Meta-analysis of open versus endovascular repair for ruptured descending thoracic aortic aneurysm

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Introduction: **Ruptured descending thoracic aortic aneurysm (rDTAA) is associated with high mortality rates. Data supporting endovascular thoracic aortic aneurysm repair (TEVAR) to reduce mortality compared with open repair are limited to small series. We investigated published reports for contemporary outcomes of open and endovascular repair of rDTAA.**

Methods: **We systematically reviewed all studies describing the outcomes of rDTAA treated with open repair or TEVAR since 1995 using MEDLINE, Cochrane Library CENTRAL, and Excerpta Medica Database (EMBASE) databases. Case reports or studies published before 1995 were excluded. All articles were critically appraised for relevance, validity, and availability of data regarding treatment outcomes. All data were systematically pooled, and meta-analyses were performed to investigate 30-day mortality, myocardial infarction, stroke, and paraplegia rates after both types of repair.**

Results: **Original data of 224 patients (70% male) with rDTAA were identified: 143 (64%) were treated with TEVAR and 81 (36%) with open repair. Mean age was 70 ± 5.6 years. The 30-day mortality was 19% for patients treated with TEVAR for rDTAA compared 33% for patients treated with open repair, which was significant (odds ratio [OR], 2.15, $P = .016$). The 30-day occurrence rates of myocardial infarction (11.1% vs 3.5%; OR, 3.70, $P < .05$), stroke (10.2% vs 4.1%; OR, 2.67; $P = .117$), and paraplegia (5.5% vs 3.1%; OR, 1.83; $P = .405$) were increased after open repair vs TEVAR, but this failed to reach statistical significance for stroke and paraplegia. Five additional patients in the TEVAR group died of aneurysm-related causes after 30 days, during a median follow-up of 17 ± 10 months. Follow-up data after open repair were insufficient. The estimated aneurysm-related survival at 3 years after TEVAR was 70.6%.**

Conclusion: **Endovascular repair of rDTAA is associated with a significantly lower 30-day mortality rate compared with open surgical repair. TEVAR was associated with a considerable number of aneurysm-related deaths during follow-up. (J Vasc Surg 2010;51:1026-32.)**

The annual incidence of ruptured aneurysm of the thoracic aorta is about 5 per 100,000, which makes it less common than ruptured abdominal aortic aneurysms.[1,2] Approximately 30% of all ruptured thoracic aortic aneurysms (TAAs) are localized at the descending thoracic aorta, the remaining ruptured TAAs are found at the ascending aorta and arch.[1] Overall mortality rates of ruptured TAAs of up to 97% have been reported, and only a few patients survive transport to the emergency department.[1]

The traditional treatment of intact and ruptured aneurysms of the descending thoracic aorta (rDTAA) has been open surgical resection of the aneurysm and replacement with an interposition graft, which was first performed by Lam and Aram in 1951.[3] Open surgical repair of the rDTAA allows inspection of the ruptured aneurysm and possible aortic branches. However, this approach requires thoracotomy, aortic cross-clamping, and in some cases, cardiopulmonary bypass.

Successful endovascular management of a rDTAA was first reported by Semba et al[4] in 1997. Endovascular thoracic aortic aneurysm repair (TEVAR) is less invasive than open repair and may result in quick exclusion of the aneurysm without thoracotomy or aortic clamping. Recent nonrandomized trials have demonstrated 30-day mortality rates of 1.9% to 2.1% after elective TEVAR compared with 5.7% to 11.7% after elective open repair.[5-7] In addition, endovascular repair has been associated with improved operative mortality rates for ruptured abdominal aortic aneurysms[8,9] and traumatic thoracic aortic ruptures.[10,11] However, the exact role of TEVAR for the management of rDTAA still has to be better defined, as a result of the low incidence of rDTAA. The purpose of the present study was to perform a meta-analysis evaluating the outcomes of endovascular vs open repair for the management of rDTAA.

METHODS

Literature search. MEDLINE, EMBASE, and Cochrane Library CENTRAL were searched until June 29, 2009. The following search string was used for MEDLINE:

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Competition of interest: none.

Additional material for this article may be found online at www.jvascsurg.org.

