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A systematic review and meta-analysis of retrograde type A aortic dissection after thoracic endovascular aortic repair in patients with type B aortic dissection

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Abstract

Background: Retrograde type A dissection (RTAD) is a devastating complication of thoracic endovascular repair (TEVAR) with low incidence but high mortality. The objective of this study is to report the incidence, mortality, potential risk factors, clinical manifestation and diagnostic modalities, and medical and surgical treatments.

Methods: A systematic review and single-arm and two-arm meta-analyses evaluated all published reports of RTAD post-TEVAR through January 2021. All study types were included, except study protocols and animal studies, without time restrictions. Outcomes of interest were procedural data (implanted stent-grafts type, and proximal stent-graft oversizing), the incidence of RTAD, associated mortality rate, clinical manifestations, diagnostic workouts and therapeutic management.

Results: RTAD occurred in 285 out of 10,600 patients: an estimated RTAD incidence of 2.3% (95% CI: 1.9–2.8); incidence of early RTAD was approximately 1.8 times higher than late. Wilcoxon signed-rank testing showed that the proportion of RTAD patients with acute type B aortic dissection (TBAD) was significantly higher than those with chronic TBAD (P = .008). Pooled meta-analysis showed that the incidence of RTAD with proximal bare stent TEVAR was 2.1-fold higher than with non-bare stents: risk ratio was 1.55 (95% CI: 0.87–2.75; P = .13). Single arm meta-analysis estimated a mortality rate of 42.2% (95% CI: 32.5–51.8), with an I^2 heterogeneity of 70.11% (P < .001).

Conclusion: RTAD is rare after TEVAR but with high mortality, especially in the first month post-TEVAR with acute TBAD patients at greater risk as well as those treated with proximal bare stent endografts.

Abbreviations: CI = confidence interval, CT = computed tomography, ICU = intensive care unit, RR = risk ratio, RTAD = retrograde type A dissection, TBAD = type B aortic dissection, TEVAR = thoracic endovascular repair.

Keywords: complication, meta-analysis, retrograde type A aortic dissection, TEVAR.

1. Introduction

Aortic dissection generally has a high rate of mortality if untreated; with Type A aortic dissection particularly, 30-day mortality can be as high as 90%.[1] The true incidence of aortic dissection is not well known, but with the advent of new diagnostic modalities over the last decade, estimations have dramatically risen.[2,3] Annually, 5 to 10 people per million experience an aortic dissection in the United States with 43,000 to 47,000

SA-H-A-S and NH contributed equally to this work.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Since our study is based on already published literature with no interaction with human subjects, no issues related to medical ethics were needed to be reported.

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lives claimed due to the involvement of the aorta and its branches.[4,5]

The condition is conventionally classified as Stanford Types A or B, with the latter involving the descending aorta. New classifications – such as TEM (Type of dissection, location the primary Entry, and Malperfusion) and the Society for Vascular Surgeons reporting standards – have further clarified the extent of the disease process and improved awareness of the disease mechanism to guide decision making and predict outcomes.[6,7] Acute Type B aortic dissection (TBAD) is an uncommon condition involving the descending aorta that remains a challenging problem for cardiothoracic and vascular surgeons as well as interventional radiologists whereas treatment of chronic TBAD can vary between medical and surgical therapies.[8–10]

Conventionally, patients with uncomplicated TBAD receive medical treatment, while evidence progressively support thoracic endovascular aortic repair (TEVAR) as the preferred treatment for complicated and some high-risk TBAD according to Society for Vascular Surgeons guidelines.[7,11] While endovascular techniques were initially used for patients not indicated for conventional surgery, indications have rapidly expanded owing to recent clinical progress over the last decades.[12] Increasing evidence shows positive TEVAR outcomes with acceptable protection against aorta-related death in mid-term follow-up. TEVAR stabilizes the dissected aorta and prevents late complications by expanding the true lumen, inducing both false lumen thrombosis and aortic wall remodeling. In comparison with traditional open aortic surgery, TEVAR has the benefits of fewer complications, smaller incisions, and shorter length of hospital stay which explains the reason that it is currently the preferred treatment for complicated TBAD.[13]

TEVAR is still linked with major complications such as acute or delayed retrograde Type A dissection (RTAD), stroke, bowel infarction, access-related complications, paraplegia, endoleaks, limb ischemia, or wound infection.[14] RTAD is a devastating complication of this procedure with a low incidence, but mortality rates exceed 40%.[15] A wide range of studies on RTAD post-TEVAR have reported small numbers of patients with unclear diagnostic and therapeutic approaches. Different etiologies have been proposed for RTAD but is essentially due to unfavorable interaction between the stent-graft and dissecting membrane that can produce a new primary entry tear and lead to rupture of the membrane. Interpretation is complicated by heterogeneity of data quality, definitions and the reported parameters; as well by its broader relation to any stent graft-induced aortic wall injury and to other iatrogenic injury in non-dissections.[13,16–18] RTAD is also sometimes referred to as proximal SINE (to complement distal stent-graft-induced new entry).[19]

We conducted this comprehensive systematic review and single-arm and two-arm meta-analyses to identify all published reports on RTAD post-TEVAR with the intention of recording the incidence, mortality, potential risk factors, clinical manifestation and diagnostic modalities, and medical and surgical treatments. The findings might assist in designing appropriate clinical strategies to minimize occurrence and diagnose and treat this complication early and effectively in the hope of improving future procedural safety and outcomes.

2. Methods

This is a systematic review carried out according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (see Table S1, Supplemental Digital Content, http://links.lww.com/MD/I478, which illustrates PRISMA 2020 checklist).[20] We used the PICOS strategy (population, intervention, comparison, outcomes, and design of studies) to formulate the research question and eligibility criteria:

Population: patients with Type B aortic dissection
Intervention: thoracic endovascular aortic repair
Comparators: none
Outcome: incidence of RTAD, re-intervention and its types, mortality of RTAD
Study design: all study designs except for study protocols, animal studies.

To eliminate the risk of analyzing the same patients more than once, the studies were assessed and duplicate publications and overlapping reports were removed. Extensive effort was made to minimize the impact of covert duplicate or metachronous re-publication from the same groups or patient cohorts; for these cases, only the latest report was included.

The search was conducted in PubMed, Cochrane Central, Embase, and Web of Science databases through January 2021.[21,22] The search terms included "TEVAR," "retrograde dissection," "thoracic stent-graft," "endograft," and "graft" with the Boolean operator "OR," was restricted to English-language results and with no limits on date of publication. All retrieved results were assessed and screened to obtain additional relevant articles not indexed in common databases.

To be included in the meta-analysis, publications had to meet all the following inclusion criteria: (1) Articles reporting complications of RTAD post-TEVAR among those who underwent endovascular repair or hybrid repair of thoracic aortic pathology; (2) Diagnosis of aortic pathology made by computed tomography (CT) imaging of the thorax, abdomen, or pelvis; (3) Series with more than 5 patients with TEVAR; (4) Demographic data and comorbidities of the patients; (5) At least one of the basic outcome criteria (number of patients with TEVAR, number of patients with RTAD, or mortality of RTAD).

After first screening of titles and abstracts in selected electronic databases, the full texts of appropriate studies were evaluated and their data were extracted by three investigators (SAHS, NH, and MMO) independently. Discrepancies among these investigators were resolved through discussions with a senior author (HE). The following data for each study were extracted: study characteristics, patient characteristics, studies quality, aortic pathology, procedural data (implanted stent-grafts type, and proximal stent-graft oversizing), mean follow-up period, number of patients with RTAD, re-intervention and its types, and RTAD mortality rate.

Since our study is based on already published literature with no interaction with human subjects, no issues related to medical ethics were needed to be reported.

2.1. Definition of extracted data

Regular and irregular imaging follow-up period was considered as ≥ 3 thoracic CTs after TEVAR and < 3, respectively. Aortic dissection was described as an acute event if it occurred within the first 14 days from the onset of symptoms, and chronic beyond 14 days. Postoperative mortality was defined as all death events occurred during follow-up. Early RTAD or early mortality was considered if occurred within the first 3 months from the TEVAR procedure, while late RTAD or late mortality occurred after 3 months from the TEVAR procedure.[23,24]

2.2. Statistical analysis

For the single-arm meta-analysis, analyses of proportions were conducted for data using a random effects model to calculate pooled incidences of RTAD and mortality rates and their confidence intervals (CI) using per protocol and intention to treat data when available. For the two-arm meta-analysis, dichotomous data were presented as risk ratios (RR) and continuous data as weighted mean differences. Summary effect measures were presented along with their corresponding 95% CIs. Statistical heterogeneity was evaluated with the I^2 statistic. I^2 value between 0% and 25% indicates insignificant heterogeneity, 26% and 50% low heterogeneity, 51% and 75% moderate heterogeneity, and 76% and 100% high heterogeneity. When I^2 was < 50%, a fixed-effects model was used and when it was > 50%, a random-effects model. For the analysis of other data that were not included in the meta-analysis, the data were analyzed using the statistical package IBM SPSS version 26.0 (Statistical Package for the Social Sciences, Chicago, IL). The categorical variables are expressed as proportions and frequencies. The continuous variables are summarized as mean ± standard-deviations. Also, in order to explore the independent nature of some categorical variables, Chi-square or exact Fisher test were used. Normality of numerical variables was checked using the Kolmogorov Smirnov test. *t*-test or Wilcoxon test were applied for comparing of two related groups. One-way ANOVA, Kruskal Wallis and Friedman tests also were implemented based on the normality test for more than two-group comparisons. A *P* value less than .05 was considered statistically significant in all analyses.

3. Results

The literature search yielded 1963 potentially eligible articles. After considering our selection criteria, 78 eligible clinical studies[4,5,8,10,12,14,17,25–95] published between 2002 and 2020 were enrolled in the qualitative and quantitative analysis (Fig. 1). Of the total included records, 59, 10, and 9 studies were single-center, national multi-center, and international multi-center studies, respectively (Table 1). Most of the studies were conducted in Europe (31/78 studies; 39.7%) and Asia (26/78 studies; 33.3%). Sixteen studies (20.5%) were conducted in North America, one in South America, and four were multi-continental studies. The studies were assigned into two categories according to the number of TBAD patients undergoing TEVAR during the study period. Thirty-nine studies (50%) with 1321 patients, and 39 (50%) with 9279 cases had < 50 and > 50 cases, respectively.

Table 2 summarizes the demographic and perioperative characteristics of 10,600 TBAD patients who underwent TEVAR. Patient populations ranged from 5 to 852, with a mean age of 57.4 years, 77.8% being male. Hypertension (83.4%) and smoking (47.7%) were the leading underlying diseases. Preoperative details are summarized in supporting information (see Table S2, Supplemental Digital Content, http://links.lww.com/MD/I479, which illustrates reported risk factors for RTAD). A majority of cases were acute TBAD: in 61/78 reports (n = 6741), 4049 cases (60%) were specified as acute TBAD; in 59 reports (n = 6686), 2997 cases (44.8%) were chronic TBAD. However, 17 and 19 studies, respectively, did not specify TBAD chronicity (see Table S3, Supplemental Digital Content, http://links.lww.com/MD/I480, which illustrates TBAD chronicity).

Of patients who experienced RTAD, mean age was 56.6 years and 85.7% were male. Hypertension (86.2%) was the most common comorbidity for RTAD, followed by smoking (65.6%), pulmonary disease (17.0%), Marfan syndrome (15.5%), renal impairment (14.6%), diabetes mellitus (14.2%), and coronary artery disease (12.5%) (Table 2).

Table 3 presents TEVAR details and the stent-grafts used in each study. From 50 enrolled studies, proximal bare stents were used in 3033 (66%) and proximal non-bare stents in 1569 cases (34%).

