European Heart Journal (2006) **27**, 489–498
doi:10.1093/eurheartj/ehi493

Endovascular stent–graft placement in aortic dissection: a meta-analysis

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Received 23 June 2005; revised 11 August 2005; accepted 19 August 2005; online publish-ahead-of-print 14 October 2005

See page 384 for the editorial comment on this article (doi:10.1093/eurheartj/ehi665)

KEYWORDS
Aorta;
Dissection;
Stent;
Endovascular;
Prognosis

Aims This article summarizes all available published data with respect to clinical success, complications, and outcomes of endovascular stent–graft placement among patients with descending aortic dissection (AD).

Methods and results We performed a meta-analysis of all published series on retrograde endovascular stent–graft placement encompassing $\geq$3 patients with AD. Thirty-nine studies, involving a total of 609 patients, were included. Procedural success was reported in 98.2 $\pm$ 0.5% of patients. Major complications were reported in 11.1 $\pm$ 1.4%, with the most dreaded neurologic complications in 2.9 $\pm$ 0.7% patients. Periprocedural stroke was encountered more frequently than paraplegia (1.9 $\pm$ 0.6% vs. 0.8 $\pm$ 0.4%). Overall complications were significantly higher in patients undergoing stent–graft placement for acute AD than in patients with chronic AD (21.7 $\pm$ 2.8% vs. 9.1 $\pm$ 2.3%, $P = 0.005$). The overall 30-day mortality was 5.3 $\pm$ 0.9%, and was three-fold higher in patients with acute AD when compared with chronic AD (9.8 $\pm$ 2.2% vs. 3.2 $\pm$ 1.4%, $P = 0.015$). In addition, 2.8 $\pm$ 0.7% of patients died over a mean follow-up period of 19.5 $\pm$ 7.1 months. Kaplan–Meier analysis yielded overall survival rates of 90.6 $\pm$ 1.6% at 6 months, 89.9 $\pm$ 1.7% at 1 year, and 88.8 $\pm$ 1.9% at 2 years, respectively.

Conclusion Endovascular stent–graft placement in type B-AD is technically feasible with success rates of >95% in selected cohort. Although minimally invasive, major complications occurred in 14–18% of patients depending upon the acuity of presentation, with very low incidence of paraplegia. Both, acute and mid-term mortality of this novel treatment strategy appear to favourably compare with surgical treatment but further studies are necessary to compare stent–graft placement with medical treatment in uncomplicated AD.

Introduction

The optimal treatment strategy for patients with aortic dissection (AD) confined to the descending aorta (Stanford type B-AD) remains controversial.[1] Despite remarkably improved operative techniques, surgical resection of the descending thoracic aorta is still associated with high morbidity and mortality.[2] Contemporary operative mortality rates of elective surgery range between 0 and 27%, but may exceed 50% in complicated AD under emergency conditions.[2,3] At present, there is consensus that patients with type B-AD should primarily be treated medically with tight blood pressure control, while reserving surgery for evolving complications [e.g. unrelenting pain, progressive aortic dilatation, malperfusion syndromes, or (imminent) rupture].[1]

Even without complications, the acute and long-term prognosis of type B-AD remains sobering despite optimal medical and surgical therapy.[4] In 1999, the concept of endovascular stent–graft closure of the proximal entry tear was introduced as a novel treatment option for patients with type B-AD.[5,6] Several single-centre reports have shown technical feasibility and clinical safety, but data from larger-scale or multi-centre, controlled trials are not yet available.

The aim of the present meta-analysis was to summarize all available published data with respect to clinical success, complications, and outcomes of endovascular stent–graft placement among patients with AD.

Methods

Data sources and study selection

Using the terms *aorta*, *dissection*, and *stent*, a comprehensive search of the English-language medical literature was performed

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using the MEDLINE database to identify all studies on endovascular stent–graft treatment, which included patients with AD. All articles published between January 1999 and May 2004 was initially considered. Bibliographies of the retrieved articles were hand-searched for additional potentially relevant studies. A multistage assessment was used to determine if articles would qualify for the analysis. At the initial stage, only the abstracts were reviewed. Publications including patients with AD undergoing retrograde endovascular stent–graft placement into the descending thoracic aorta were selected for data extraction. Articles reporting on antegrade, surgical ('open') stent–graft placement via the aortic arch were not included. Case reports were also not included and a minimum series of three patients with AD treated with stent–grafts was required for inclusion. At the second stage, the full text versions of the selected articles were reviewed for data extraction. Multiple reports of previously listed patients were refined for data on the most recent number of patients or data with most information on clinical characteristics or outcomes to avoid duplicate reporting.