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Table I. Availability of data in the evaluated reports

Variable available	*All patients (n = 224) no. (%)*	*TEVAR (n = 143) no. (%)*	*Open repair (n = 81) no. (%)*
Age	143 (64)	111 (78)	32 (40)
Gender	93 (42)	72 (50)	21 (26)
Contained rupture	191 (85)	135 (94)	56 (69)
Consideration for repair type	224 (100)	143 (100)	81 (100)
Repair ≤24 hours	177 (79)	131 (92	46 (57)
Anesthesia type	177 (79)	96 (67)	81 (100)
Cardiopulmonary bypass	45 (56)		45 (56)
Endograft brand	94/143 (66)	94 (66)	. . .
Endograft diameter	38/143 (27)	38 (27)	. . .
Endograft length	21/143 (15)	21 (15)	. . .
30-day mortality	224 (100)	143 (100)	81 (100)
Death during follow-up	116/170 (68)	107/116 (91)	9/54 (17)
Days to in-hospital death	30/54 (56)	20/27 (74)	10/27 (37)
Days to follow-up death	5/5 (100)	5/5 (100)	. . .
Cause of in-hospital death	42/54 (78)	24/27 (89)	18/27 (67)
Cause of follow-up death	5/5 (100)	5/5 (100)	. . .
Paraplegia	203 (91)	130 (91)	73 (90)
Stroke	182 (81)	123 (86)	59 (73)
Myocardial infarction	187 (84)	142 (99)	45 (56)
Vascular reintervention	165 (74)	121 (85)	44 (54)
Endoleak	90/143 (63)	90/143 (63)	. . .
Endograft-related complications	84/143 (59)	84/143 (59)	. . .
Length of follow-up	116/170 (68)	107/116 (91)	9/54 (17)

TEVAR, Endovascular thoracic aortic aneurysm repair.

"rupture"[tiab] *or* "ruptured"[tiab] *or* "ruptures"[tiab] *or* emergen*[tiab] *or* "acute"[tiab] *or* perforat*[tiab]) *and* ("thoracic"[title] *or* "descending"[title]) *and* ("aorta"[title] *or* "aortic"[title]) *and* ("aneurysm"[tiab] *or* "aneurysms"[tiab] *or* "aneurysmatic"[tiab]. This resulted in 846 articles. A similar search string was used for EMBASE, resulting in 1390 articles. A manual search of the Cochrane library CENTRAL database did not reveal any relevant articles. After duplicate articles were removed, 1743 articles remained. No language or publication date restrictions were applied.

Article selection. All titles and abstracts were read by two independent investigators (F.H.J. and B.E.M.). Inclusion criteria were (1) articles describing patients with rDTAA treated with TEVAR or open repair; (2) the following patient outcomes were described: 30-day mortality (required) and 30-day complications, including stroke, paraplegia, and myocardial infarction (MI), preferably. Aneurysm rupture was defined as fresh blood outside the aortic wall on imaging or during surgery. Exclusion criteria included (1) articles published before 1995, to guarantee that the report represents contemporary practice; (2) case reports; (3) thoracic aortic pathologies other than rDTAA, such as ruptured thoracoabdominal aneurysms, aneurysms of the ascending aorta or arch, penetrating aortic ulcers, or pseudoaneurysms; (4) no clear description of outcomes of TEVAR or open repair; and (5) no original data presented in the article.

Studies that evaluated other thoracic aortic pathologies besides rDTAA were excluded, unless treatment outcome variables were described separately for the different pathologies. In this manner, many studies had to be excluded for analysis. Other articles written by identical authors or institutions were studied in detail and excluded as necessary to prevent inclusions of duplicate cases. Reports from administrative databases were not included because administrative data are thought to be less reliable and could have been published before in other included reports. A total of 28 relevant articles were identified and included in the final selection (Appendix, online only).[4,12-38]

Data extraction. Two independent investigators (F.H.J. and B.E.M.) analyzed the identified articles. The characteristics extracted included age and gender of patients; comorbidities, including aneurysm characteristics such as diameter, contained or free rupture, associated dissection; presence of hypovolemic shock at admission; time between diagnosis and aneurysm repair; repair type; consideration for preferred repair type; cerebrospinal fluid drainage; anesthesia type; endograft details, including brand, diameter, length, and number of stent grafts used; successful aneurysm exclusion; 30-day mortality; mortality >30 days; time between aneurysm repair and death; cause of death; permanent paraplegia; stroke; MI; endograft-related complications, including endoleak, graft migration, and fracture; need for vascular reintervention ≤30 days; length of stay in days, and length of follow-up in months. All extracted information was subsequently systematically entered in one database. Original data for 224 patients with rDTAA treated with open repair or TEVAR were identified. Availability of the studied variables in the evaluated reports is reported in Table I.