RTAD occurred in 285 cases out of 10,600 patients, representing an estimated RTAD incidence of 2.3% (95%

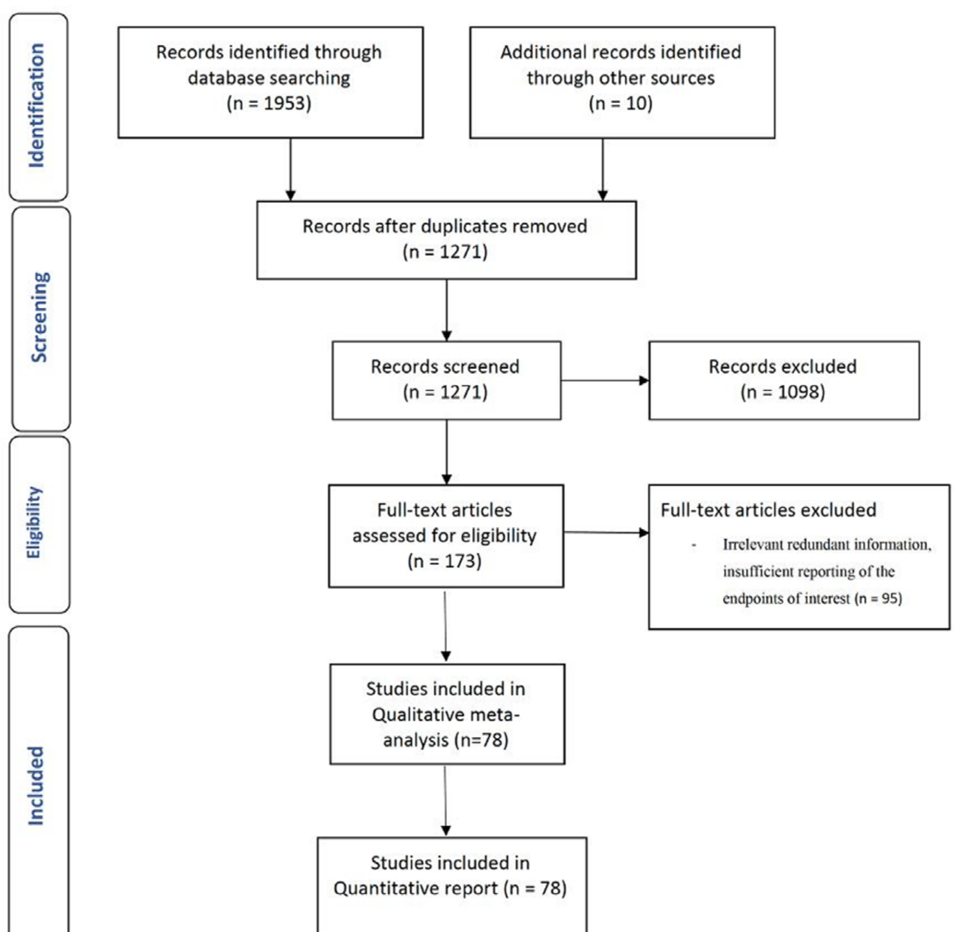

Figure 1. PRISMA flow chart of the study.

Table 1

Details and characteristics of studies reporting retrograde type A dissection after thoracic endovascular aortic repair.

First author	Year	Duration	Geography	Center		Mean follow-up (mo)	TEVARs (n)	RTAD (n)	Age (yr)		Male sex (%)	
									TEVAR	RTAD	TEVAR	RTAD
Czermak[25]	2002	(1996–2001)	Austria	Innsbruck	SC	17.8	5	1	51.12	43	NR	NR
Kato[26]	2002	(1997–2001)	Japan	Mie, Matsusaka	SC	27	28	1	66.6	NR	22	NR
Palmer[27]	2002	(1999–2001)	Germany	Ulm	SC	14	14	2	60.3	47.5	12	2
Fattori[28]	2003	(1997–2002)	Italy	Bologna	SC	25	22	2	NR	NR	NR	NR
Grabenwoger[29]	2004	(1996–2003)	Austria	Vienna	SC	NR	20	1	NR	NR	NR	NR
Hansen[30]	2004	(1998–2003)	USA	Torrance	SC	24	24	1	69 (43–86)	NR	NR	NR
Lee[31]	2004	(1994–2002)	South Korea	Seoul	SC	34	37	1	NR	NR	NR	NR
Dong Xu[32]	2005	(2001–2004)	China	Beijing	SC	32	24	3	NR	NR	NR	NR
Fattori[33]	2006	(1996–2004)	Italy, Germany, France, Netherlands, etc.	Multicenter	IMC	24	180	2	NR	NR	NR	NR
Duebener[34]	2007	(2000–2006)	Germany	Luebeck	SC	38	13	1	59.5	NR	10	NR
Zipfel[35]	2007	(1999–2005)	Germany	Berlin	SC	23	57	1	62	38	43	0
Kpodonu[36]	2008	(2000–2006)	USA	Pennsylvania	NMC	NR	91	6	NR	69	NR	3
Neuhauser[14]	2008	(1997–2007)	Austria	Innsbruck	SC	43	28	5	NR	65	NR	4
Dong[37]	2009	(2000–2007)	China	Shanghai	SC	26	443	11	NR	43	NR	NR
Chiesa[38]	2011	(1999–2011)	Italy	Milan	SC	NR	188	3	NR	NR	NR	NR
Kim[39]	2011	(2002–2009)	USA	Torrance	SC	12.4	41	3	67.6	NR	31	NR
Oberhuber[40]	2011	(1999–2011)	Germany	Ulm	SC	12.7	19	1	60	NR	17	NR
Parsa[41]	2011	(2005–2009)	USA	North Carolina	SC	27	51	2	57	NR	37	NR
Wiedemann[4]	2013	(1996–2010)	Austria	Vienna	SC	52	80	3	59	NR	58	NR
Lotfi[42]	2013	(1997–2011)	UK	London	SC	15	11	3	NR	NR	NR	NR
Wiedemann[5]	2014	(1999–2011)	Austria, France, Italy, Spain, USA	Multicenter	IMC	37	110	6	61	NR	86	NR
Faure[43]	2014	(2000–2011)	France	Montpellier	SC	12.2	41	1	66	NR	34	NR
Idrees[44]	2014	(2000–2012)	USA	Cleveland, Ohio	SC	48	766	15	NR	65	NR	NR
Zhang[45]	2014	(1998–2012)	China	Shanghai	SC	58.4	252	2	54.1	NR	206	NR
Gorlitzer[46]	2012	(2005–2011)	Austria, Switzerland	Vienna, Bern	IMC	NR	29	4	NR	62	NR	2
Huang[47]	2013	(2004–2011)	China	Guangzhou	SC	NR	563	4	54.09	62.75	485	3
Cochernnec[48]	2013	(2004–2011)	France	Creteil	SC	24.5	17	4	60	63.75	11	2
Shuyang Lu[49]	2012	(2006–2011)	China	Shanghai	SC	34.79	419	9	NR	56.6	277	6
Yang[50]	2012	(2006–2011)	Taiwan	Taipei	SC	24.1	61	1	62.7	NR	51	NR
Bunger[51]	2013	(2006–2012)	Germany	Rostock	SC	27.9	45	1	59.9	55	38	1
Canaud[52]	2014	(2002–2012)	UK	London	SC	NR	309	11	63.1	NR	248	NR
Lombardi[53]	2012	(2007–2012)	Italy, Germany, Australia, USA	Multicenter	IMC	12	40	3	58	NR	28	NR
Jia[54]	2013	(2007–2010)	China	Beijing, Zhengzhou, Xinxiang	NMC	28.5	208	3	52.1	NR	154	NR
Li[55]	2014	(2005–2012)	China	Beijing	NMC	32.2	669	6	NR	41.2	NR	20
Hanna[56]	2014	(2005–2012)	USA	North Carolina	SC	34.1	50	1	59	NR	36	NR
De Rango[57]	2014	(2005–2013)	Italy	Rome, Perugia	NMC	29.2	104	4	69.8	NR	90	NR
Appoo[58]	2015	(2008–2012)	Canada	Alberta	SC	72	16	0	63.8	NR	NR	NR
Desai[59]	2015	(2005–2012)	USA	Philadelphia	SC		132	9	64.1	NR	80	NR
Kische[60]	2015	(2009–2015)	Germany	Berlin, Rostock	NMC	25.6	35	1	63	NR	27	NR
Bockler[61]	2016	(2009–2010)	Germany, UK, Italy, Sweden	Multicenter	IMC	24	24	1	NR	NR	NR	NR
Faure[62]	2016	(2005–2015)	France	Montpellier	SC	24.3	33	1	65.1	62	26	1
Wang[63]	2016	(2005–2013)	China	Zhengzhou	SC	32	360	5	52	51.8	304	4
Asaloumidis[64]	2017	(2000–2014)	Greece	Thessaloniki	SC	74	40	2	65	NR	33	NR
Zhao Liu[65]	2017	(2008–2016)	China	Nanjing	SC	30.5	58	6	57.3	NR	40	NR
Min-Hong Zhang[66]	2017	(2011–2013)	China	Beijing	SC	26.4	85	3	64.3	NR	59	NR
Tjaden[67]	2018	(2010—2016)	USA, Europe, Brazil and Oceania	Multicenter	IMC	26	264	6	62	NR	211	NR
Tao Ma[68]	2018	(2005–2013)	China, UK	Shanghai, London	IMC	31.2	852	27	55	NR	720	NR
Laquian[69]	2018	(2011–2014)	USA	Florida, Alabama	NMC	17.9	27	1	63	NR	17	NR
Chen[70]	2018	(2007–2014)	China	Hebei, Beijing	NMC	17.9	167	1	NR	NR	112	NR
Piotr Buczkowski[71]	2019	(2007–2017)	Poland	Poznan	SC	55	68	2	NR	NR	NR	NR
Eleshra[72]	2020	(2010–2017)	Germany	Hamburg	SC	28	64	1	64.8	NR	49	NR
Fukushima[73]	2019	(2011–2017)	Japan	Chiba	SC	14.2	24	0	67.7	NR	21	NR
Wang [74]	2019	(2013–2014)	USA	Multicenter	IMC	1	397	6	60.4	NR	286	NR
Yammine[17]	2019	(2012–2017)	USA	North Carolina	SC	14.25	186	15	61.6	61.5	112	8
Miura[75]	2019	(2013–2017)	Japan	Sapporo	SC	19.6	22	0	63	NR	16	NR

(*Continued*)

Table 1

(*Continued*)

First author	Year	Duration	Geography	Center		Mean follow-up (mo)	TEVARs (n)	RTAD (n)	Age (yr)		Male sex (%)	
									TEVAR	RTAD	TEVAR	RTAD
Chassin-Trubert[76]	2020	(2013–2019)	France	Montpellier	SC	26	17	0	NR	NR	NR	NR
Pellenc[77]	2019	(2015–2018)	France	Paris	SC	22	20	0	NR	NR	NR	NR
Jiechang Zhu[78]	2018	(2015–2016)	China	Tianjin	SC	6.95	20	0	53	NR	16	NR
Riesterer[79]	2018	(2002–2017)	Germany	Freiburg	SC	16	34	1	NR	NR	NR	NR
Giles[12]	2019	(2005–2016)	USA	Gainesville	SC	17	258	12	61.5	NR	203	NR
Kuo[80]	2019	(2006–2016)	USA	Los Angeles	SC	14	71	2	58.6	NR	52	NR
Joo[81]	2019	(1994–2017)	South Korea	Seoul	SC	NR	17	2	50.4	42	14	2
Cao[82]	2020	(2015–2018)	China	Beijing	SC	17.6	76	4	50.3	NR	51	NR
El-Beyrouti[83]	2020	(2018–2019)	Germany	Mainz, Tübingen	NMC	11.6	5	0	NR	NR	NR	NR
Charltonouw[84]	2018	(1999–2014)	USA	Houston	SC	51.6	43	3	NR	NR	NR	NR
Lou[85]	2020	(2012–2018)	USA	South Carolina	SC	36	91	3	52.6	NR	60	NR
Lee[86]	2020	(2003–2017)	South Korea	Seoul, Incheon and Cheonan	NMC	39.4	87	2	58.3	NR	62	NR
Oshi[87]	2020	(2009–2019)	Japan	Fukuoka	SC	39.2	40	1	66.5	NR	26	NR
Puech-Leao[88]	2020	(2004–2017)	Brazil	Sao Paulo	SC	57	42	4	59.1	NR	32	NR
Sobocinski[89]	2020	(2005–2015)	Sweden, France	Multicenter	IMC	1	41	2	58.8	NR	32	NR
Shuo Zhao[90]	2020	(2009–2018)	China	Shandong	SC	10.7	79	1	49.9	NR	61	NR
Bavaria[91]	2015	(2010–2012)	USA	Multicenter	NMC	12	50	2	57.2	NR	40	NR
Peidro[92]	2018	(2007–2015)	France	Marseille	SC	29	26	2	NR	NR	NR	NR
Ding[93]	2018	(2011–2016)	China	Guangzhou	SC	30.8	16	1	51.3	64	12	1
Nozdrzykowskia[94]	2015	(2002–2013)	Germany	Leipzig	SC	NR	129	1	NR	NR	NR	NR
Lei Liu[95]	2016	(2013–2014)	China	Shanghai	SC	15.4	203	11	55	52.4	167	7
Hu[10]	2019	(2013–2017)	China	Zhejiang	SC	25.8	571	12	NR	NR	NR	NR
Gao[8]	2019	(2001–2013)	China	Beijing	SC	77.7	751	4	52.8	NR	619	NR

IMC = international multicenter, NMC = national multicenter, NR = not reported, RTAD = retrograde type A dissection, SC = single center, TEVAR = thoracic endovascular aortic repair.