Data extraction and statistical analysis

Each article was analysed with respect to 53 predefined variables regarding clinical characteristics, procedural data, in-hospital, and long-term outcomes using a standardized protocol (see Appendix). Extraction of data was performed by the first author (H.E.) and independently verified by co-authors (C.A.N., D.B., S.K., A.S.). Discrepancies in the interpretation of extracted data were resolved by mutual consensus. Articles containing insufficient data (<25% of predefined variables extractable) were excluded from the analysis ($n = 1$). Only data clearly obtained in patients with AD subjected to endovascular stent–graft placement were extracted; data concerning patients with other thoracic aortic pathologies (e.g. thoracic aortic aneurysms) were discarded. Unspecified information was classified as not available. As a result, the number of patients (denominator) varies with the specific variables reported in the analysis.

Rates of events were calculated as the number of events divided by the number of treated patients with available data. The approach to calculate individual rates for different studies and to combine these rates into a weighted average gives identical results if the weights are defined as the proportion of available patients provided in a specific study. To avoid potential underestimation of events owing to the differing patient numbers, a worst case-model was calculated for variables with important clinical impact (i.e. overall complications, major complications, minor complications, neurologic complications, in-hospital mortality, and late mortality). This model assumes that all reported, but unspecified events occurred in dissection patients. Results are presented as mean $\pm$1 standard deviation or median and range, when appropriate. Comparisons between patients with acute and chronic AD were made using the two-sided χ^2 test for categorical variables and two-sided Student's *t*-test for continuous variables. A *P*-value <0.05 was considered statistically significant. No adjustment for multiple testing was applied as the statistical analysis was performed in an exploratory manner. The Kaplan–Meier non-parametric method was used to generate estimates of survival at 30 days, 6 months, 1 year, and 2 years, respectively, and compared using the log-rank test. Only studies reporting the exact time of fatal events were included into Kaplan–Meier analysis. The 30-day mortality of patients undergoing stent–graft placement for acute AD was compared with mortality of medically and surgically treated patients with acute type B-AD from the International Registry on Aortic Dissection (IRAD), as previously described.[7]

Definitions

AD was classified according to the Stanford classification.[8] Dissection was considered an acute event if it occurred within the first 14 days from onset of symptoms, whereas it was considered chronic beyond 14 days.[1] Complications were classified as major, when life-threatening or prompting major therapeutic consequences (e.g. access complications requiring surgical revision), whereas complications that did not require further treatment (e.g. transient renal failure not requiring dialysis) were defined as minor. Procedural success was defined by the technically successful deployment of the endoprosthesis at the intended target location. Any death that occurred suddenly or could not be related to other causes was classified as due to aortic rupture. Re-intervention was defined as the need for any surgical conversion or additional endovascular stent–graft procedures. To evaluate potential influence of operator's experience on outcome, studies were analysed according to the reported total number of patients treated by endovascular stent–graft placement, including dissections and other diseases of the thoracic aorta (e.g. thoracic aortic aneurysms). Centres with a published total number of patients beyond the median (>20 patients) were considered more experienced than those with total numbers below the median. Furthermore, the results of stent–graft placement were analysed in relation to the study publication date. Therefore, studies were categorized into two groups: studies published between 1999 and 2001 representing the early experience and those published between 2002 and 2004.

Results

Study selection

Comprehensive literature search identified 330 citations published within the predetermined time span of the analysis. Of these, 47 studies met the inclusion criteria and were selected for data extraction. Careful review identified seven of these articles as potential duplicate publications. A single publication was excluded for insufficient data.[9] The remaining 39 studies[5,6,10–46] provided the basis for the current analysis comprising of 1007 patients subjected to endovascular stent–graft repair of the thoracic aorta, 609 (60.5%) of which had AD (*Table 1*).

Patient population

Characteristics of the selected patient population are given in *Table 2*. The majority of patients underwent endovascular stent–graft placement for type B-AD (96.0%); 4% of the patients had retrograde type A-AD with an entry tear in the descending aorta. Of note, a substantial proportion of patients (16.1%) had evidence of (contained) aortic rupture as evidenced by periaortic collection of blood and underwent emergency procedures.