Statistical analysis. Statistical analyses were performed (F.H.J.) using SPSS 15.0 software (SPSS Inc, Chicago, Ill) and Comprehensive Meta-Analysis 2 software. In

Table II. Baseline characteristics of patients with ruptured descending thoracic aortic aneurysm

Characteristic	*Open repair (n = 81) no. (%) or mean ± SD*	*TEVAR (n = 143) no. (%) or mean ± SD*	P
Age, y	70.2 ± 1.9	70.0 ± 6.5	.831
Male gender	14 (66.7)	51 (70.8)	.714
Contained rupture	24 (42.9)	75 (55.6)	.110
Consideration for repair type			<.001
Institution's standard treatment	42 (51.9)	8 (5.6)	. . .
Emergency treatment	0 (0)	82 (57.3)	. . .
Extensive comorbidities	0 (0)	53 (37.1)	. . .
Anatomy	11 (13.6)	0 (0)	. . .
Only available treatment	28 (34.6)	0 (0)	. . .
Repair ≤24 hours	41 (89.1)	106 (80.9)	.201
General anesthesia	81 (100)	92 (95.8)	.063
Cardiopulmonary bypass	27 (60)	. . .	. . .
Endograft brand			
Medtronic Talent[a]	. . .	46 (32.2)	. . .
Gore Excluder[b]	. . .	21 (14.7)	. . .
Gore TAG[b]	. . .	12 (8.4)	. . .
Handmade or other	. . .	15 (10.5)	. . .
Missing	. . .	49 (34.3)	. . .
Endograft diameter, mm	. . .	37 ± 0.7	. . .
Endograft length, mm	. . .	125 ± 10	. . .

SD, Standard deviation; *TEVAR,* endovascular thoracic aortic aneurysm repair.
[a]Medtronic, Minneapolis, Minn.
[b]W. L. Gore and Associates, Flagstaff, Ariz.

all cases, missing data were not defaulted to negative, and denominators reflect only cases reported. The Levene test for equality of variances was used to assess the variance of the 30-day mortality, paraplegia, stroke, and MI rates among the evaluated studies. Equal variances were confirmed for all evaluated outcome variables. Contingency tables with χ^2 test were used to compare categoric outcome variables between patients treated with open repair and TEVAR, such as 30-day mortality, paraplegia, stroke, and MI occurrence rates. Continuous variables were compared between both repair groups using the *t* test. The estimated aneurysm-related survival during follow-up was demonstrated using Kaplan-Meier life table analysis. Differences were considered statistically significant at values of $P < .05$ and when the 95% confidence interval (CI) for the odds ratio (OR) did not contain 1.

RESULTS

Baseline characteristics. We identified 28 articles describing 224 patients with rDTAA, including 143 patients (63.8%) treated with TEVAR and 81 (36.2%) treated with open repair. Mean age of patients with rDTAA was 70.0 ± 5.6 years, and 65 (69.9%) were men (Table II). Ruptured aneurysms treated with TEVAR were more frequently contained rather than a free rupture, 75 of 135 (55.6%) vs 24 of 56 (42.9%; $P = .110$). However, these data were only available for 85% of patients (Table I).

Aneurysm repair was performed ≤24 hours in 147 of 177 patients (83.1%). Considerations for offering open repair were the institution's standard treatment in 42 patients (51.9%), endovascular repair was not available for 28 (34.6%, in particular before 1999), or anatomy for was unsuitable for endovascular repair in the remaining 11 (13.6%). TEVAR was preferred rather than open repair because of emergency in 82 patients (57.3%), comorbidities in 53 (37.1%), and TEVAR was simply the institution's standard treatment for all descending thoracic aortic pathologies in the remaining 8 (5.6%).