CI: 1.9–2.8), with an I^2 heterogeneity of 44.09% ($P < .001$) (Fig. 2). The incidence of RTAD in the studies conducted in Europe (64/1718 cases; 3.7%), Asia (94/5280 cases; 1.7%), North America (81/2294 cases; 3.5%) as well as multi-continental studies (42/1266 cases; 3.3%) were similar; one smaller study in South America had a higher incidence (4/42 cases; 9.5%). With the exception of one study in South America, no significant difference was found in RTAD incidence among the continents using the Kruskal–Wallis test ($P = .08$).

Of the overall 285 cases with RTAD, time to occurrence after TEVAR was reported in 147: 89 (60.6%) occurred within 30 days; 43 (29.2%) between 1 and 12 months; 15 (10.2%) later than 1 year. Of the 89 early RTADs (within 30 days), 50 (34.0%) were intraoperative or perioperative (within 15 days of TEVAR) (see Table S4, Supplemental Digital Content, http://links.lww.com/MD/I481, which illustrates time to occurrence of RTAD). The Friedman test showed that the incidence of RTAD was significantly different in these time periods ($P = .005$). From the enrolled trials, 51 studies with 5058 total cases and 143 RTAD patients reported early RTAD in 94 cases (65.7%). However, 27 studies (5542 total cases and 142 RTAD patients) did not mention any information about the early occurrence of RTAD (Table 4). Forty-seven studies comprising 4592 cases and 128 RTAD patients showed late RTAD in 46 cases (35.9%). However, 31 studies (6008 total and 157 RTAD cases) did not report any information about late RTAD (Table 4). Using Wilcoxon signed-rank test, a significant difference was found in the incidence of RTAD between early and late occurrence ($P < .001$), i.e., the incidence of early RTAD was 1.8 times higher than that of late RTAD.

RTAD occurred in 2.2% (114/5230), and 0.9% (45/5169) of the cases in the acute TBAD and chronic TBAD groups, respectively (see Table S4, Supplemental Digital Content, http://links.lww.com/MD/I481, which illustrates time to occurrence of RTAD). Using Wilcoxon signed-rank test revealed that the proportion of RTAD patients with acute TBAD was significantly higher than those with chronic TBAD among all reported RTAD cases ($P = .008$). Twenty-four studies with 3521 patients provided comparative information on two arms of both acute and chronic TBAD for meta-analysis. The incidence of RTAD in patients with acute TBAD was higher but not statistically significant as compared to the patients with chronic TBAD with a RR of 1.42 (95% CI: 0.95–2.12; $P = .08$; Fig. 3) using a random model. There was no heterogeneity among the studies ($P = .8$, $Chi^2 = 16.9$, and $I^2 = 0\%$).

Although 44 studies described oversizing in TEVAR, most of them provided interval ranges without a detailed numerical description. Of them, stent-graft oversizing was ≤ 10% in 22 studies with 3013 TBAD cases, while it was between 10% to 20% in 20 studies with 2867 TBAD patients, and ≥ 20% in only 2 studies with 350 cases (see Table S5, Supplemental Digital Content, http://links.lww.com/MD/I482, which illustrates stent-graft oversizing). The incidence of RTAD was 3.6% (110/3013), 2.3% (65/2867), and 3.4% (12/350) in the stent-graft oversizing categories of ≤10%, 10% to 20%, and ≥20%.

The incidence of RTAD was 2.1% (112/5328) and 0.9% (39/4381) in the proximal bare stents and non-bare stents groups, respectively (Table 2). According to Wilcoxon signed-rank test, among all reported RTAD cases, the proportion of RTAD patients in proximal bare stents group (112/153 cases; 73.2%) was not significantly different from non-bare stents group (39/129 cases; 30.2%) ($P = .11$). Fourteen studies with 2347 patients provided comparative information on two arms of both proximal bare and non-bare stents for meta-analysis. Pooled meta-analysis showed that the incidence of RTAD in proximal bare stents group was 2.1-fold higher than non-bare stents group with a RR of 1.55 (95% CI: 0.87–2.75; $P = .13$; Fig. 4) using a random model. There was no heterogeneity among the studies in this meta-analysis ($P = .71$, $Chi^2 = 9.80$, and $I^2 = 0\%$; Fig. 4).

Of 78 selected studies, 14 reported clinical manifestations of RTAD. Chest pain and sudden fluctuations in blood pressure were the main symptoms of RTAD. Four studies described RTAD as asymptomatic after TEVAR. Detailed description of the clinical presentation of RTAD is provided in Table S6, Supplemental Digital Content, http://links.lww.com/MD/I483, which illustrates clinical manifestation of RTAD. Of 285 cases with RTAD, 160 (56.1%) and 29 (10.2%) were

Table 2

Risk factors in type B aortic dissection patients who underwent thoracic endovascular aortic repair and those who experienced retrograde type A dissection.

Risk factors	Studies (n)	Total TBAD patients (N)		Patients with risk factor (n)	Patients with risk factor (%)
All patients who underwent thoracic endovascular aortic repair					
Male gender	52	7110		5534	77.8
Hypertension	47	6134		5118	83.4
Diabetes mellitus	37	4779		474	9.9
Coronary artery disease	38	4477		668	14.9
Renal impairment	38	3581		446	12.4
Pulmonary disease	35	3369		446	13.2
Marfan syndrome	20	2925		44	1.5
ASA I	3	958		42	4.3
ASA II	11	1482		279	18.8
ASA III	13	1558		565	36.2
ASA IV	13	1558		598	38.3
ASA V	8	1126		52	4.6
Smoking	34	5283		2521	47.7
Age (yr)	57.4				NR
Risk factors	Studies (n)	Patients with risk factor (n)	Total RTAD (n)	Total TBAD patients (N)	Total TBAD patients (%)
Patients with retrograde type A dissection					
Male gender	16	66	77	2747	85.7
Hypertension	7	44	51	2099	86.2
Diabetes mellitus	4	5	35	1634	14.2
Coronary artery disease	4	4	32	1306	12.5
Renal impairment	5	6	41	1725	14.6
Pulmonary disease	5	7	41	1725	17.0
Marfan syndrome	11	9	58	2444	15.5
ASA	NR	NR	NR	NR	NR
Smoking	4	21	32	1306	65.6
Age (yr)	56.6				NR

ASA = American Society of Anesthesiology physical status classification, NR = not reported, RTAD = retrograde type A dissection, TBAD = type B aortic dissection.

diagnosed by CT at regular and irregular imaging follow-up period, respectively. According to Kruskal Wallis Test, cumulative incidence of RTAD did not statistically differ among the studies with regular or irregular imaging follow-up period ($P = .63$). Twenty-three studies with 4412 TBAD cases and 96 RTAD patients (33.7%) did not share detailed information on imaging follow-up time (see Table S7, Supplemental Digital Content, http://links.lww.com/MD/I484, which illustrates imaging follow-up).

Table 5 shows the surgical and non-surgical treatment of RTAD; 52 studies comprising 7546 TBAD and 214 RTAD cases reported that 156 (72.9%) were treated surgically (Fig. 5). Eight cases (5.1%) were re-operated using the frozen elephant trunk technique. Other total arch repair (including ascending aorta repair and aortic arch repair) was performed in 16.7% (26/156); hemiarch repair or ascending aorta repair alone or Bentall procedure was performed in 19.9% (31/156); and repeated endovascular treatment was performed in 3.8% (6/156). The details of surgical approaches in 61 cases (39.1%) were not reported (see Table S8, Supplemental Digital Content, http://links.lww.com/MD/I485, which illustrates reported treatments of RTAD of enrolled studies). Of 9 studies comprising 73 RTAD cases and 2123 TBAD patients, 17 RTAD patients (23.2%) received non-surgical therapy including conservative wait-and-see and medical treatment (see Table S8, Supplemental Digital Content, http://links.lww.com/MD/I485, which illustrates reported treatments of RTAD of enrolled studies).

Death among RTAD cases was reported in 76 out of 198 RTAD cases in 52 studies with different follow-up periods (Table 6) and (see Table S9, Supplemental Digital Content, http://links.lww.com/MD/I486, which illustrates time and reasons of mortality of RTAD). Single arm meta-analysis estimated a mortality rate of 42.2% (95% CI: 32.5–51.8), with an I^2 heterogeneity of 70.11% ($P < .001$) (Fig. 6).

From 79 RTAD cases who died after TEVAR, the time of death was reported in 39 cases. Of whom, 24 cases (61.5%) died within the first 30 days, 7 (17.9%) died between 1–12 months after TEVAR, and 8 (10.2%) deaths occurred one year after TEVAR. From 24 RTAD cases who died in early first month, the time of death was intraoperatively until first two weeks after TEVAR in 19 cases (20.5%). The rate of early mortality was 25 out of total 109 RTAD cases (22.9%) in 39 studies. The rate of late mortality was 11 out of a total 104 RTAD cases (10.5%) from 36 studies. However, 39 (176 cases with RTAD) and 42 studies (181 cases with RTAD) did not report any information about the early and late mortality rate of RTAD, respectively (Table 6) and (see Table S9, Supplemental Digital Content, http://links.lww.com/MD/I486, which illustrates time and reasons of mortality of RTAD). The rate of early mortality of RTAD was 2.1 times higher than that of late mortality. Using Wilcoxon signed-rank Test, no significant difference was found in RTAD incidence between early and late mortality of RTAD ($P = .44$).

4. Discussion

During the past decade, TEVAR has become one of the most common surgical procedure in many thoracic aortic pathologies.[14,96–99] This method is less invasive than open surgery but still has several complications, including some new ones that are only now being characterized and understood. Some recognized complications that can occur after TEVAR include aneurysm development, aortic rupture, stroke, bowel infarction, paraplegia, limb ischemia, endoleak, and access-related complications.[14,98,100,101] There are also important device-related complications such as stent-graft induced aortic wall injury incurred by TBAD patients after TEVAR, which can require secondary intervention if distal but can be fatal if proximal (RTAD). Although the risk of proximal SINE is low, the fatality of this complication requires vigilance in patients who develop new onset symptoms in the early period after TEVAR treatment. Careful technique, minimal oversizing, and use of disease

Table 3

Details of published reports of thoracic endovascular aortic repair and incidence of retrograde type A dissection.