Procedural data and in-hospital course

Procedural success was obtained in 98.2 $\pm$ 0.5% of patients (*Table 3*). Emergency surgical conversion was required in 1.1 $\pm$ 0.4% (*Table 3*). In another 1.2 $\pm$ 0.4% of patients, elective surgical conversion was performed during the in-hospital period, accounting for a total in-hospital conversion rate of 2.3 $\pm$ 0.6%. In-hospital complications were reported in 13.6 $\pm$ 1.5% of patients (worst-case estimate: 17.6 $\pm$ 1.4%) (*Tables 3* and *4*). Complications were predominantly of major clinical significance (11.1 $\pm$ 1.4%, worst-case estimate: 10.2 $\pm$ 1.2%), whereas minor complications were reported less frequently (2.5 $\pm$ 0.7%, worst-case estimate: 7.4 $\pm$ 0.9%). The most critical in-hospital complications were related to retrograde extension of the dissection into the ascending aorta (1.9 $\pm$ 0.6%) and neurologic

Table 1 Detailed overview over the analysed reports

Author	Year	Patients with AD (*n*)	Proc. success (*n*)	Emergency conversion (*n*)	Overall complications (*n*)	Major complications (*n*)	Overall neurologic complications (*n*)	Paraplegia (*n*)	30-day mortality (*n*)	Late surgical conversion (*n*)	Aortic rupture during follow-up (*n*)	Late mortality during follow-up (*n*)
Dake[5]	1999	19	19/19	0	4	3	0	0	3	0	0	0
Nienaber[6]	1999	12	12/12	0	0	0	0	0	0	0	0	0
Czermak[10]	2000	7	6/7	0	2	2	0	0	0	1	0	1
Hausegger[11]	2001	5	5/5	0	1	0	0	0	0	0	0	0
Kang[12]	2001	6	6/6	0	0	0	0	0	0	0	0	0
Sailer[13]	2001	7	7/7	0	n.a.	n.a.	0	0	0	0	0	0
Taylor[14]	2001	6	6/6	0	1	1	n.a.	0	1	0	0	n.a.
Tiesenhausen[15]	2001	4	4/4	0	0	0	0	0	0	0	0	0
White[16]	2001	9	9/9	0	0	0	0	0	0	0	0	1
Won[17]	2001	12	10/12	0	n.a.	n.a.	0	0	0	0	0	n.a.
Bortone[18]	2002	12	12/12	0	1	1	0	0	1	0	0	0
Cambria[18]	2002	4	4/4	0	n.a.	n.a.	0	0	0	0	0	n.a.
Duda[20]	2002	5	5/5	1	1	1	0	0	0	0	0	n.a.
Haulon[21]	2002	4	4/4	0	2	2	1	0	2	0	0	0
Herold[22]	2002	18	18/18	0	3	1	0	0	1	0	2	2
Hutschala[23]	2002	9	9/9	0	1	1	1	1	0	0	0	0
Kato[24]	2002	38	38/38	0	9	7	1	0	2	2	1	0
Nienaber[25]	2002	127	127/127	0	4	3	2	1	2	n.a.	3	2
Palma[26]	2002	58	n.a.	2	n.a.	n.a.	n.a.	0	n.a.	3	2	n.a.
Pamler[27]	2002	14	14/14	2	4	3	1	1	0	0	0	1
Quinn[28]	2002	15	15/15	0	3	2	0	0	4	0	0	1
Rousseau[29]	2002	20	20/20	1	2	2	1	0	2	1	1	0
Saccani[30]	2002	3	3/3	0	1	1	0	0	0	0	0	1
Shim[31]	2002	15	14/15	0	0	0	0	0	1	2	0	1
Totaro[32]	2002	25	25/25	1	n.a.	n.a.	0	0	0	0	0	0
Balzer[33]	2003	8	7/8	0	n.a.	n.a.	0	0	0	0	0	0
Beregi[34]	2003	12	11/12	0	4	2	1	0	2	0	1	1
Fattori[35]	2003	22	22/22	0	1	1	0	0	1	2	1	0
Gerber[36]	2003	3	3/3	0	1	1	0	0	1	0	0	0
Grabenwöger[37]	2003	11	11/11	0	2	2	1	1	0	0	0	0
Krogh-Sorensen[38]	2003	3	3/3	0	0	0	0	0	0	0	0	0
Lambrechts[39]	2003	11	11/11	0	n.a.	n.a.	0	0	0	0	0	2
Lonn[40]	2003	20	20/20	0	10	10	5	1	3	0	0	0
Lopera[41]	2003	10	9/10	0	2	2	1	0	0	0	2	1
Matravers[42]	2003	9	8/9	0	1	1	0	0	2	0	1	0
Nienaber[43]	2003	11	11/11	0	1	1	0	0	0	0	0	0
Ramaiah[44]	2003	20	20/20	0	n.a.	n.a.	n.a.	0	n.a.	0	0	n.a.
Ianelli[45]	2004	8	8/8	0	n.a.	n.a.	0	0	0	0	0	0
Scheinert[46]	2004	7	7/7	0	n.a.	n.g.	n.a.	0	n.a.	1	0	0
All		609	543/551 (98.5%)	7/609 (1.2%)	61/449 (13.6%)	50/449 (11.1%)	15/518 (2.9%)	5/609 (0.8%)	28/524 (5.3%)	12/482 (2.5%)	14/609 (2.3%)	14/504 (2.8%)