Early mortality. The 30-day mortality was significantly lower in patients treated with TEVAR for rDTAA than in patients treated with open repair: 27 of 143 (18.9%) vs 27 of 81 (33.3%); OR, 2.15 (95% CI, 1.15-4.01; $P = .016$). Data regarding the cause of 30-day mortality were available in 42 of 54 deaths (78%, Table I). The most frequent causes of 30-day mortality after open repair were exsanguination, cardiac complications, or stroke, which were each responsible for 5 of 18 deaths (27.7%, Fig 1). Besides these, multiorgan failure (MOF) and infectious complications were common causes of death in the TEVAR group. Mean interval between aneurysm repair and death ≤30 days was 2.1 days after open repair vs 7.8 days after TEVAR ($P = .022$).

Early complications. MI was reported in 5 of 45 patients (11.1%) after open repair and in 5 of 142 patients (3.5%) after TEVAR (OR, 3.5; 95% CI, 1.02-13.37; $P = .047$; Table III). Stroke occurred in 6 of 59 patients (10.2%) in the open repair group vs 5 of 123 patients (4.1%) in the TEVAR group (OR, 2.67; $P = .117$). In most cases, these complications resulted in death. Permanent paraplegia was reported in 4 of 73 (5.5%) after open repair and in 4 of 130 (3.1%) after TEVAR (OR, 1.83; $P = .405$).

Additional vascular interventions ≤30 days were described in 11 of 121 patients (9.1%) after TEVAR vs 1 of 44 patients (2.3%) after open repair (OR, 0.23; $P = .169$).

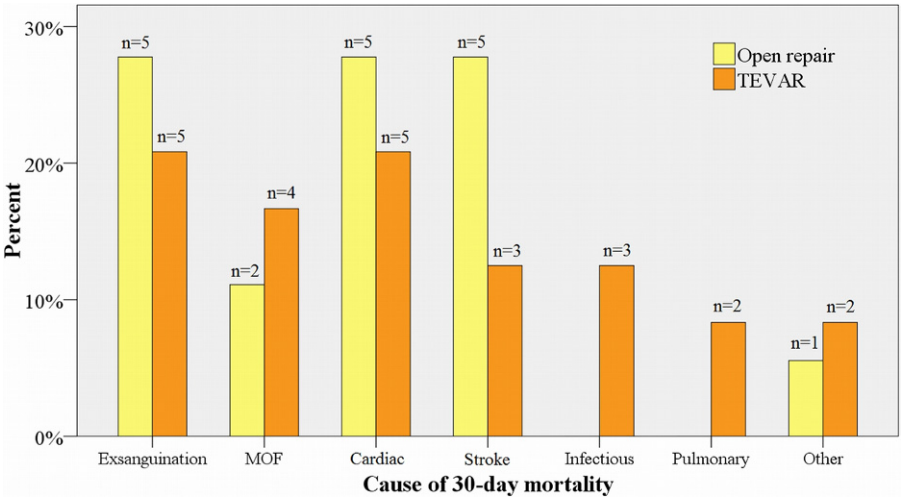

Fig 1. Causes of 30-day mortality after endovascular repair of thoracic aortic aneurysms (*TEVAR*) are compared with open repair. Other causes of death were iatrogenic dissection with abdominal malperfusion after TEVAR (n = 1), superior mesentery artery infarction after TEVAR (n = 1), and acute renal failure after open repair of a ruptured descending thoracic aortic aneurysm.

Table III. Thirty-day outcomes of open repair and thoracic endovascular aneurysm repair for ruptured descending thoracic aortic aneurysms

Outcome	*Open repair (n = 81) no. (%)*	*TEVAR (n = 143) no. (%)*	*OR (95% CI)*	P
30-day mortality	27 (33.3)	27 (18.9)	2.15 (1.15-4.01)	.016
Myocardial infarction	5 (11.1)	5 (3.5)	3.70 (1.02-13.4)	.047
Stroke	6 (10.2)	5 (4.1)	2.67 (0.78-9.14)	.117
Paraplegia[a]	4 (5.5)	4 (3.1)	1.83 (0.44-7.53)	.405
Additional vascular intervention[b]	1 (2.3)	11 (9.1)	0.23 (0.03-1.86)	.169

CI, Confidence interval; *OR,* odds ratio; *TEVAR,* endovascular thoracic aortic aneurysm repair.
[a]Patients who sustained permanent paraplegia after ruptured descending thoracic aortic aneurysm repair.
[b]Included conversion to open repair because of proximal endoleak (n = 2), repair of a ruptured common iliac artery, external iliac artery or femoral artery (n = 5), additional TEVAR because of type 1 endoleak (n = 2), and carotid-carotid bypass because of overstenting of the left carotid artery (n = 1). Re-exploration for bleeding after open repair of ruptured descending thoracic aortic aneurysms was reported once.