First author	Year	Stent-graft detail	Total TEVARs (N)	TEVAR device: Bare stent	TEVAR device: Non-bare stent	RTAD (n)	TEVAR in patients with RTAD: Bare stent	TEVAR in patients with RTAD: Non-bare stent
Czermak	2002	Talent (Medtronic)	5	5	0	1	1	0
Kato	2002	Z stents covered with expanded polytetrafluoroethylene (Impra); Z stents covered with woven polyester	28	0	28	1	0	1
Palmer	2002	Thoracic Excluder (Gore); Talent (Medtronic)	14	3	11	2	1	NR
Fattori	2003	Talent (Medtronic); Thoracic Excluder (Gore)	22	NR	NR	2	NR	NR
Grabenwoger	2004	Talent (Medtronic)	20	20	0	1	1	0
Hansen	2004	AneuRx (Medtronic); Talent (Medtronic); and Excluder (Gore)	24	NR	NR	1	NR	NR
Lee	2004	Custom-designed stent-grafts (Impra); 2-component system consisted of a 3-part unsupported nitinol wire stents covered with a graft of synthetic polyester fabric (Dacron; Ube)	37	NR	NR	1	1	0
Dong Xu	2005	TALENT (Medtronic); ENDOFIT (Endomed); VASOFLOW (Vascore); AEGIS (Microport); KINPRIDE (Grikin)	24	NR	NR	3	NR	NR
Fattori	2006	Talent (Medtronic)	180	180	0	2	2	0
Duebener	2007	Talent and Valiant (Medtronic)	13	13	0	1	1	0
Zipfel	2007	Talent (Medtronic), E-vita (Jotec), Zenith TX1 (Cook), Relay (Bolton Medical), Endofit (Endomed), Valiant (Medtronic), and TAG (Gore).	57	NR	NR	1	0	1
Kpodonu	2008	TAG (Gore)	91	0	91	6	0	6
Neuhauser	2008	Thoracic Excluder (Gore); Talent (Medtronic)	28	NR	NR	5	4	1
Dong	2009	Talent (Medtronic)	443	401	42	11	11	0
Chiesa	2011	Not reported	188	NR	NR	3	NR	NR
Kim	2011	Talent or Valiant (Medtronic)	41	41	0	3	3	0
Oberhuber	2011	TAG/cTAG (Gore); Captivia and Valiant (Medtronic); Zenith (Cook)	19	10	9	1	0	1
Parsa	2011	TAG (Gore), Zenith TX2 (Cook), Talent (Medtronic)	51	1	50	2	0	2
Wiedemann	2013	Talent (Medtronic); Thoracic Excluder (Gore); Relay (Bolton Medical); Endomed (LeMaitre Vascular), Cook	80	52	28	3	3	0
Lotfi	2013	TAG; 8 C-TAG (Gore); TX2; 4 TX1 (Cook); Talent; Valiant (Medtronic); Relay (Bolton Medical); Endofit (LeMaitre)	11	NR	NR	3	NR	NR
Wiedemann	2014	Talent; Thoracic Excluder; Relay; Zenith; Hemashield; Valiant	110	53	57	6	3	3
Faure	2014	Thoracic Excluder and C-TAG (Gore); Talent and Valiant (Medtronic); Zenith TX2 (Cook)	41	9	32	1	NR	NR
Idrees	2014	Gore, Cook, Medtronic	766	NR	NR	15	NR	NR
Zhang	2014	Hercules (Microport); Talent and Valiant (Medtronic); Zenith (Cook); Relay (Bolton Medical)	252	NR	NR	2	NR	NR
Gorlitzer	2012	Valiant (Medtronic); Thoracic Excluder (Gore)	29	24	5	4	4	0
Huang	2013	Talent (Medtronic); Hercules (Microport); Zenith TX2 (Cook)	563	420	143	4	4	0
Cochernnec	2013	Cook; Medtronic; Gore; Relay	17	7	10	4	2	2
Shuyang Lu	2012	Talent; Valiant; Hercules; Zenith TX2	419	NR	NR	9	6	3
Yang	2012	Zenith TX2 (Cook)	61	0	61	1	0	1
Bunger	2013	Valiant (Medtronic); Zenith TX2 (Cook); Relay (Bolton Medical)	45	NR	NR	1	NR	NR
Canaud	2014	Talent, Valiant, AneuRyx (Medtronic); Vasoflow (Weike Medical); Relay (Bolton Medical); Grikin (Grikin); Ankura (Lifetech); E-vita (Jotec); TAG (Gore)	309	NR	NR	11	11	NR
Lombardi	2012	Zenith TX2 (Cook)	40	0	40	3	0	3
Jia	2013	Valiant (Medtronic); Zenith TX2 (Cook); Hercules (Microport)	208	NR	NR	3	NR	NR
Li	2014	Talent (Medtronic), Relay (Bolton), Zenith TX2 (Cook), Hercules (Microport), TAG (Gore), Valiant (Medtronic)	669	168	501	6	5	1
Hanna	2014	TAG/cTAG (Gore); Zenith TX2 (Cook); Talent and Valiant with Captivia (Medtronic)	50	17	33	1	NR	NR
De Rango	2014	Zenith (Cook); TAG/cTAG (Gore); Relay (Bolton Medical); Talent and Valiant (Medtronic)	104	NR	NR	4	NR	NR
Appoo	2015	TAG and cTAG (Gore); Zenith TX2 (Cook)	16	2	14	0	0	0
Desai	2015	Valiant Captivia (Medtronic) (2 of 50; 5% at 1 year) and cTAG (Gore) (5 of 50; 10% at 1 year)	132	NR	NR	9	NR	NR
Kische	2015	Zenith; Valiant; Talent	35	NR	NR	1	NR	NR
Bockler	2016	cTAG (Gore)	24	24	0	1	1	0
Faure	2016	Excluder (Gore); TAG (Gore); Talent (Medtronic); Valiant (Medtronic), and Zenith TX2 (Cook)	33	NR	NR	1	NR	NR
Wang	2016	Talent (Medtronic); Captivia (Medtronic); Zenith TX2 (Cook); TAG (Gore); (Microport)	360	NR	NR	5	4	NR
Asaloumidis	2017	Talent (14); TAG (13); Excluder (2); Valiant (2); Captivia (6); Relay (2); AneuRx (1)	40	24	16	2	2	0

(*Continued*)

Table 3

(*Continued*)

First author	Year	Stent-graft detail	Total TEVARs (N)	TEVAR device: Bare stent	TEVAR device: Non-bare stent	RTAD (n)	TEVAR in patients with RTAD: Bare stent	TEVAR in patients with RTAD: Non-bare stent
Zhao Liu	2017	Talent and Captivia (Medtronic); TX- 1/TX-2 (Cook); Hercules (Microport); Sinus (OptiMed)	58	NR	NR	6	NR	NR
Min-Hong Zhang	2017	Not reported	85	NR	NR	3	NR	NR
Tjaden	2018	CTAG or TAG (Gore)	264	264	0	6	6	NR
Tao Ma	2018	Talent and Valiant (Medtronic), Zenith TX2 (Cook), Hercules and Castor (Microport), Ankura (Lifetech), Relay (Bolton Medical), EndoFit (LeMaitre), E-vita (Jotec), and TAG (Gore).	852	NR	NR	27	NR	NR
Laquian	2018	Not reported	27	NR	NR	1	NR	NR
Chen	2018	Not reported	167	NR	NR	1	NR	NR
Piotr Buczkowski	2019	Zenith (Cook), JOTEC and Gore	68	0	68	2	0	2
Eleshra	2020	Not reported	64	NR	NR	1	NR	NR
Fukushima	2019	Zenith TX2 Pro-Form (Cook Medical), cTAG (Gore), Relay (Terumo Aortic), Najuta (Kawasumi)	24	NR	NR	0	NR	NR
Wang	2019	Valiant (Medtronic), CTAG (Gore), and TX2/Alpha (Cook Medical)	397	NR	NR	6	NR	NR
Yammine	2019	Valiant (Medtronic)	186	172	0	15	15	0
Miura	2019	Relay (Terumo Aortic)	22	22	0	0	0	0
Chassin-Trubert	2020	Valiant Captivia (Medtronic)	17	17	0	0	0	0
Pellenc	2019	TX2/TX2 alpha (Cook); cTAG (Gore); Relay (Terumo Aortic); Valiant (Medtronic)	20	NR	NR	0	0	0
Jiechang Zhu	2018	Valiant (Medtronic), Relay (Terumo Aortic) and Ankura (Lifetech)	20	20	0	0	0	0
Riesterer	2018	Relay NBS (non-bare stent) (Bolton Medical/Terumo Aortic)	34	0	34	1	0	1
Giles	2019	Not reported	258	NR	NR	12	NR	NR
Kuo	2019	TAG/cTAG (Gore), TX2/Alpha (Cook), Valiant (Medtronic)	71	40	31	2	NR	NR
Joo	2019	Valiant (using the Captivia delivery system; Medtronic), Seal (S&G Biotech), TX2 (Cook), TAG (Gore), and unidentified	17	13	2	2	2	0
Cao	2020	Zenith TX2 (Cook), Valiant (Medtronic), CTAG (Gore), Hercules (MicroPort) and Ankura (Lifetech)	76	65	11	4	3	1
El-Beyrouti	2020	RelayPro NBS (Terumo Aortic)	5	NR	NR	0	NR	NR
Charltonouw	2018	Not reported	43	NR	NR	3	NR	NR
Lou	2020	Valiant with Captivia (Medtronic), Zenith TX 2 (Cook), and CTAG (Gore)	91	80	11	3	NR	NR
Lee	2020	Seal (S&G Biotech); Valiant (Medtronic); Zenith TX2 (Cook)	87	51	36	2	NR	NR
Oshi	2020	TAG or cTAG (Gore), Valiant (Medtronic), Zenith TX2 (Cook), and Relay Plus (Terumo Aortic)	40	NR	NR	1	NR	NR
Puech-Leao	2020	Not reported	42	NR	NR	4	NR	NR
Sobocinski	2020	Not reported	41	NR	NR	2	NR	NR
Shuo Zhao	2020	Not reported	79	NR	NR	1	NR	NR
Bavaria	2015	Valiant Captivia (Medtronic)	50	50	0	2	2	0
Peidro	2018	TAG/cTAG (Gore); Valiant/Talent (Medtronic); Zenith/Pro-Form (Cook)	26	NR	NR	2	NR	NR
Ding	2018	Valiant (Medtronic); Ankura (Lifetech); ZTEG-2PT (Cook)	16	15	1	1	1	0
Nozdrzykowskia	2015	TAG/cTAG (Gore); Talent/Valiant/Captivia (Medtronic); Zenith (Cook); and Endofit (LeMaitre Vascular)	129	NR	NR	1	NR	NR
Lei Liu	2016	Zenith TX2 (Cook); CTAG (Gore); Talent (Medtronic); and Hercules, Aegis, and Ankura (Microport)	203	85	118	11	5	6
Hu	2019	Valiant (Medtronic), TAG (Gore), Zenith TX2 (Cook), and Ankura (Lifetech).	571	NR	NR	12	8	4
Gao	2019	GRIMED (GRIMED) in 234 patients, Talent (Medtronic) in 20, Valiant (Medtronic) in 173, Hercules (MicroPort) in 125, Zenith TX2 (Cook) in 86, Relay (Bolton Medical) in 76 and E-vita (Jotec) in 37.	751	665	86	4	NR	NR

NR = not reported, RTAD = retrograde type A dissection, TEVAR = thoracic endovascular aortic repair.

specific stent-grafts may reduce the risk for RTAD. Distally, SINE is more frequently seen during follow-up in patients treated for chronic dissection. The most important risk factor is oversizing of the stent-graft compared to the true lumen distal landing zone.[102] Therefore, procedure and device-related factors, the natural progression of initial aortic dissection, and unfavorable aortic-dissection anatomy are among the etiological factors mentioned.[13,103]

The RTAD rate after TEVAR might be reduced by improving stent-graft design (non-bare stents and tapering, for example), limited oversizing, and more careful manipulation during deployment.[13] It can also be argued that most of the information and hypotheses about this complication are not well-cited because RTAD has been reported as a rare complication with limited information in each study. To this end, we decided to thoroughly evaluate and analyze all available information about RTAD after TEVAR in TBAD patients.

