienst der Krankenversicherungen). However, reimbursement is based on grouping of diagnoses. The fact that certain diagnoses are not DRG relevant, means that insufficient documentation and coding error might cause bias, but also makes over reporting very unlikely. Sources of bias can be selection bias (subset of hospitals or non-reporting of a subset of patients), information

Table 5. Volume outcome analysis across 1,373 hospitals treating DTA aneurysm in Germany between 2004 and 2015

	Low volume hospitals (n = 770)	Medium volume hospitals (n = 460)	High volume hospitals (n = 143)
Cases with TAA	1020 (20.5)	2098 (42.2)	1851 (37.3)
No. of cases per hospital/year	1–2	3–8	≥9[a]
Non-ruptured cases	817 (80.1)	1581 (75.4)	1410 (76.2)
Type of treatment			
TEVAR	923 (90.5)	1668 (79.5)	1466 (79.2)
OAR	97 (9.5)	430 (20.5)	385 (20.8)
Sex (Male)	667 (65.3)	1372 (65.4)	1199 (64.8)
Age, years (mean ± standard deviation)	71 ± 11	69 ± 12	68 ± 12
In-hospital mortality	90 (8.8)	234 (11.2)	159 (8.6)
Type of admission			
Scheduled admission	668 (65.4)	1208 (57.6)	1107 (59.8)
Emergency	236 (23.1)	476 (22.7)	359 (19.4)
Transferred	116 (11.4)	414 (6.7)	385 (20.8)
Median Elixhauser score ($Q_1 - Q_3$)	5 (2–12)	6 (2–12)	6 (2–11)
Median length of stay ($Q_1 - Q_3$), days	10 (7–18)	12 (7–20)	11 (7–18)
Type of discharge			
Regular discharge	747 (73.2)	1312 (62.5)	1098 (59.3)
Rehabilitation	72 (7.1)	254 (12.1)	195 (10.5)
Other hospital	94 (9.2)	269 (12.8)	383 (20.7)
In-hospital complications[b]			
Stroke	xxx	15 (0.7)	xxx
Acute/recurrent myocardial infarction	20 (2)	21 (1)	37 (2)
Acute paraplegia/spinal infarction	12 (1.2)	20 (1)	28 (1.5)
Acute peripheral limb ischaemia	37 (3.6)	62 (3)	56 (3)
Major amputation lower limb	0	xxx	xxx
Acute mesenteric infarction	7 (0.7)	18 (0.9)	19 (1)
Bowel resection	5 (0.5)	21 (1)	13 (0.7)
Acute renal artery infarction	xxx	xxx	xxx
Renal failure	227 (22.3)	503 (24)	388 (21)
Coagulopathy	143 (14)	383 (18.3)	434 (23.4)
Dialysis/haemofiltration	56 (5.6)	172 (8.2)	151 (8.2)

Data are presented as n (%), unless stated otherwise. TAA = Thoracic aortic aneurysm; TEVAR = thoracic endovascular aortic repair; OAR = open aortic repair; $Q_1 - Q_3$ = interquartile range; regular discharge = home after discharge; DTA = descending thoracic aorta; xxx = $n < 3$, not included in analysis as data were censored due to data protection law.
[a] 95% confidence interval 9–21.
[b] In-hospital complications were based on coded perioperative comorbidities.

bias due to absence of external monitoring, and residual confounding (e.g., by non-observed or non-recorded risk factors).

However, one must be aware that the present study is not based on a clinical registry for quality assurance but on data that were collected for hospital remuneration. Data collection is mandatory for all German hospitals and the process of data validation (completeness, correctness) is regulated by German social law. In summary, the data used in the present study can be considered complete at a national level, and validated by several mechanisms (technical, administrative, external control by an independent agency, the Medizinischer Dienst der Krankenkassen). In contrast, the data are "administrative" rather than "clinical" and they are not collected for quality assurance but for hospital remuneration. However, because "hard" variables were used (procedure code, ICD-10 diagnosis code, and mortality as outcome), the validity of the results can be considered as good as can be achieved by a secondary data analysis.[36]

There is no documentation regarding clinical data that might have influenced the decision on whether or not to perform surgery in a particular patient, or regarding the grounds upon which the choice of procedure (TEVAR/OAR) was based. Pre-operative comorbidity, the surgeon's experience, and other factors might lead to confounding and result in a selected patient cohort in each group. The raw data on share of patients that received open or endovascular surgery and mortality rates, on the other hand, represent an accurate and valid description of treatment reality in Germany. After discharge, complications and death cannot be monitored with this analysis. This might lead to an underestimation of in hospital mortality, for example, for patients discharged to another hospital after DTA aneurysm repair. Furthermore, aneurysm specific data (e.g., diameter, morphology, calcification, and growth or reintervention rates) are not captured.