Interventions after TEVAR included repair of a lacerated common iliac artery, external iliac artery, or femoral artery in 5 patients, conversion to open repair because of proximal endoleak in 2, additional TEVAR because of type 1 endoleak in 2, and carotid-carotid bypass in 1 because of overstenting of the left carotid artery. One re-exploration for bleeding after open repair of rDTAA was reported. Endoleak was reported in 10 of 90 patients (11.1%) at some point during follow-up after TEVAR, which included type I endoleak in 9 and type II endoleak in 1. Endograft migration was reported once.

Death during follow-up. Reliable data regarding deaths during follow-up were available for 107 of the 116 TEVAR patients (92%) who were alive >30 days and for 9 of 52 (17%) in the open repair group. Median follow-up was 17 ± 10 months for the TEVAR group and 36 ± 13 months for the open repair group. In the TEVAR group, five patients died of aneurysm-related causes after 30-days; the median time interval until death was 139 days (range, 87-1080 days). Exsanguination due to rupture of the stented aneurysm or the adjacent aortic segment was the cause of death in four patients. Untreated type 1 endoleak caused the rupture in two cases, perforation of the aortic wall by the bare portion of the stent-graft occurred once, and an infected stent graft led to aortic rupture in the last patient. The fifth aneurysm-related death during TEVAR follow-up was the result of sepsis due to an aortobronchial fistula. The estimated aneurysm-related survival for patients treated with TEVAR was 70.6% after 3 years (Fig 2). No aneurysm-related deaths were reported in the open repair group during follow-up.

DISCUSSION

This review of the available literature found that TEVAR of rDTAA was associated with a significantly lower 30-day mortality rate compared with open repair. The 5-year survival rate of patients with untreated TAAs is only 20% to 54%,[39,40] which is primarily the result of aneurysm

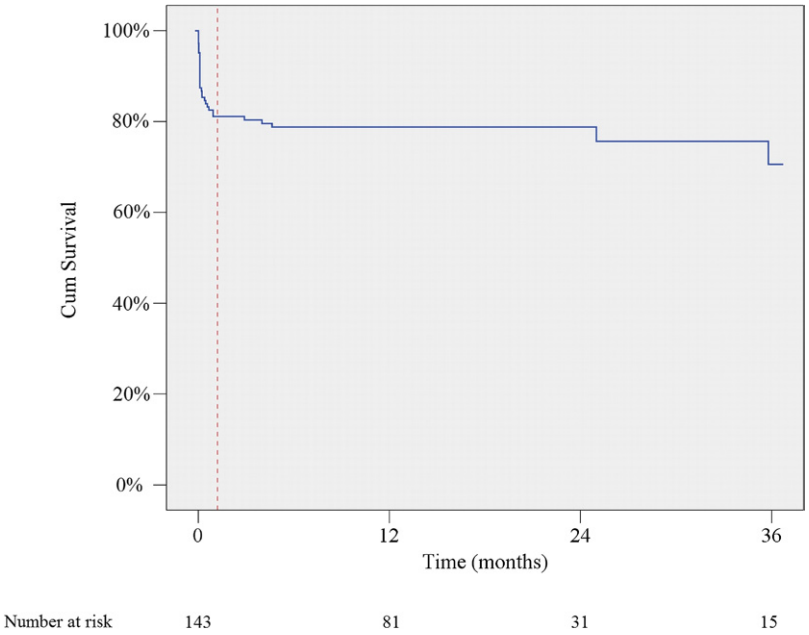

Fig 2. Aneurysm-related survival in patients treated with thoracic endovascular aneurysm repair (TEVAR) for a ruptured descending thoracic aortic aneurysm. The estimated aneurysm-related survival at 3 years after TEVAR was 70.6%. The *red dashed line* indicates 30 days after the endovascular procedure. Survival estimates were not performed for patients treated with open repair because the follow-up data were not available for 83% of patients.