Our single-arm meta-analysis estimated that the incidence of RTAD after TEVAR in patients with TBAD to be 2.3%. Therefore, it is not a very common complication. There is probably a difference in the incidence of RTAD after TEVAR on different continents. There are also several factors affecting it, such as the genetic background of connective tissue diseases, stents that have been used before, and differences in procedure-related

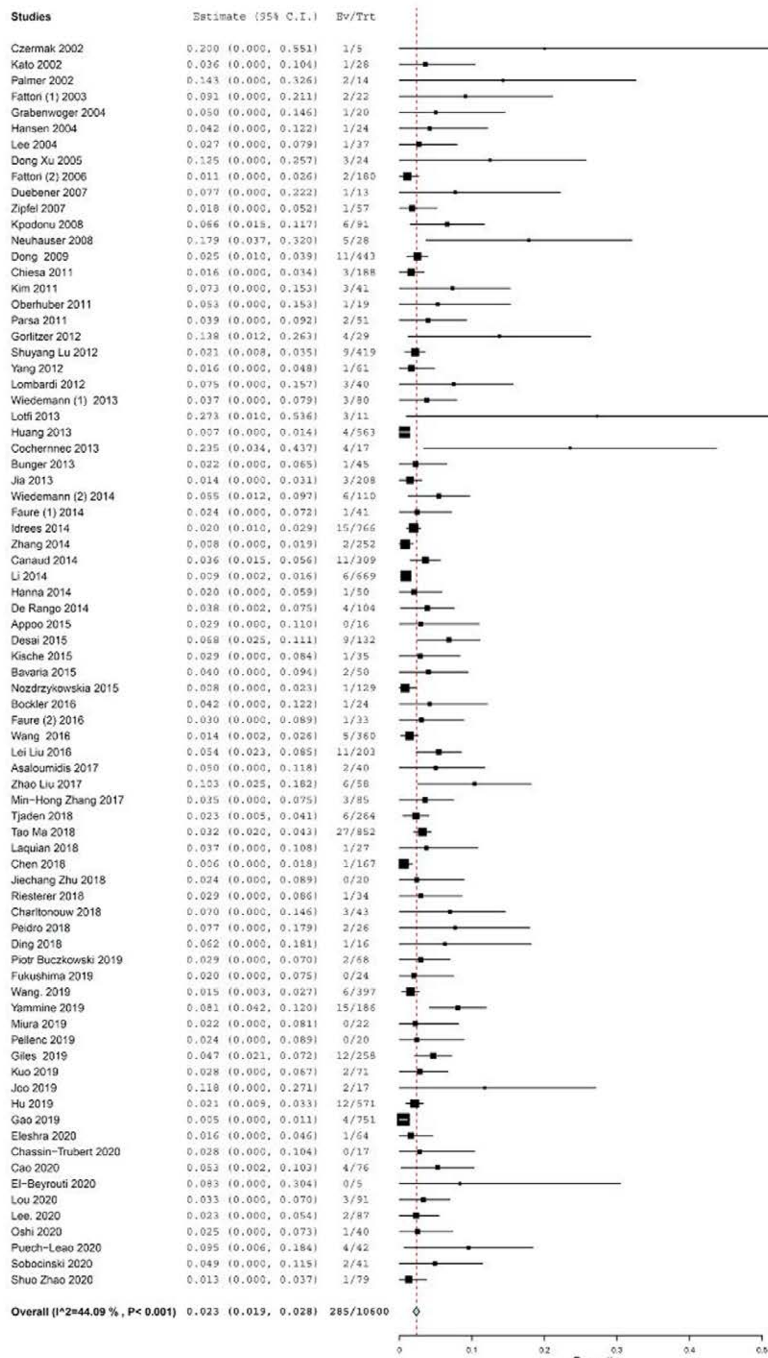

Figure 2. Forest plot of proportion single-arm meta-analysis for RTAD after TEVAR. RTAD = retrograde type A dissection, TEVAR = thoracic endovascular repair.

factors. However, it cannot be ignored that the incidence of RTAD has been less pronounced in Asian studies. On the other hand, most Asian studies have been conducted in China. Besides, the incidence of RTAD is similar on the continents of America and Europe and higher than the reported incidences in Asian studies. Consequently, although this complication is considered rare, it needs to be greater attention in European and American countries. Centers with < 50 TBAD cases undergoing TEVAR were 2.26 times more likely to incur RTAD compared to centers with > 50 TBAD cases. As a result, it can be acknowledged that highly experienced centers reported a lower incidence of RTAD, suggesting the important hypothesis that this complication was significantly related to the procedure and postoperative management, strongly dependent on the surgeon's experience. The decline in RTAD incidence from the introduction of TEVAR to the present may support the hypothesis that the incidence of RTAD decreases with increased experience and better technique. In general, it may be concluded that in China, due to the large population and existence of certain TEVAR centers with a certain number of surgeons, the surgeons have probably more experience in performing TEVAR. European and American countries, while being less populated, have more centers performing TEVAR. For this reason, most surgeons may not yet have reached their full potential. For instance, the risk of RTAD occurrence can increase when surgeons pass a guide wire through a tortuous aortic arch. The risk is exacerbated when getting it through anatomically abnormal areas or when the aorta is distorted or very thin, meaning that any friction

Table 4

Timing of RTAD.

Time post-TEVAR	Studies (n)	Patients (n)	RTAD (n)	TEVAR (n)
0–14 d	46	50	128	3730
Early (within 30 d)	50	89	153	4834
1—12 mo	46	43	138	4368
After 1 yr	47	15	141	4556
Early RTAD				
Reported	51	94	143	5058
Not reported	27	Not reported	142	5542
Late RTAD				
Reported	47	46	128	4592
Not reported	31	Not reported	157	6008

RTAD = retrograde type A dissection, TEVAR = thoracic endovascular aortic repair.

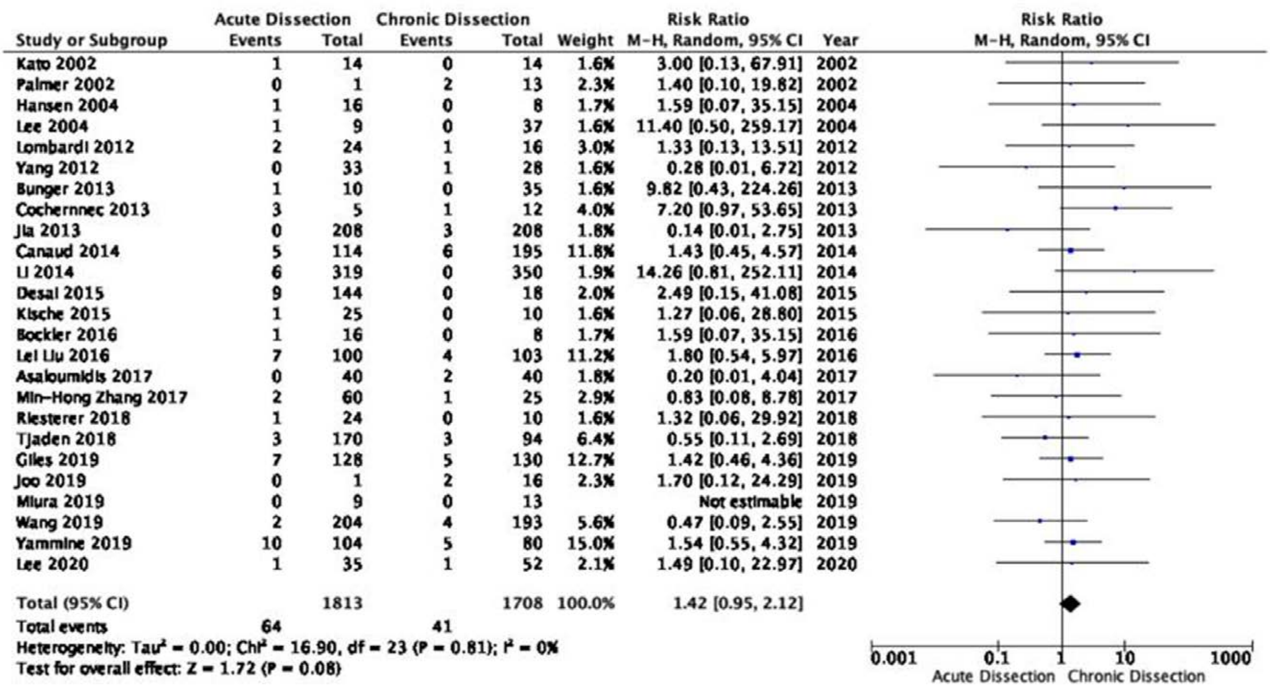

Figure 3. Forest plot for comparing of rates of RTAD post-TEVAR between acute and chronic type of TBAD. CI = confidence interval, RTAD = retrograde type A dissection, TBAD = type B aortic dissection, TEVAR = thoracic endovascular repair.

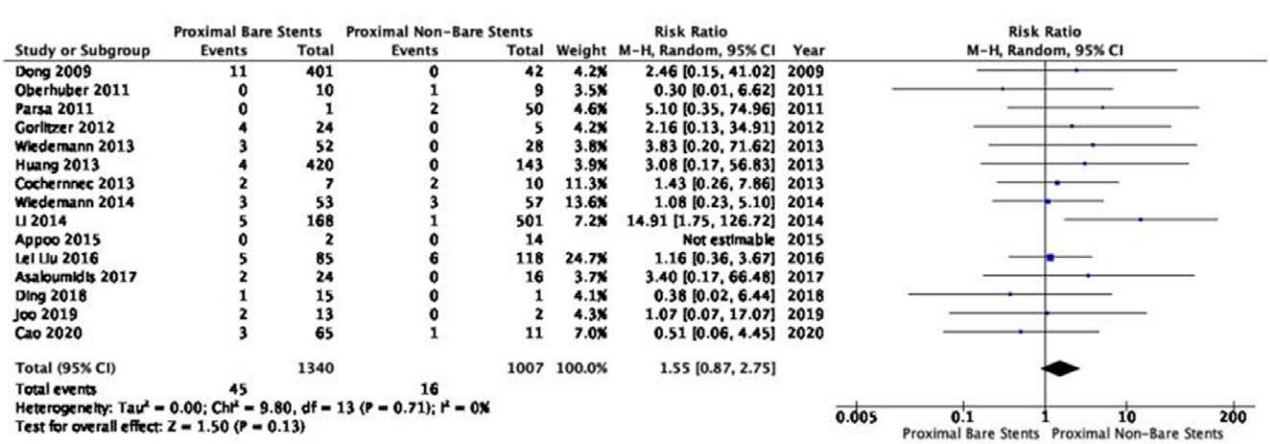

Figure 4. Forest plot for comparing of rates of RTAD post-TEVAR between implanted proximal bare and non-bare stents. CI = confidence interval, RTAD = retrograde type A dissection, TEVAR = thoracic endovascular repair.

Table 5

Therapeutic options of RTAD.

	Treatment	Nr of studies	Nr of treatment	Total RTAD	Total TEVAR
A)Theraputic options					
Non-surgical	Reported	9	17	73	2123
	ND	69	ND	212	8477
Surgical	Reported	52	156	214	7546
	ND	26	ND	71	3054
Interventions		**Nr of studies**	**Nr of treatment**	**Percentage**	
B)Surgical interventions					
Surgical treatment	No exact data about open repair	22	61	39.10	
	Total arch repair (Ascending Aorta + aortic arch replacement)	12	26	16.67	
	Ascending repair or hemiarch repair or Bentall procedure or aortic root	22	31	19.87	
	Ascending TEVAR or Re-Stent or Stent-Dilatation	4	6	3.85	
	Frozen Elephant Trunck	2	8	5.13	
	* Undifferentiated	2	24	15.38	

RTAD = retrograde type A dissection, TEVAR = thoracic endovascular aortic repair.