Table 2 Patient characteristics

	Data available (*n*)	Number of events or cases (*n*%)
Total numbers of studies included	39	–
Total number of patients reported	1007	–
Number of patients with AD	609	60.5%
Number of patients with AD per study	39	11 (3–127)[a]
Patient age (years)	442	61.0
Male gender	240	182 (75.8 ± 2.6%)
Acute dissection	427	248 (58.1 ± 1.8%)
Presenting with rupture	491	79 (16.1 ± 1.2%)

[a]Median.

Table 3 In-hospital data

	Data available (*n*)	Number of events (*n*%)
Procedure success	551	543 (98.5 ± 0.5%)
Number of stent-grafts per patient	261	1.3
Surgical conversion	609	7 (2.3 ± 0.6%)
Adjunctive endovascular procedures	324	5 (1.5 ± 0.6%)
Overall complications	449	61 (13.6 ± 1.5%)
Major complications	449	50 (11.2 ± 1.4%)
Minor complications	449	11 (2.4 ± 0.7%)
Procedure-related complications	429	29 (6.8 ± 1.2%)
Retrograde type A-AD	429	8 (1.9 ± 0.6%)
Access complications	429	10 (2.3 ± 0.7%)
Neurologic complications	518	15 (2.9 ± 0.7%)
Stroke	518	10 (1.9 ± 0.6%)
Paraplegia	609	5 (0.8 ± 0.4%)
In-hospital mortality	524	27 (5.2 ± 0.9%)
In-hospital mortality, procedure related	397	9 (2.3 ± 0.7%)
In-hospital mortality, non-procedure related	397	16 (4.0 ± 0.9%)
30-day mortality	524	28 (5.3 ± 0.9%)

Table 4 Worst-case estimates

	Data available (*n*)	Number of events (*n*)
Overall in-hospital complications	585	103 (17.6 ± 1.4%)
Major complications during index hospitalization	585	60 (10.2 ± 1.2%)
Minor complications during index hospitalization	585	43 (7.4 ± 0.9%)
Neurologic complications during index hospitalization	609	21 (3.4 ± 0.7%)
Stroke	609	16 (2.6 ± 0.6%)
In-hospital mortality	609	38 (6.2 ± 0.9%)
Additional late mortality over 19.5 ± 7.1 months	609	25 (4.1 ± 0.9%)

complications (2.9 ± 0.7%, worst case estimate: 3.4 ± 0.7%). Concerning neurologic complications, periprocedural stroke occurred in 1.9 ± 0.6% of patients (worst-case estimate: 2.6 ± 0.6%), whereas paraplegia was encountered in five of the 609 (0.8 ± 0.4%) patients.

Twenty-seven of 524 patients with available data died during the in-hospital period (*Table 3*), yielding an overall in-hospital mortality rate of 5.2 ± 0.9% (worst-case estimate: 6.2 ± 0.9%, *Table 4*). Within the 30-day period, there was one additional death, yielding a 30-day (operative) mortality rate of 5.3 ± 0.9%.

Follow-up data

Some follow-up information was available for all 609 patients (*Table 5*). However, the time to follow-up (mean 19.5 ± 7.1 months) was available for only 561 patients. False lumen thrombosis was reported in 75.5 ± 2.4% of patients (*Table 5*). In 2.5 ± 0.7% patients, late surgical conversion was required, and in addition, 4.6 ± 0.9% of patients adjunctive endovascular stent–graft procedures were performed. Thus, the total re-intervention rate was 11.9 ± 0.2% over the follow-up period of 19.5 ± 7.1 months, including the index hospitalization.