rupture. Risk factors for rupture of TAAs are increasing age, female gender, chronic obstructive pulmonary disease (COPD), and most importantly, increasing TAA diameter.[40-43] For TAAs >6 cm in diameter, risks of dissection, rupture or death are about 15% per year.[40,42] Because these risks substantially exceed the risk of surgical resection of TAA, elective intervention is generally recommended in aneurysms >6 cm.[42,44-46] Among patients with rTAAs, the overall mortality approaches 100%, and just a few of these patients will be admitted alive to the emergency department.[1] Although patients who arrive at the hospital alive are thought to have a more realistic outcome, a large portion of this group will not survive the operation.[47]

The traditional treatment of rDTAA has been open surgical resection of the aneurysm and replacement with an interposition graft. Since the introduction of endovascular techniques for the management of abdominal and thoracic aortic disease, this less invasive technique has improved operative mortality rates of elective and emergency interventions compared with open surgical repair.[5-11,48] Significant benefits of endovascular repair have not yet been reported for rDTAA, which likely is the result of the relatively low incidence of this disease. To our knowledge, the largest comparative study evaluated <30 patients with rDTAA.[21] In addition, studies often combine results of rDTAA, traumatic aortic injuries, penetrating aortic ulcers, and type B dissections, even though these are completely different pathologies.

In this evaluation, the 30-day mortality was 33% after open repair of rDTAA compared with 19% after TEVAR. Open repair of rDTAA is a more invasive procedure than TEVAR, and patients treated with open repair appeared to present more frequently with MI, stroke, and paraplegia during or shortly after the operation. MI and stroke were important causes of death after open repair. TEVAR does not require thoracotomy, aortic clamping, or cardiopulmonary bypass and offers prompt exclusion of the ruptured aneurysm, which minimizes additional blood loss. These advantageous characteristics of endovascular management of rDTAA appear to result in superior short-term outcomes compared with open repair, and TEVAR may therefore be the treatment of first choice in patients with rDTAA.

The cause of concern with endovascular repair of aortic disease remains its durability and the development of endograft-related complications.[49] Endoleak was present in at least 11% after TEVAR, and during a median follow-up of 17 months, 5 of the 107 TEVAR patients with available follow-up data had died of endograft-related complications, and the estimated aneurysm-relate survival at 3 years was 71%. Rupture of the stented aneurysm or the adjacent aorta was the main cause of death in these patients, and was caused by type 1 endoleak, perforation of the aortic wall by the bare portion of the stent graft, or an infected stent graft.

Risks of endograft-related complications may be increased after emergency procedures, because physicians in this setting can only use those endografts that are available on the shelf stock, and urgent situations may not allow optimal endograft sizing and deployment. Furthermore, hypovolemic shock may result in an decreased aortic diameter, which may also contribute to inadequate endograft

sizing.[50] Therefore, continued surveillance using computed tomography angiography after TEVAR, and further improvement of endovascular techniques and endografts design is required.[21,49]

Meta-analyses such as the present study have several limitations; the most important disadvantage is that the data are limited to information provided by the original articles. This can result in incomplete data, such as the follow-up data that was unavailable for most of the patients treated with open repair.

Furthermore, there was a tendency for TEVAR to be used more frequently for aneurysms with a contained rupture rather than for those with a free rupture. Blood loss may be more extensive in case of free rupture, which could result in hemodynamic instability and poorer outcomes. However, data regarding this variable were missing in 15% as well.

In addition, some complications or even deaths may have been under-reported in the evaluated studies. Articles in which the description of the outcome variables was unclear were therefore excluded from the meta-analysis. The present study does represent the largest evaluation of patients with rDTAA treated with TEVAR and open repair, and it may offer the best evidence that is currently available regarding the management of this life-threatening disease.

CONCLUSION

Published reports indicate that endovascular repair of rDTAA is associated with a significantly lower 30-day mortality rate compared with open surgical repair. Furthermore, complications such as MI, stroke, and paraplegia appear to be lower after endovascular repair of rDTAA. However, endovascular repair was associated with a considerable number of aneurysm-related deaths during follow-up, mainly caused by late rupture after TEVAR. Continued surveillance after TEVAR and further improvement of the design of endografts is required to decrease the endograft-related complications and deaths during follow-up.