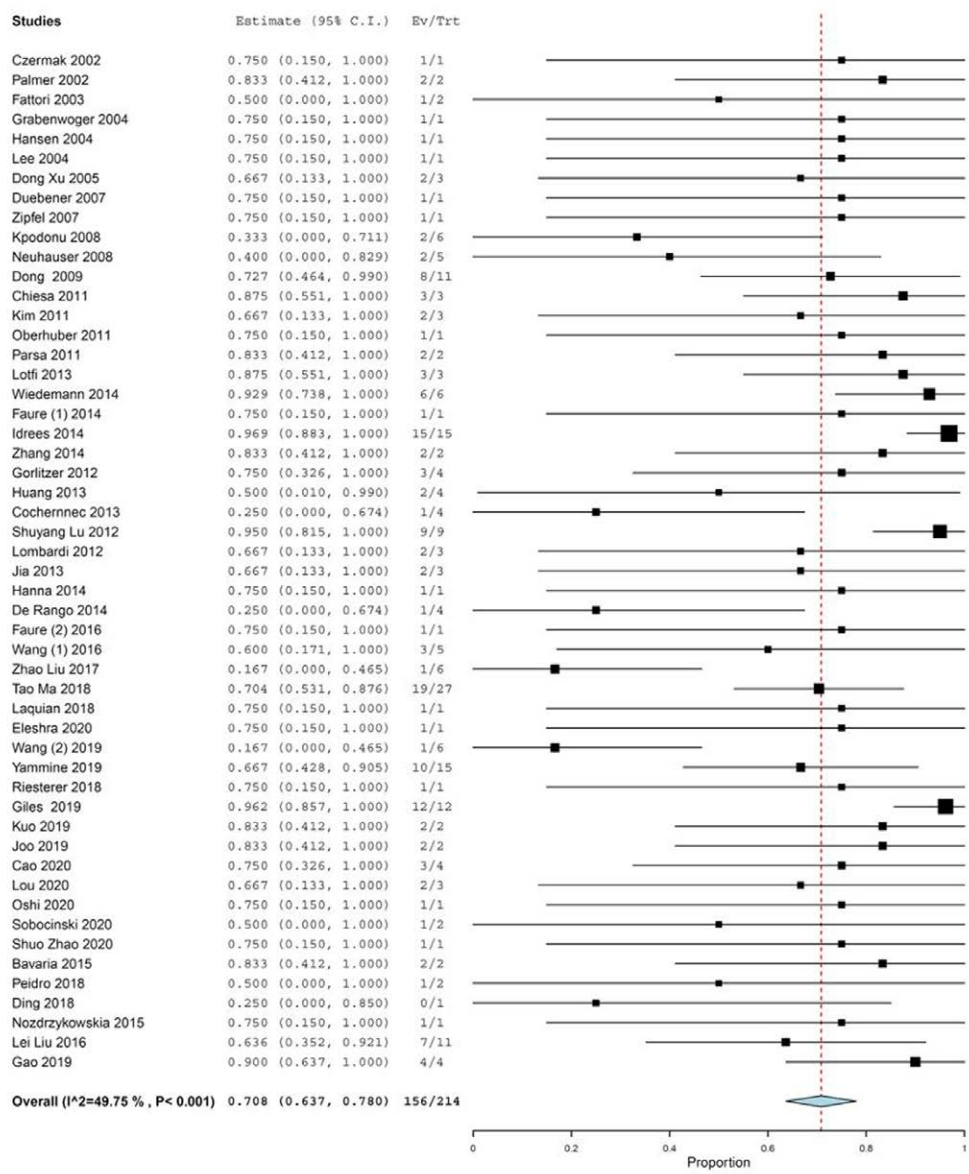

Figure 5. Forest plot of proportion single-arm meta-analysis for surgical re-intervention as therapeutic option of RTAD after TEVAR. CI = confidence interval, RTAD = retrograde type A dissection, TEVAR = thoracic endovascular repair.

from catheter or guide wire can damage the wall. Such risks can be effectively mitigated by more experienced centers and surgeons.[13,16]

Our findings also showed that RTAD occurred primarily as a hyperacute or acute condition rather than a chronic condition. Thus, the first month after TEVAR was the maximum duration for RTAD incidence; in addition, from the moment of TEVAR operation until the first two weeks, the probability of its occurrence was the highest. Our estimates revealed that the incidence of early RTAD was approximately 1.8 times higher than that of late RTAD. One hypothesis is that patients with acute TBAD are more likely to have urgent or emergent TEVAR which may be less accurate in preoperative assessments compared with chronic TBAD patients. Moreover, acute pathological changes in the aorta may increase the probability of extension of dissection and therefore predispose to RTAD. Having said that, Tjaden et al[67] found no significant difference between the risk of RTAD in acute compared to chronic TBAD. In this meta-analysis, the number of RTAD patients with acute TBAD was significantly higher than the number of RTAD patients with chronic TBAD. However, the corresponding risk ratio of 1.42 was not statistically significant. Although the findings were borderline, clinically, it can be accepted that RTAD could be more incurred by patients with acute TBAD. Therefore, more accurate diagnostic and therapeutic evaluation should be adopted to prevent this complication in acute TBAD cases. After evaluating the data, it was shown that there were no significant regional differences in the availability of follow-up data and imaging data.

Some other studies reported that proximal bare stent configuration was associated with an increased risk of RTAD.[104] Chen et al claimed that with a risk ratio of 2.06, the incidence of RTAD in TEVAR was higher in the proximal bare stent than the proximal non-bare stent.[103] This meta-analysis found that risk of RTAD in the proximal bare stents group was 2.1-fold more than in the proximal non-bare stents group. According to our comparative meta-analysis, the difference in the incidence of RTAD was not significant in the two groups of proximal bare stents and non-bare stents with a risk ratio of 1.50. This finding can be interpreted in the way that the quality of proximal bare stents design and the experience of surgeons working with these stents' models have probably increased in recent years. However, it cannot be ignored that according to previous studies, the percentage of RTAD in the proximal bare stent group was higher, even though it was not significant. Besides, it is clinically significant that if the patient is at risk of RTAD after TEVAR, such as patients with Marfan syndrome, connective tissue diseases, and acute TBAD who want to undergo non-elective TEVAR, proximal non-bare stents might be the best choice.

Dong et al explained that using angiotensin-converting enzyme inhibitors, B-blockers, calcium antagonists, or angiotensin receptor blockers was only suggested as medical management procedures when RTAD was limited, and the patient's situation was clinically stable.[105] In the present study, 11.5% of the studies with 73 patients reported non-surgical treatment with RTAD, implying that conservative wait-and-see treatment or re-surgical treatment was not accepted by patients, hence the use of non-surgical treatments. It is clear that surgical treatment should be applied in patients with unstable and limited progression since using drug treatment is not sufficient. Our findings suggested that some of the most common surgical reinterventions could treat RTAD, including ascending aorta repair alone, hemiarch replacement, and Bentall procedure. Clinically, after RTAD diagnosis followed by TEVAR, it is recommended to make treatment decisions by an interdisciplinary aortic team including vascular surgeons, cardiac surgeons, radiologists, intensive-care specialists, and anesthesiologists to evaluate the re-intervention carefully and to manage clinical and radiological follow-ups and postoperative care.

The RTAD mortality rate post-TEVAR, although low, was significantly higher than spontaneous type A aortic dissection.[106,107] This was clearly more significant during the first month post-TEVAR compared to 1 to 12 months, and one year after TEVAR. Of those who died due to RTAD during the first month after TEVAR, 79.1% died during surgery or in the first hours and days after surgery. Due to the significant and high mortality rate of this uncommon complication, RTAD should be considered as one of the differential diagnoses with high risk during ICU stay or hospital stay after surgery and even after discharge. If the patient suddenly suffers from any chest pain, back pain, chest discomfort, sudden changes in blood pressure, syncope, or any other sudden clinical signs, appropriate radiological evaluations should be performed to perform appropriate reintervention as soon as possible and to avoid sudden death. Numerous studies have also suggested that the occurrence of RTAD coincides with the onset of multi-organ failure and eventual death.[108,109] It should be mentioned that most research done on RTAD had a small sample size, and the mortality rate varied according to various treatment strategies applied.[108,109] Hence further well-designed, large scale clinical trials with longer-term follow-up are needed to accurately evaluate mortality rate of RTAD after TEVAR and its diagnostic workout and surgical management. We recommend that future studies investigate

Table 6

Mortality of RTAD.

Situation of report		Nr of studies	Nr of dead	Total RTAD	Total TEVAR of these Studies	Mortality rate
A)Report of mortality						
Reported		52	76	198	6915	38.30%
Not reported		26	43	87	3685	
Time of mortality		**Nr of studies**	**Nr of dead**	**Total RTAD**	**Total TEVAR**	**Mortality rate**
B)Time interval of mortality						
0–14 d		38	19	107	3473	17.76
Early 30 d		39	24	109	3514	22.02
1–12 mo		37	7	106	3446	6.60
After 1 yr		36	8	104	3375	7.69
C)Early or late mortality						
Early mortality	Reported	39	25	109	3514	22.94
	ND	39	ND	176	7086	
Late mortality	Reported	36	11	104	3375	10.58
	ND	42	ND	181	7225	

RTAD = retrograde type A dissection, TEVAR = thoracic endovascular aortic repair.

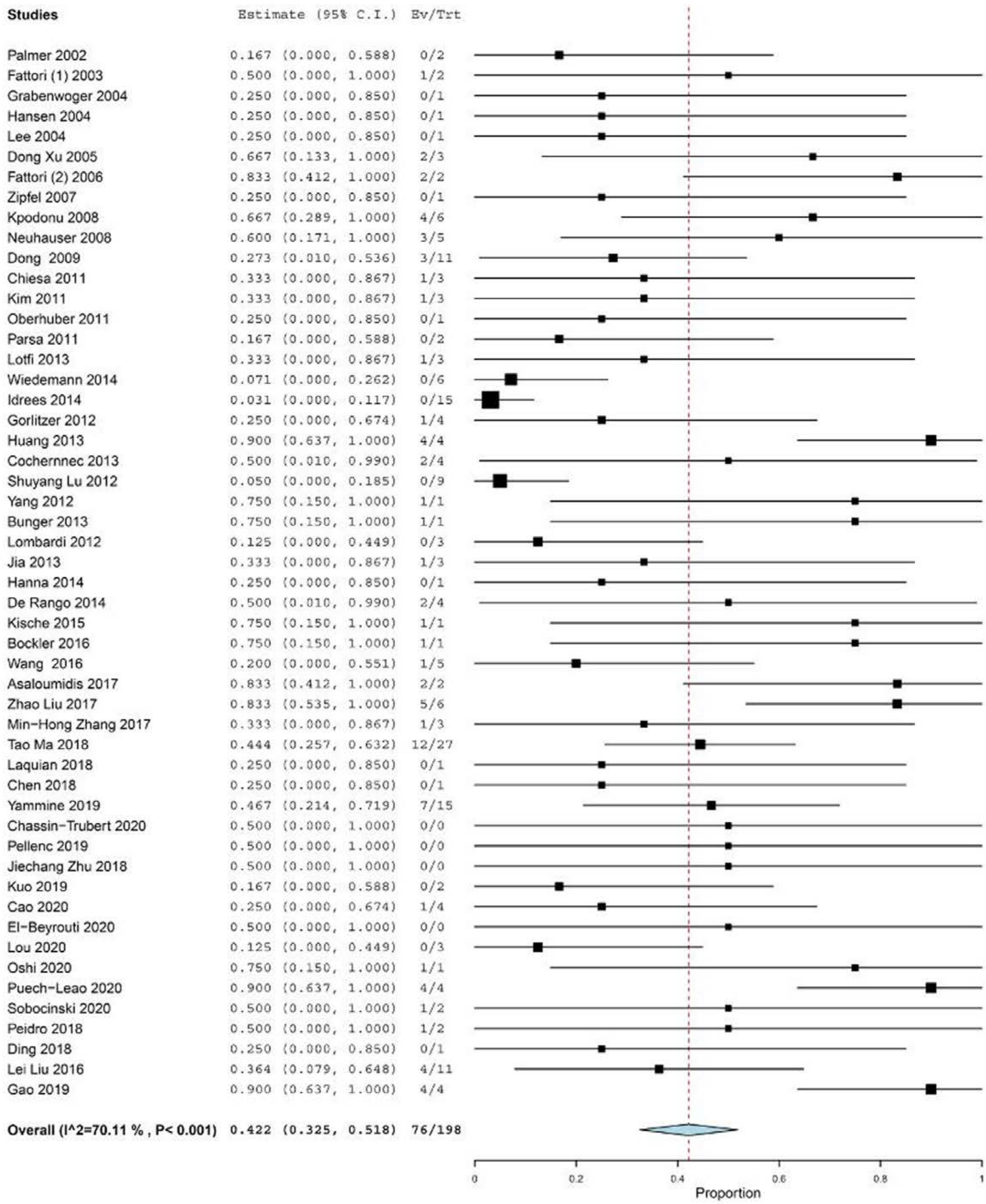

Figure 6. Forest plot of proportion single-arm meta-analysis for the mortality rate of RTAD after TEVAR. CI = confidence interval, RTAD = retrograde type A dissection, TEVAR = thoracic endovascular repair.

the correlation between genetic parameters and incidence for RTAD, as well as patients who die due to RTAD.