Table 5 Follow-up data over 19.5 ± 7.1 months after stent–graft placement

	Data available (*n*)	Number of events (*n*)
Duration of follow-up (months)	561	19.5 ± 7.1
False lumen thrombosis	237	179 (75.5 ± 2.4%)
Late surgical conversion	482	12 (2.5 ± 0.7%)
Adjunctive endovascular procedures	511	24 (4.6 ± 0.9%)
Late complications	442	18 (4.1 ± 0.8%)
Late mortality	504	14 (2.8 ± 0.7%)

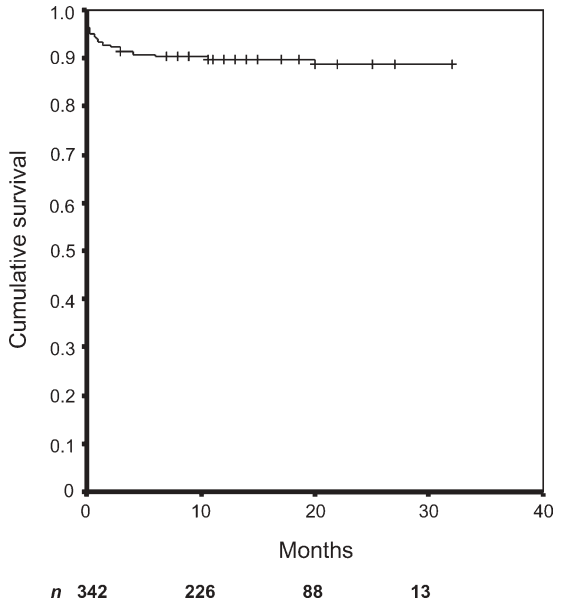

Figure 1 Kaplan–Meier estimate of overall survival.

Aortic rupture occurred in 2.3 ± 0.6% of patients during follow-up. A total of 2.8 ± 0.7% of patients (all cause mortality) died (worst-case estimate 4.1 ± 0.9%) during follow-up. *Figure 1* shows survival rates for all patients in whom the exact time to death was available in Kaplan–Meier format. The survival rates were 93.3 ± 1.4% at 30 days, 90.6 ± 1.6% at 6 months, 89.9 ± 1.7% at 1 year, and 88.8 ± 1.9% at 2 years, respectively.

Results of stent—graft placement in relation to publication date

Reported technical success rates were lower in the early studies published between 1999 and 2001 when compared with more recent studies published between 2002 and 2004 (*Table 6*). In contrast, overall complications and neurologic complication rates in particular were higher in the more recently published studies. There was no difference in operative or 1 year-mortality between both groups (*Table 6*).

Influence of operator's experience

There was evidence of an influence of operator's experience and expertise on the in-hospital outcome. Centres with a total number of patients beyond the median had better results than centres with low numbers of treated patients (*Table 7*).

Acute vs. chronic dissection

Of the total 39 studies, 36 specified whether patients underwent stent–graft placement for acute or chronic AD (*Table 7*). Most studies (56%) reported on the treatment of patients with both acute and chronic AD. Twelve (33%) studies reported exclusively on patients with acute AD, whereas 4 (11%) only on patients with chronic dissections. Although significantly younger, in-hospital complications were documented more often in patients undergoing stent–graft placement for acute AD when compared with patients with chronic AD (21.7 ± 2.8% vs. 9.1 ± 2.3%, $P = 0.005$, *Table 7*). Particularly, major complications were reported more frequently in patients with acute AD (14.5 ± 2.6% vs. 7.9 ± 2.1%, $P = 0.124$, *Table 7*). *Figure 2* depicts the 30-day mortality in patients with acute type B-AD undergoing stent–graft placement in comparison with medically and surgically treated type B-AD patients derived from IRAD.[7] The 30-day mortality of patients undergoing stent–graft treatment for acute AD was higher than for chronic AD (9.8 ± 2.2% vs. 3.2 ± 1.4%, $P = 0.015$, *Figure 3*), but failed to differ anymore at 1 year after stent–grafting ($P = 0.088$ vs. chronic AD). The overall survival rates for patients with acute AD were 90.2 ± 2.2% at 30 days, 87.4 ± 2.1% at 6 months, and remained at 87.4 ± 2.1% at 2 years, respectively. Survival rates for patients with chronic AD were 96.8 ± 1.4% at 30 days, 94.3 ± 1.9% at 6 months, 92.7 ± 2.1% at 1 year, and 91.1 ± 2.6% at 2 years, respectively (Table 8).

Discussion

At present, most institutions favour a 'complication-specific' approach for type B-AD patients with medical anti-hypertensive treatment and the use of beta-blockers as the primary therapy, whereas reserving surgery for recurrent pain, life-threatening complications, or rapid aortic expansion.[1] The concept of the third available treatment option, i.e. endovascular stent–graft placement, was propelled by the desire to induce aortic remodelling by sealing the proximal entry tear, at the same time avoiding the risks associated with open surgery.[47] This rationale was originally based on the clinical observation that patients with spontaneous thrombosis of the false lumen have a better long-term prognosis than without.[4] Conversely, persistent perfusion of the false lumen has been identified as an independent predictor of progressive aortic enlargement and adverse long-term outcome.[48] Nevertheless, spontaneous thrombosis of the false lumen is a rare observation (≤4% of patients)[4] and most often requires surgical interventions to exclude it from the true lumen.