AUTHOR CONTRIBUTIONS

Conception and design: FJ, ST, BM
Analysis and interpretation: FJ, ST, HV, FM, BS, BM
Data collection: FJ
Writing the article: FJ, ST, HV
Critical revision of the article: ST, HV, FM, BS, BM
Final approval of the article: FJ, ST, HV, FM, BS, BM
Statistical analysis: FJ
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Overall responsibility: BM

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Additional material for this article may be found online at www.jvascsurg.org.

Appendix (online only). Evaluated reports

No.	*Reference*	*Patients, no.*	*rDTAA, no.*
1.	Hyhlik-Dürr A, Geisbüsch P, von Tengg-Kobligk H, Klemm K, Böckler D. Intentional overstenting of the celiac trunk during thoracic endovascular aortic repair: preoperative role of multislice CT angiography. J Endovasc Ther 2009;16:48-54.	5	2
2.	Attia C, Farhat F, Boussel L, Villard J, Revel D, Douek P. Endovascular repair of lesions involving the descending thoracic aorta. Mid-term morphological changes. Interact Cardiovasc Thorac Surg 2008; 7:595-9.	75	8
3.	Minatoya K, Ogino H, Matsuda H, Sasaki H, Yagihara T, Kitamura S. Replacement of the descending aorta: recent outcomes of open surgery performed with partial cardiopulmonary bypass. J Thorac Cardiovasc Surg 2008;136:431-5.	113	16
4.[a]	Bos WT, Verhoeven EL, Zeebregts CJ, Tielliu IF, Prins TR, Oranen BI, et al. Emergency endovascular stent grafting for thoracic aortic pathology. Vascular 2007 Jan-Feb;15:12-7	30	8
5.	Amabile P, Rollet G, Vidal V, Collart F, Bartoli JM, Piquet P. Emergency treatment of acute rupture of the descending thoracic aorta using endovascular stent-grafts. Ann Vasc Surg 2006;20:723-30.	17	1
6.	Delis KT, Gloviczki P, Bjarnason H, Sullivan TM, McKusick MA, Kalra M, et al. Endovascular repair of ruptured saccular aneurysms of the descending thoracic aorta. J Vasc Interv Radiol 2006;17: 1527-33.	4	4
7.	Kaya A, Heijmen RH, Overtoom TT, Vos JA, Morshuis WJ, Schepens MA. Thoracic stent grafting for acute aortic pathology. Ann Thorac Surg 2006;82:560-5.	28	7
8.	Wheatley GH 3rd, Gurbuz AT, Rodriguez-Lopez JA, Ramaiah VG, Olsen D, Williams J, et al. Midterm outcome in 158 consecutive Gore TAG thoracic endoprostheses: single center experience. Ann Thorac Surg 2006;81:1570-7; discussion 1577.	158	11
9.	Farber MA, Criado FJ. Endovascular repair of nontraumatic ruptured thoracic aortic pathologies. Ann Vasc Surg 2005;19:167-71.	22	11
10.[b]	Doss M, Wood JP, Balzer J, Martens S, Deschka H, Moritz A. Emergency endovascular interventions for acute thoracic aortic rupture: four-year follow-up. J Thorac Cardiovasc Surg 2005;129:645-51.	60	26
11.	Morishita K, Kurimoto Y, Kawaharada N, Fukada J, Hachiro Y, Fujisawa Y, et al. Descending thoracic aortic rupture: role of endovascular stent-grafting. Ann Thorac Surg 2004;78:1630-4.	29	6
12.	Bortone AS, De Cillis E, D'Agostino D, de Luca Tupputi Schinosa L. Endovascular treatment of thoracic aortic disease: four years of experience. Circulation 2004 Sep 14;110(11 suppl 1):II262-7.	132	6
13.	Melnitchouk S, Pfammatter T, Kadner A, Dave H, Witzke H, Trentz O, et al. Emergency stent-graft placement for hemorrhage control in acute thoracic aortic rupture. Eur J Cardiothorac Surg 2004; 25:1032-8.	24	3
14.	Ishida M, Kato N, Hirano T, Cheng SH, Shimono T, Takeda K. Endovascular stent-graft treatment for thoracic aortic aneurysms: short- to midterm results. J Vasc Interv Radiol 2004;15:361-7.	40	8