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References

[1] Ahlsson A, Wickbom A, Geirsson A, et al. Is there a weekend effect in surgery for type a dissection?: results from the nordic consortium for acute type A aortic dissection database. Ann Thorac Surg. 2019;108:770–6.
[2] McClure RS, Brogly SB, Lajkosz K, et al. Epidemiology and management of thoracic aortic dissections and thoracic aortic aneurysms in Ontario, Canada: a population-based study. J Thorac Cardiovasc Surg. 2018;155:2254–64.e4.
[3] Sacks D, Baxter B, Campbell BCV, et al.; From the American Association of Neurological Surgeons (AANS), American Society of Neuroradiology (ASNR), Cardiovascular and Interventional Radiology Society of Europe (CIRSE), Canadian Interventional Radiology Association (CIRA), Congress of Neurological Surgeons (CNS), European Society of Minimally Invasive Neurological Therapy (ESMINT), European Society of Neuroradiology (ESNR), European Stroke Organization (ESO), Society for Cardiovascular Angiography and Interventions (SCAI), Society of Interventional Radiology (SIR), Society of NeuroInterventional Surgery (SNIS), and World Stroke Organization (WSO). Multisociety consensus quality improvement revised consensus statement for endovascular therapy of acute ischemic stroke. Int J Stroke. 2018;13:612–32.
[4] Wiedemann D, Mahr S, Vadehra A, et al. Thoracic endovascular aortic repair in 300 patients: long-term results. Ann Thorac Surg. 2013;95:1577–83.
[5] Wiedemann D, Ehrlich M, Amabile P, et al. Emergency endovascular stent grafting in acute complicated type B dissection. J Vasc Surg. 2014;60:1204–8.
[6] Sievers HH, Rylski B, Czerny M, et al. Aortic dissection reconsidered: type, entry site, malperfusion classification adding clarity and enabling outcome prediction. Interact Cardiovasc Thorac Surg. 2020;30:451–7.
[7] Lombardi JV, Hughes GC, Appoo JJ, et al. Society for Vascular Surgery (SVS) and Society of Thoracic Surgeons (STS) reporting standards for type B aortic dissections. J Vasc Surg. 2020;71:723–47.
[8] Gao HQ, Xu SD, Ren CW, et al. Analysis of perioperative outcome and long-term survival rate of thoracic endovascular aortic repair in uncomplicated type B dissection: single-centre experience with 751 patients. Eur J Cardiothorac Surg. 2019;56:1090–6.
[9] Gao Z, Qin Z, An Z, et al. Prognostic value of preoperative hemoglobin levels for long-term outcomes of acute type B aortic dissection post-thoracic endovascular aortic repair. Front Cardiovasc Med. 2020;7:588761.
[10] Hu W, Zhang Y, Guo L, et al. A graft inversion technique for retrograde type A aortic dissection after thoracic endovascular repair for type B aortic dissection. J Cardiothorac Surg. 2019;14:29.
[11] MacGillivray TE, Gleason TG, Patel HJ, et al. The Society of Thoracic Surgeons/American Association for thoracic surgery clinical practice guidelines on the management of type B aortic dissection. J Thorac Cardiovasc Surg. 2022;163:1231–49.
[12] Giles KA, Beck AW, Lala S, et al. Implications of secondary aortic intervention after thoracic endovascular aortic repair for acute and chronic type B dissection. J Vasc Surg. 2019;69:1367–78.
[13] Wang L, Zhao Y, Zhang W, et al. Retrograde type A aortic dissection after thoracic endovascular aortic repair: incidence, time trends and risk factors. Semin Thorac Cardiovasc Surg. 2020.
[14] Neuhauser B, Greiner A, Jaschke W, et al. Serious complications following endovascular thoracic aortic stent-graft repair for type B dissection. Eur J Cardiothorac Surg. 2008;33:58–63.
[15] Sirignano P, Pranteda C, Capoccia L, et al. Retrograde type B aortic dissection as a complication of standard endovascular aortic repair. Ann Vasc Surg. 2015;29:127.e5–9.
[16] Chen Y, Zhang S, Liu L, et al. Retrograde type A aortic dissection after thoracic endovascular aortic repair: a systematic review and meta-analysis. J Am Heart Assoc. 2017;6.
[17] Yammine H, Briggs CS, Stanley GA, et al. Retrograde type A dissection after thoracic endovascular aortic repair for type B aortic dissection. J Vasc Surg. 2019;69:24–33.
[18] Doberne JW, Sabe AA, Vekstein AM, et al. Stent Graft-induced aortic wall injury (SAWI) - incidence, risk factors, and outcomes. Ann Thorac Surg. 2022.
[19] Pantaleo A, Jafrancesco G, Buia F, et al. Distal Stent Graft-induced new entry: an emerging complication of endovascular treatment in aortic dissection. Ann Thorac Surg. 2016;102:527–32.
[20] Moher D, Liberati A, Tetzlaff J, et al.; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 2010;8:336–41.
[21] Goossen K, Tenckhoff S, Probst P, et al. Optimal literature search for systematic reviews in surgery. Langenbecks Arch Surg. 2018;403:119–29.
[22] Kalkum E, Klotz R, Seide S, et al. Systematic reviews in surgery-recommendations from the Study Center of the German society of surgery. Langenbecks Arch Surg. 2021.
[23] Jormalainen M, Raivio P, Biancari F, et al. Late Outcome after Surgery for Type-A aortic dissection. J Clin Med. 2020;9.
[24] Hirji S, McGurk S, Kiehm S, et al. Utility of 90-Day Mortality vs 30-Day mortality as a quality metric for transcatheter and surgical aortic valve replacement outcomes. JAMA Cardiol. 2020;5:156–65.
[25] Czermak BV, Waldenberger P, Perkmann R, et al. Placement of endovascular stent-grafts for emergency treatment of acute disease of the descending thoracic aorta. Am J Roentgenol. 2002;179:337–45.
[26] Kato N, Shimono T, Hirano T, et al. Midterm results of stent-graft repair of acute and chronic aortic dissection with descending tear: the complication-specific approach. J Thorac Cardiovasc Surg. 2002;124:306–12.
[27] Pamler RS, Kotsis T, Görich J, et al. Complications after endovascular repair of type B aortic dissection. J Endovasc Ther. 2002;9:822–8.
[28] Fattori R, Napoli G, Lovato L, et al. Descending thoracic aortic diseases: stent-graft repair. Radiology. 2003;229:176–83.
[29] Grabenwoger M, Fleck T, Ehrlich M, et al. Secondary surgical interventions after endovascular stent-grafting of the thoracic aorta. Eur J Cardiothorac Surg. 2004;26:608–13.
[30] Hansen CJ, Bui H, Donayre CE, et al. Complications of endovascular repair of high-risk and emergent descending thoracic aortic aneurysms and dissections. J Vasc Surg. 2004;40:228–34.
[31] Lee K-H, Won JY, Lee DY, et al. Elective stent-graft treatment of aortic dissections. J Endovasc Ther. 2004;11:667–75.
[32] Dong Xu S, Zhong Li Z, Huang FJ, et al. Treating aortic dissection and penetrating aortic ulcer with stent graft: thirty cases. Ann Thorac Surg. 2005;80:864–8.
[33] Fattori R, Nienaber CA, Rousseau H, et al.; Talent Thoracic Retrospective Registry. Results of endovascular repair of the thoracic aorta with the Talent Thoracic stent graft: the Talent Thoracic Retrospective Registry. J Thorac Cardiovasc Surg. 2006;132:332–9.
[34] Duebener L, Hartmann F, Kurowski V, et al. Surgical interventions after emergency endovascular stent-grafting for acute type B aortic dissections. Interact Cardiovasc Thorac Surg. 2007;6:288–92.
[35] Zipfel B, Hammerschmidt R, Krabatsch T, et al. Stent-grafting of the thoracic aorta by the cardiothoracic surgeon. Ann Thorac Surg. 2007;83:441–8; discussion 448.
[36] Kpodonu J, Preventza O, Ramaiah VG, et al. Retrograde type A dissection after endovascular stenting of the descending thoracic aorta. Is the risk real? Eur J Cardiothorac Surg. 2008;33:1014–8.
[37] Dong ZH, Fu WG, Wang YQ, et al. Retrograde type A aortic dissection after endovascular stent graft placement for treatment of type B dissection. Circulation. 2009;119:735–41.
[38] Chiesa R, Tshomba Y, Logaldo D, et al. Hybrid repair of aortic aneurysms and dissections: the European perspective. Tex Heart Inst J. 2011;38:687–90.
[39] Kim KM, Donayre CE, Reynolds TS, et al. Aortic remodeling, volumetric analysis, and clinical outcomes of endoluminal exclusion of acute complicated type B thoracic aortic dissections. J Vasc Surg. 2011;54:316–24; discussion 324.
[40] Oberhuber A, Winkle P, Schelzig H, et al. Technical and clinical success after endovascular therapy for chronic type B aortic dissections. J Vasc Surg. 2011;54:1303–9.
[41] Parsa CJ, Williams JB, Bhattacharya SD, et al. Midterm results with thoracic endovascular aortic repair for chronic type B aortic dissection with associated aneurysm. J Thorac Cardiovasc Surg. 2011;141:322–7.
[42] Lotfi S, Clough RE, Ali T, et al. Hybrid repair of complex thoracic aortic arch pathology: long-term outcomes of extra-anatomic bypass grafting of the supra-aortic trunk. Cardiovasc Intervent Radiol. 2013;36:46–55.
[43] Faure EM, Canaud L, Agostini C, et al. Reintervention after thoracic endovascular aortic repair of complicated aortic dissection. J Vasc Surg. 2014;59:327–33.
[44] Idrees J, Arafat A, Johnston DR, et al. Repair of retrograde ascending dissection after descending stent grafting. J Thorac Cardiovasc Surg. 2014;147:151–4.
[45] Zhang L, Zhou J, Lu Q, et al. Potential risk factors of re-intervention after endovascular repair for type B aortic dissections. Catheter Cardiovasc Interv. 2015;86:E1–10.
[46] Gorlitzer M, Weiss G, Moidl R, et al. Repair of stent graft-induced retrograde type A aortic dissection using the E-vita open prosthesis. Eur J Cardiothorac Surg. 2012;42:566–70.