Table 6 Results of stent-graft placement in relation to publication date

	Data available (*n*)				*P*
	Publication date 1999–2001 (*n* = 87)		Publication date 2002–2004 (*n* = 522)		
Number of publications		10		29	–
Patients/center (median)		9 (5–19)		18 (3–127)	–
Procedural success	87	96.6 ± 1.8%	464	98.9 ± 0.4%	<0.001
Overall complications	68	11.8 ± 3.7%	381	13.9 ± 1.6%	<0.001
Neurologic complications	81	0%	437	3.4 ± 0.8%	<0.001
30-day mortality	69	4.3 ± 2.5%	273	7.3 ± 1.6%	0.38[a]
1-year survival	69	92.7 ± 3.1%	273	89.4 ± 1.9%	0.40[a]

[a]Log-rank test.

Table 7 Influence of endovascular experience

	Data available (*n*)				*P*
	Endovascular experience ≤20 patients (*n* = 211)		Endovascular experience >20 patients (*n* = 398)		
Number of centers		10		29	–
Patients/center (median)		14 (4–20)		31 (22–127)	–
Procedural success	211	98.1 ± 0.9%	340	98.8 ± 0.5%	<0.001
Overall complications	196	20.9 ± 2.7%	261	7.7 ± 1.6%	<0.001
Neurologic complications	211	5.7 ± 1.5%	307	1.0 ± 0.5%	<0.001
30-day mortality	211	8.5 ± 1.8%	313	3.2 ± 1.0%	<0.001[a]
1-year survival	186	88.0 ± 2.4%	156	92.2 ± 2.2%	0.13[a]

[a]Log-rank test.

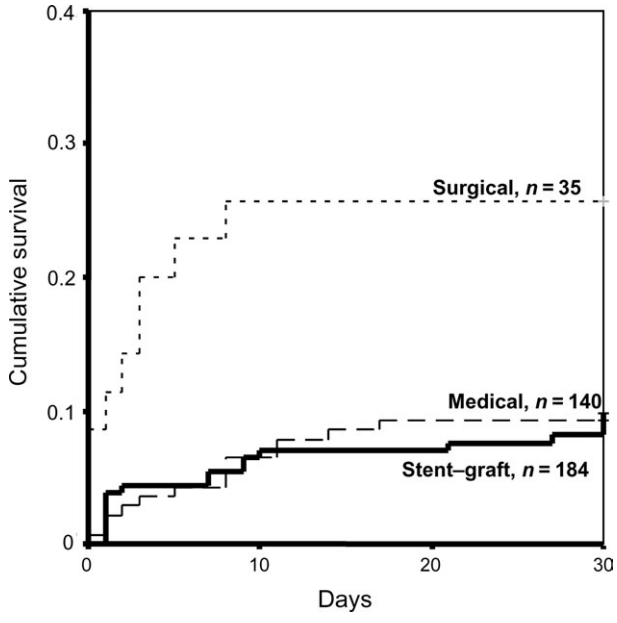

Figure 2 Kaplan–Meier estimates of 30-day mortality of patients with acute type B-AD (——, $n = 184$) in comparison with medically (– – –, $n = 140$), and surgically (-----, $n = 35$) treated patients derived from IRAD.[7]

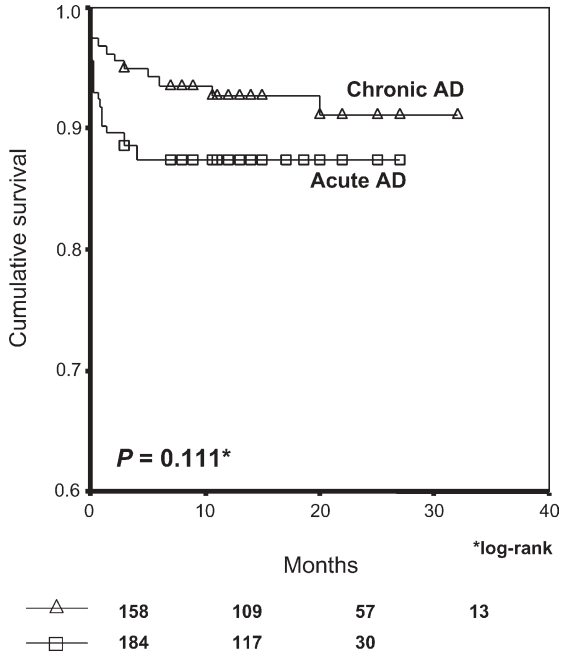

Figure 3 Kaplan–Meier estimates of survival of patients undergoing stent-graft placement for acute AD (□) in comparison to patients with chronic AD (△).