15.	Iannelli G, Piscione F, Di Tommaso L, Monaco M, Chiariello M, Spampinato N. Thoracic aortic emergencies: impact of endovascular surgery. Ann Thorac Surg 2004;77:591-6.	15	4
16.	Van Herzeele I, Vermassen F, Durieux C, Randon C, De Roose J. Endovascular repair of aortic rupture. Eur J Vasc Endovasc Surg 2003;26:311-6.	20	5
17.	Krohg-Sørensen K, Hafsahl G, Fosse E, Geiran OR. Acceptable short-term results after endovascular repair of diseases of the thoracic aorta in high risk patients. Eur J Cardiothorac Surg 2003;24:379-87.	20	2
18.	Sunder-Plassmann L, Scharrer-Pamler R, Liewald F, Kapfer X, Görich J, Orend KH. Endovascular exclusion of thoracic aortic aneurysms: mid-term results of elective treatment and in contained rupture. J Card Surg 2003;18:367-74.	45	15
19.	Lepore V, Lönn L, Delle M, Bugge M, Jeppsson A, Kjellman U, et al. Endograft therapy for diseases of the descending thoracic aorta: results in 43 high-risk patients. J Endovasc Ther 2002;9:829-37.	43	7
20.	Girardi LN, Krieger KH, Altorki NK, Mack CA, Lee LY, Isom OW. Ruptured descending and thoracoabdominal aortic aneurysms. Ann Thorac Surg 2002;74:1066-70.	40	18
21.	Morgan R, Loosemore T, Belli AM. Endovascular repair of contained rupture of the thoracic aorta. Cardiovasc Intervent Radiol 2002;25:291-4.	4	2
22.	Czermak BV, Waldenberger P, Perkmann R, Rieger M, Steingruber IE, Mallouhi A, et al. Placement of endovascular stent-grafts for emergency treatment of acute disease of the descending thoracic aorta. AJR Am J Roentgenol 2002;179:337-45.	18	5
23.[c]	Alric P, Marty-Ané CH. Endovascular treatment of ruptured thoracic aortic aneurysms. J Thorac Cardiovasc Surg 2002;124:180-2.	7	7
24.	Estrera AL, Rubenstein FS, Miller CC 3rd, Huynh TT, Letsou GV, Safi HJ. Descending thoracic aortic aneurysm: surgical approach and treatment using the adjuncts cerebrospinal fluid drainage and distal aortic perfusion. Ann Thorac Surg 2001;72:481-6.	182	8
25.	Semba CP, Kato N, Kee ST, Lee GK, Mitchell RS, Miller DC, et al. Acute rupture of the descending thoracic aorta: repair with use of endovascular stent-grafts. J Vasc Interv Radiol 1997;8:337-42.	11	6
26.	Pokela R, Satta J, Juvonen T, Lahtinen J, Mosorin M, Lepojärvi M, et al. Surgical and long-term outcome of graft replacement of aneurysms of the descending thoracic aorta. Analysis of 28 consecutive cases. Scand Cardiovasc J 1997;31:141-5.	28	3
27.	Hayashi J, Eguchi S, Yasuda K, Komatsu S, Tabayashi K, Masuda M, et al. Operation for nondissecting aneurysm in the descending thoracic aorta. Ann Thorac Surg 1997;63:93-7.	120	10

Appendix (online only). Continued.

No.	*Reference*	*Patients, no.*	*rDTAA, no.*
28.	Verdant A, Cossette R, Pagé A, Baillot R, Dontigny L, Pagé P. Aneurysms of the descending thoracic aorta: three hundred sixty-six consecutive cases resected without paraplegia. J Vasc Surg 1995;21: 385-90; discussion 390-1.	366	15

rDTAA, ruptured descending thoracic aortic aneurysm.

[a]Two patients who died preoperatively of rDTAA were excluded.

[b]The following article was used for additional information of the included patients: Doss M, Balzer J, Martens S, Wood JP, Wimmer-Greinecker G, Moritz A, et al. Emergent endovascular stent grafting for perforated acute type B dissections and ruptured thoracic aortic aneurysms. Ann Thorac Surg 2003;76:493-8; discussion 497-8.

[c]The following article was used for additional information of the included patients: Alric P, Berthet JP, Branchereau P, Veerapen R, Marty-Ané CH. Endovascular repair for acute rupture of the descending thoracic aorta. J Endovasc Ther 2002;9 (suppl 2):II51-9.