[47] Huang WH, Luo SY, Luo JF, et al. Perioperative aortic dissection rupture after endovascular stent graft placement for treatment of type B dissection. Chin Med J (Engl). 2013;126:1636–41.
[48] Cochennec F, Tresson P, Cross J, et al. Hybrid repair of aortic arch dissections. J Vasc Surg. 2013;57:1560–7.
[49] Lu S, Lai H, Wang C, et al. Surgical treatment for retrograde type A aortic dissection after endovascular stent graft placement for type B dissection. Interact Cardiovasc Thorac Surg. 2012;14:538–42.
[50] Yang C-PO, Hsu C-P, Chen W-Y, et al. Aortic remodeling after endovascular repair with stainless steel-based stent graft in acute and chronic type B aortic dissection. J Vasc Surg. 2012;55:1600–10.
[51] Bünger CM, Kische S, Liebold A, et al. Hybrid aortic arch repair for complicated type B aortic dissection. J Vasc Surg. 2013;58:1490–6.
[52] Canaud L, Ozdemir BA, Patterson BO, et al. Retrograde aortic dissection after thoracic endovascular aortic repair. Ann Surg. 2014;260:389–95.
[53] Lombardi JV, Cambria RP, Nienaber CA, et al.; STABLE investigators. Prospective multicenter clinical trial (STABLE) on the endovascular treatment of complicated type B aortic dissection using a composite device design. J Vasc Surg. 2012;55:629–40.e2.
[54] Jia X, Guo W, Li TX, et al. The results of stent graft versus medication therapy for chronic type B dissection. J Vasc Surg. 2013;57:406–14.
[55] Li B, Pan XD, Ma WG, et al. Stented elephant trunk technique for retrograde type A aortic dissection after endovascular stent graft repair. Ann Thorac Surg. 2014;97:596–602.
[56] Hanna JM, Andersen ND, Ganapathi AM, et al. Five-year results for endovascular repair of acute complicated type B aortic dissection. J Vasc Surg. 2014;59:96–106.
[57] De Rango P, Cao P, Ferrer C, et al. Aortic arch debranching and thoracic endovascular repair. J Vasc Surg. 2014;59:107–14.
[58] Appoo JJ, Herget EJ, Pozeg ZI, et al. Midterm results of endovascular stent grafts in the proximal aortic arch (zone 0): an imaging perspective. Can J Cardiol. 2015;31:731–7.
[59] Desai ND, Gottret JP, Szeto WY, et al. Impact of timing on major complications after thoracic endovascular aortic repair for acute type B aortic dissection. J Thorac Cardiovasc Surg. 2015;149(2 Suppl):S151–6.
[60] Kische S, D'Ancona G, Belu IC, et al. Perioperative and mid-term results of endovascular management of complicated type B aortic dissection using a proximal thoracic endoprosthesis and selective distal bare stenting. Eur J Cardiothorac Surg. 2015;48:e77–84.
[61] Böckler D, Brunkwall J, Taylor PR, et al.; CTAG registry investigators. Thoracic endovascular aortic repair of aortic arch pathologies with the conformable thoracic aortic graft: early and 2 year results from a european multicentre registry. Eur J Vasc Endovasc Surg. 2016;51:791–800.
[62] Faure EM, Canaud L, Marty-Ané C, et al. Hybrid aortic arch repair for dissecting aneurysm. J Thorac Cardiovasc Surg. 2016;152:162–8.
[63] Wang G, Zhai S, Li T, et al. Mechanism and management of retrograde type A aortic dissection complicating TEVAR for type B aortic dissection. Ann Vasc Surg. 2016;32:111–8.
[64] Asaloumidis N, Karkos CD, Trellopoulos G, et al. Outcome after endovascular repair of subacute type B aortic dissection: a combined series from two greek centers. Ann Vasc Surg. 2017;42:136–42.
[65] Liu Z, Zhang Y, Liu C, et al. Treatment of serious complications following endovascular aortic repair for type B thoracic aortic dissection. J Int Med Res. 2017;45:1574–84.
[66] Zhang MH, Du X, Guo W, et al. Early and midterm outcomes of thoracic endovascular aortic repair (TEVAR) for acute and chronic complicated type B aortic dissection. Medicine (Baltimore). 2017;96:e7183.
[67] Tjaden BL, Jr., Sandhu H, Miller C, et al. Outcomes from the gore global registry for endovascular aortic treatment in patients undergoing thoracic endovascular aortic repair for type B dissection. J Vasc Surg. 2018;68:1314–23.
[68] Ma T, Dong ZH, Fu WG, et al. Incidence and risk factors for retrograde type A dissection and stent graft-induced new entry after thoracic endovascular aortic repair. J Vasc Surg. 2018;67:1026–33.e2.
[69] Laquian L, Scali ST, Beaver TM, et al. Outcomes of thoracic endovascular aortic repair for acute type B dissection in patients with intractable pain or refractory hypertension. J Endovasc Ther. 2018;25:220–9.
[70] Chen L, Yang SJ, Guo FL, et al. Experience with thoracic endovascular aortic repair applied in treating Stanford type B aortic dissection: an analysis of 98 cases. Adv Clin Exp Med. 2018;27:1259–62.
[71] Buczkowski P, Puślecki M, Majewska N, et al. Endovascular treatment of complex diseases of the thoracic aorta-10 years single centre experience. J Thorac Dis. 2019;11:2240–50.
[72] Eleshra A, Kölbel T, Tsilimparis N, et al. Candy-plug generation II for false lumen occlusion in chronic aortic dissection: feasibility and early results. J Endovasc Ther. 2019;26:782–6.
[73] Fukushima S, Ohki T, Toya N, et al. Initial results of thoracic endovascular repair for uncomplicated type B aortic dissection involving the arch vessels using a semicustom-made thoracic fenestrated stent graft. J Vasc Surg. 2019;69:1694–703.
[74] Wang GJ, Cambria RP, Lombardi JV, et al. Thirty-day outcomes from the society for vascular surgery vascular quality initiative thoracic endovascular aortic repair for type B dissection project. J Vasc Surg. 2019;69:680–91.
[75] Miura S, Kurimoto Y, Maruyama R, et al. Thoracic endovascular aortic repair on zone 2 landing for type B aortic dissection. Ann Vasc Surg. 2019;60:120–7.
[76] Chassin-Trubert L, Mandelli M, Ozdemir BA, et al. Midterm follow-up of fenestrated and scalloped physician-modified endovascular grafts for zone 2 TEVAR. J Endovasc Ther. 2020;27:377–84.
[77] Pellenc Q, Roussel A, De Blic R, et al. False lumen embolization in chronic aortic dissection promotes thoracic aortic remodeling at midterm follow-up. J Vasc Surg. 2019;70:710–7.
[78] Zhu J, Zhao L, Dai X, et al. Fenestrated thoracic endovascular aortic repair using physician modified stent grafts for acute type B aortic dissection with unfavourable landing zone. Eur J Vasc Endovasc Surg. 2018;55:170–6.
[79] Riesterer T, Beyersdorf F, Scheumann J, et al. Accuracy of deployment of the Relay non-bare stent graft in the aortic arch. Interact Cardiovasc Thorac Surg. 2019;28:797–802.
[80] Kuo EC, Veranyan N, Johnson CE, et al. Impact of proximal seal zone length and intramural hematoma on clinical outcomes and aortic remodeling after thoracic endovascular aortic repair for aortic dissections. J Vasc Surg. 2019;69:987–95.
[81] Joo HC, Youn YN, Kwon JH, et al. Late complications after hybrid aortic arch repair. J Vasc Surg. 2019;70:1023–30.e1.
[82] Cao L, Ge Y, He Y, et al. Association between aortic arch angulation and bird-beak configuration after thoracic aortic stent graft repair of type B aortic dissection. Interact Cardiovasc Thorac Surg. 2020;31:688–96.
[83] El Beyrouti H, Lescan M, Doemland M, et al. Early results of a low-profile stent-graft for thoracic endovascular aortic repair. PLoS One. 2020;15:e0240560.
[84] Charlton-Ouw KM, Sandhu HK, Leake SS, et al. New type A dissection after acute type B aortic dissection. J Vasc Surg. 2018;67:85–92.
[85] Lou XY, Duwayri YM, Jordan WD, et al. The safety and efficacy of extended TEVAR in acute type B aortic dissection. Ann Thorac Surg. 2020;110:799–806.
[86] Lee SJ, Kang WC, Ko YG, et al. Aortic remodeling and clinical outcomes in type B aortic dissection according to the timing of thoracic endovascular aortic repair. Ann Vasc Surg. 2020;67:322–31.
[87] Oishi Y, Yamashita Y, Kimura S, et al. Preoperative distal aortic diameter is a significant predictor of late aorta-related events after endovascular repair for chronic type B aortic dissection. Gen Thorac Cardiovasc Surg. 2020;68:1086–93.
[88] Puech-Leao P, Estenssoro AEV, Wakassa TB, et al. Long-term results of endovascular treatment of chronic type B aortic dissection by closure of the primary tear. Ann Vasc Surg. 2020;66:179–82.
[89] Sobocinski J, Dias NV, Hongku K, et al. Thoracic endovascular aortic repair with stent grafts alone or with a composite device design in patients with acute type B aortic dissection in the setting of malperfusion. J Vasc Surg. 2020;71:400–7.e2.
[90] Zhao S, Gu H, Chen B, et al. Dynamic indicators that impact the outcomes of thoracic endovascular aortic repair in complicated type B aortic dissection. J Vasc Interv Radiol. 2020;31:760–8.e1.
[91] Bavaria JE, Brinkman WT, Hughes GC, et al. Outcomes of thoracic endovascular aortic repair in acute type B aortic dissection: results from the valiant United States investigational device exemption study. Ann Thorac Surg. 2015;100:802–8; discussion 808. discussion 89.
[92] Peidro J, Boufi M, Loundou AD, et al. Aortic anatomy and complications of the proximal sealing zone after endovascular treatment of the thoracic aorta. Ann Vasc Surg. 2018;48:141–50.
[93] Ding H, Luo S, Liu Y, et al. Outcomes of hybrid procedure for type B aortic dissection with an aberrant right subclavian artery. J Vasc Surg. 2018;67:704–11.
[94] Nozdrzykowski M, Luehr M, Garbade J, et al. Outcomes of secondary procedures after primary thoracic endovascular aortic repair. Eur J Cardiothorac Surg. 2016;49:770–7.
[95] Liu L, Zhang S, Lu Q, et al. Impact of oversizing on the risk of retrograde dissection after TEVAR for acute and chronic type B dissection. J Endovasc Ther. 2016;23:620–5.
[96] Usai MV, Nugroho NT, Oberhuber A, et al. Influence of TEVAR on blood pressure in subacute type B aortic dissection (TBAD) patients

with refractory and non-refractory arterial hypertension. Int Angiol. 2021;40:60–6.
[97] Bondesson J, Suh GY, Marks N, et al. Influence of thoracic endovascular aortic repair on true lumen helical morphology for stanford type B dissections. J Vasc Surg. 2021.
[98] Czerny M, Pacini D, Aboyans V, et al. Current options and recommendations for the use of thoracic endovascular aortic repair in acute and chronic thoracic aortic disease: an expert consensus document of the European Society for Cardiology (ESC) Working Group of Cardiovascular Surgery, the ESC Working Group on Aorta and Peripheral Vascular Diseases, the European Association of Percutaneous Cardiovascular Interventions (EAPCI) of the ESC and the European Association for Cardio-Thoracic Surgery (EACTS). Eur J Cardiothoracic Surg. 2021;59:65–73.
[99] Khayat M, Cooper KJ, Khaja MS, et al. Endovascular management of acute aortic dissection. Cardiovasc Diagn Ther. 2018;8(Suppl 1):S97–107.
[100] Neuhauser B, Czermak BV, Fish J, et al. Type A dissection following endovascular thoracic aortic stent-graft repair. J Endovasc Ther. 2005;12:74–81.
[101] Eggebrecht H, Nienaber CA, Neuhäuser M, et al. Endovascular stent-graft placement in aortic dissection: a meta-analysis. Eur Heart J. 2006;27:489–98.
[102] Burdess A, Mani K, Tegler G, et al. Stent-graft induced new entry tears after type B aortic dissection: how to treat and how to prevent? J Cardiovasc Surg (Torino). 2018;59:789–96.
[103] Chen YQ, Zhang SM, Liu L, et al. Retrograde type A aortic dissection after thoracic endovascular aortic repair: a systematic review and meta-analysis. J Am Heart Assoc. 2017;6.
[104] Williams JB, Andersen ND, Bhattacharya SD, et al. Retrograde ascending aortic dissection as an early complication of thoracic endovascular aortic repair. J Vasc Surg. 2012;55:1255–62.
[105] Dong Z, Fu W, Wang Y, et al. Stent graft-induced new entry after endovascular repair for Stanford type B aortic dissection. J Vasc Surg. 2010;52:1450–7.
[106] Conzelmann LO, Weigang E, Mehlhorn U, et al. Mortality in patients with acute aortic dissection type A: analysis of pre- and intraoperative risk factors from the German Registry for Acute Aortic Dissection Type A (GERAADA). Eur J Cardiothoracic Surg. 2016;49:e44–52.
[107] Ghoreishi M, Sundt TM, Cameron DE, et al. Factors associated with acute stroke after type A aortic dissection repair: an analysis of the society of thoracic surgeons national adult cardiac surgery database. J Thorac Cardiovasc Surg. 2020;159:2143–54.e3.
[108] An Z, Song Z, Tang H, et al. Retrograde type A dissection after thoracic endovascular aortic repair: surgical strategy and literature review. Heart Lung Circ. 2018;27:629–34.
[109] An Z, Tan MW, Song ZG, et al. Retrograde type a dissection after ascending aorta involved endovascular repair and its surgical repair with stented elephant trunk. Ann Vasc Surg. 2019;58:198–204.e1.