Our meta-analysis encompassing 609 type B-dissection patients demonstrates that endovascular stent–graft treatment of AD is feasible and can be performed with technical success rates of >95%. Furthermore, the acute and mid-term survival of about 90% at 2 years following stent–graft placement appear to favourably compare with medically and surgically treated type B-AD patients, although, in the absence of randomization-direct comparison with medical and

Table 8 Comparison of acute vs. chronic dissection

	Data available (n)				P
	Acute AD ($n = 248$)		Chronic AD ($n = 197$)		
Age (years)	192	59.7 ± 5.7	94	67.7 ± 7.0	<0.001
Male gender	123	78.9 ± 3.4%	78	74.4 ± 4.4%	0.570
Procedure success	213	93.4 ± 0.9%	174	96.0 ± 1.2%	0.381
In-hospital surgical conversion	213	1.4 ± 0.7%	174	2.3 ± 1.0%	0.787
Overall complications	180	21.7 ± 2.8%	132	9.1 ± 2.3%	0.005
Major complications	166	14.5 ± 2.6%	126	7.9 ± 2.1%	0.124
Minor complications	157	6.4 ± 1.7%	120	1.7 ± 1.1%	0.142
Procedure-related complications	157	8.3 ± 2.0%	120	8.3 ± 2.3%	0.838
Retrograde type A-AD	171	1.8 ± 0.9%	146	3.4 ± 1.4%	0.558
Access complications	157	3.8 ± 1.3%	120	1.7 ± 1.1%	0.484
Neurologic complications	188	2.1 ± 1.0%	166	1.8 ± 0.9%	0.868
Stroke	188	1.1 ± 0.7%	166	1.2 ± 0.7%	0.705
Paraplegia	234	0.9 ± 0.6%	174	0.5 ± 0.5%	0.796
30-day mortality	184	9.8 ± 2.2%	158	3.2 ± 1.4%	0.015[a]
1-year survival rate	117	87.4 ± 2.1%	109	92.7 ± 2.1%	0.088[a]

[a]Log-rank test.

surgical treatment strategies is not possible as patient selection may differ. However, despite higher incidence of aortic rupture, the outcomes of stent–graft placement appear to be in the range of medically treated patients which—at least—suggests that stent–graft placement is not associated with increased mortality.

Neurologic complications and paraplegia in particular remain the most dreadful potential complications of stent–graft placement as for surgical repair of type B dissection. At present, the exact mechanism is not completely understood; however, occlusion of numerous critical intercostal arteries (Adamkiewicz artery) by stent–grafts is commonly believed to determine an increased risk of paraplegia.[35] Particularly simultaneous abdominal and thoracic aortic repair with loss of lumbar and intercostal arteries appears to pose an increased risk of spinal cord damage caused by insufficient collateral circulation.[49] Our analysis shows that the overall risk of neurologic complications with stent–grafting ranges between 2.9 and 3.4%. The 1% risk of paraplegia appears to be remarkably low, considering that contemporary studies have suggested the risk of paraplegia after surgical repair of the descending thoracic aorta to be between 7 and 36%.[2] Data on perioperative stroke following surgical repair of type B-AD are less well known. Our data demonstrate that stroke occurred in 1.9–2.6% of patients following stent–graft treatment. It is commonly believed that stroke occurs because of manipulation of guidewire or stent–graft delivery system within the aortic arch. Further technical developments and miniaturization of the relatively rigid stent–graft devices will hopefully help to reduce the risk of periprocedural stroke.

Although the favourable survival and the low incidence of neurologic complications appear to be somewhat encouraging in these initial experiences, it should be noted that in-hospital complications were encountered in 14–18% of patients. About half of these complications were related directly to the procedure itself. Patients undergoing stent–graft placement for acute dissections were found to be at higher risk of death and major complications than those with chronic AD despite their younger age. However, it should be recognized that in patients with acute AD implantation of stent–grafts is often prompted by complications of the dissection making the acute AD patients more prone for higher complications and lower survival when compared with stable patients with chronic AD undergoing elective stent–graft placement.

Our analysis suggests a strong influence of operator's experience on the results of stent–graft placement. Centres that reported an overall endovascular experience of more than 20 patients treated with stent–grafts had significantly higher success rates and fewer complications than less experienced centres. Over time, technical success rates have improved. At the same time, however, overall complications and neurologic complications in particular have increased. One may speculate that with growing confidence in the technical performance, the indication of stent–graft placement has been gradually expanded to treat high-risk patients who are more prone for complications.