CONCLUSIONS

This nationwide analysis reveals population based outcome data after surgical repair of DTA aneurysms. The number of patients hospitalised for DTA aneurysm in Germany increases each year. A large proportion of patients is not treated surgically but of those treated, more than 80% received endovascular therapy in a low or medium volume centre with comparable in hospital mortality rates to high volume centres: annual hospital volume is not associated with in hospital mortality. Aneurysm rupture, older age, and co-morbidity burden are independent risk factors for increased mortality. Endovascular DTA aneurysm repair can be performed with low peri-operative mortality in a non-emergency setting. Therefore, elective repair should be considered for individuals at high risk of rupture who are fit for surgery.

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CONFLICT OF INTEREST

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejvs.2018.08.013.

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COUP D’OEIL

Emphysematous Aortitis by *Clostridium septicum*: A Rare and Lethal Complication of Right Colon Cancer

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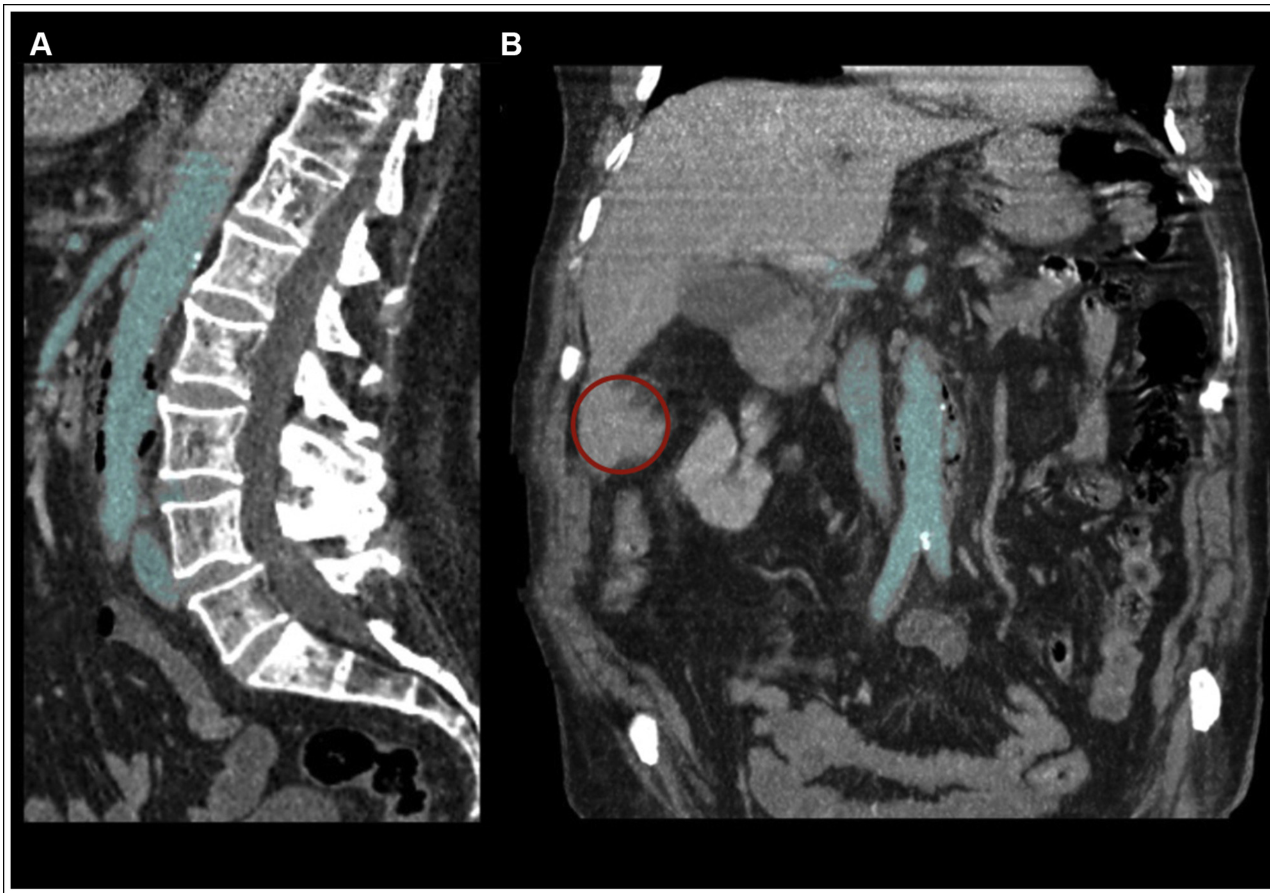

An 84 year old hypertensive man presented with four days of abdominal pain and fever. A computed tomography scan revealed emphysematous aortitis with gas in the abdominal aortic wall (A) and a colonic tumour in the hepatic flexure (B, circled). Emergency surgery with infected aortic segment excision and axillofemoral bypass was performed. No colonic resection was carried out owing to the patient’s haemodynamic status. Intra-operative tissue cultures were positive for *Clostridium septicum*. In the immediate post-operative period, the patient died as a result of septicaemia. Emphysematous aortitis caused by *C. septicum* bacteraemia is a rare and life threatening condition strongly associated with colonic carcinoma.

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