With growing experience in endovascular stent–graft treatment the spectrum of acute and mid-term complications has broadened to include potentially disastrous events, other than paraplegia or stroke.[50] Anecdotal case reports have highlighted the risk of retrograde extension of the dissection into the ascending aorta, potentially caused by stent–graft induced intimal injury.[51] This analysis demonstrates that retrograde type A-AD occurs in about 2% of patients during the in-hospital period, and occurs in a similar proportion during the follow-up. This emphasizes the importance of lifelong clinical and imaging surveillance following endovascular stent–graft treatment.

Our meta-analysis highlights some other technical limitations of endovascular stent–graft placement in type B-AD. Stent–grafting fails to abolish the false lumen in about a quarter of patients suggesting that it perhaps may not be a definitive treatment for type B-AD. Even in the presence of thrombosed thoracic false lumen, the distal thoracic or abdominal aorta may enlarge during follow-up. Thus, there is a continued risk of aortic rupture (about 2% during

follow-up) after stent–graft placement and a need for adjunctive stent–graft placement or conversion to open surgery in about 12% of patients over time. Nevertheless, the incidence of aortic rupture and the need of repeat endovascular or surgical interventions may also be related to progression of the disease itself, and may not necessarily reflect treatment failure. This is supported by the fact that 11–20% and 10–44% of type B-AD patients need repeat surgery when treated medically or surgically, respectively.[2,48]

Strengths and limitations

Our analysis is the first to provide an overview of the currently available literature on endovascular stent–graft placement in type B-AD, an emerging treatment option for this potentially lethal disease. Although not prospective and randomized comparison with other treatment strategies for patients with type B-AD, it provides an important insight into the technical success, its potential advantages and complications, and survival rates. Nevertheless, our analysis should be viewed in the light of its limitations. This meta-analysis is a selection of patients from relatively small, observational series that may represent a selected group of patients rather than a representative set of patients with AD. The predominance of reported major complications may reflect a selection bias. So far, only short- to mid-term follow-up data are available. Long-term outcomes need to be evaluated. The currently available data on follow-up outcomes also fail to provide morphological follow-up and rather focus on clinical endpoints. A distinction between a careful morpho-anatomical long-term surveillance and a clinical prognostic follow-up is missing and greatly awaited to analyse any causal relationship between morphology (successful stent–graft-induced aortic reconstruction) and outcomes of patients.

Conclusion

Our meta-analysis suggests that stent–graft placement of type B-AD is feasible with technical success rates of >95%. Although challenges remain, our analysis suggests favourable neurologic complication and survival rates when compared with those previously reported for surgical treatment of AD. Nevertheless, our data highlight an urgent need to assess the efficacy of currently available therapeutic options for patients with type B-AD, i.e. medical therapy, surgery, and stent–graft placement, in future randomized clinical trials.

Acknowledgement

Dr Eggebrecht was supported by a research grant from the University Duisburg-Essen (IFORES 10+2).

Conflict of interest: none declared.

Appendix

List of variables abstracted from each article (if available)

Patient characteristics
- Number of patients with dissection
- Total number of patients reported
- Age
- Gender
- Type of dissection
- Acuity of dissection
- Presence of (contained) aortic rupture
- Cardiovascular risk factors
- Medical comorbidities

In-hospital data
- Overall complications
- Major complications
- Minor complications
- Procedure-related complications
- Retrograde type A-dissection
- Access complications
- Myocardial complications
- Renal complications
- Visceral complications
- Pulmonary complications
- Overall neurologic complications
- Paraplegia
- Stroke
- Need for early surgical conversion
- Adjunctive endovascular procedure
- Length of intensive care unit stay
- Length of hospital stay
- Overall in-hospital mortality
- Aorta-related mortality
- Non-aorta related mortality

Procedural data
- Use of general anesthesia
- Number of stent-grafts per patient
- Stent-graft diameter
- Stent-graft length
- Procedure success
- Need for emergent surgical conversion
- Procedure time
- Fluoroscopy time
- Amount of contrast media

Follow-up data
- Duration of follow-up
- Need for late surgical conversion
- Adjunctive endovascular procedure during follow-up
- Late complications
- Late neurologic complications
- Late retrograde type A-dissection
- Aortic rupture during follow-up
- False lumen thrombosis
- Stent migration
- Shrinkage of false lumen diameter
- Increase of true lumen diameter
- 30-day mortality
- Overall late mortality during follow-up
- Aorta-related late mortality
- Non-aorta related late mortality

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