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REVIEW ARTICLE

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Endovascular ascending aortic repair in type A dissection: A systematic review

Yunus Ahmed MD[1,2] | Ignas B. Houben MD[1,2] | C. Alberto Figueroa PhD[3] | Nicholas S. Burris MD[4] | David M. Williams MD[4] | Frans L. Moll MD, PhD[1] | Himanshu J. Patel MD[2] | Joost A. van Herwaarden MD, PhD[1]

[1]Department of Vascular Surgery, Utrecht University Medical Center, Utrecht, The Netherlands

[2]Department of Cardiac Surgery, University of Michigan, Ann Arbor, Michigan, USA

[3]Departments of Surgery & Biomedical Engineering, University of Michigan, Ann Arbor, Michigan, USA

[4]Department of Radiology, University of Michigan, Ann Arbor, Michigan, USA

Correspondence
Yunus Ahmed, MD, Department of Cardiac Surgery, University of Michigan, 5144 Frankel Cardiovascular Center, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-5864, USA.
Email: yuah@med.umich.edu

Abstract

Purpose: Up to 10% of acute type A aortic dissection (TAAD) patients are deemed unfit for open surgical repair, exposing these patients to high mortality rates. In recent years, thoracic endovascular aortic repair has proven to be a promising alternative treatment modality in specific cases. This study presents a comprehensive overview of the current state of catheter-based interventions in the setting of primary TAAD.

Methods: A literature search was conducted, using MEDLINE and PubMed databases according to PRISMA guidelines, updated until January 2020. Articles were selected if they reported on the endovascular repair of DeBakey Type I and II aortic dissections. The exclusion criteria were retrograde type A dissection, hybrid procedures, and combined outcome reporting of mixed aortic pathologies (e.g., pseudoaneurysm and intramural hematoma).

Results: A total of 31 articles, out of which 19 were case reports and 12 case series, describing a total of 92 patients, were included. The median follow-up was 6 months for case reports and the average follow-up was 14 months for case series. Overall technical success was 95.6% and 30-day mortality of 9%. Stroke and early endoleak rates were 6% and 18%, respectively. Reintervention was required in 14 patients (15%).

Conclusion: This review not only demonstrates that endovascular repair in the setting of isolated TAAD is feasible with acceptable outcomes at short-term follow-up, but also underlines a lack of mid-late outcomes and reporting consistency. Studies with longer follow-up and careful consideration of patient selection are required before endovascular interventions can be widely introduced.

KEYWORDS
ascending aorta, stent graft, systematic review, thoracic endovascular aortic repair, type A dissection

Yunus Ahmed and Ignas B. Houben contributed equally to this study as co-first authors.

1 | INTRODUCTION

Type A aortic dissection (TAAD) is a complex and challenging disease with morbidity and surgical mortality as high as 20%.[1–3] In the acute phase, patients are exposed to increased mortality risk, estimated to be 1% each hour after the onset of symptoms, and up to 95% in-hospital mortality for medically treated acute TAAD patients.[2,4,5] Considering the life-threatening course of this pathology, emergent intervention is paramount. Open surgical intervention is considered to be the gold standard in contemporary treatment, with acceptable outcomes.[6,7]

In recent years, thoracic endovascular aortic repair (TEVAR) has been established as a viable treatment modality for various descending thoracic aortic pathologies with favorable outcomes.[8–10] Moreover, the use of TEVAR has gradually progressed to the aortic arch and even ascending aorta, making it one of the last frontiers of endovascular aortic therapy. When considering patients who present with an acute TAAD, approximately 10% are deemed unfit for open surgical intervention, due to high and/or prohibitive risk.[2,4] Recent studies report widely varying percentages (2%–79%) of inoperable patients with anatomy amenable for catheter-based interventions.[11,12] Since the first TAAD endovascular repair, performed in 2000, endovascular therapy has seen rapid technological advancements in both device design and the capabilities of imaging technology used to assess endovascular candidacy and plan intervention.[13] As such, endovascular aortic repair has emerged as a feasible and potentially suitable alternative for patients who are deemed unfit to undergo surgical intervention. Endovascular repair of TAAD is an understudied field, presenting novel challenges in device and delivery system design, and the endovascular procedure itself. In recent years, various studies reported on the endovascular repair of aortic arch and ascending aortic disease.[14–20] However, there are distinct differences in anatomy and complexity of disease when dealing with a dissected aorta. Compared to conditions such as aneurysms, intramural hematoma (IMH), or penetrating atherosclerotic ulcer (PAU), dissection is characterized by loss of structural wall integrity through delamination and complicates the identification of stable landing zones.[20] Therefore, we aim to present a comprehensive literature overview of contemporary results of TEVAR, exclusively in the setting of TAAD with an entry tear in the ascending aorta.

2 | METHODS

A thorough search of the MEDLINE and PubMed database was conducted, updated until January 2020. The used search terms were "Thoracic Endovascular Aortic Repair," "Type A Dissection," and "Ascending Aorta," including all variations of these terms. Relevant articles retrieved from the reference lists were subsequently added. The search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[21] Two authors (Yunus Ahmed and Ignas B. Houben) independently extracted and assessed all data for eligibility and reached the consensus on the final selection. Articles were included if they reported on the endovascular intervention of TAAD, with the entry tear located in the ascending aorta (i.e., DeBakey Classification I and II). The exclusion criteria were retrograde TAAD and hybrid procedures. Supra-aortic arch revascularization and debranching procedures before endovascular repair of TAAD were not excluded. Furthermore, articles reporting on combined aortic pathology in the ascending aorta (e.g., thoracic aortic aneurysm [TAA]/pseudoaneurysm, IMH, or PAU) that did not explicitly report on TAAD outcomes were excluded.

3 | RESULTS

The initial search yielded a total of 805 articles, out of which 736 were excluded based on title and/or abstract. The remaining 69 articles were thoroughly reviewed for eligibility, in addition to 9 articles that were extracted from selected articles reference lists. An additional 47 articles were excluded owing to the description of pathology other than ascending aortic dissection, intervention other than endovascular ascending aortic repair with stent graft or inadequate or duplicate reporting of outcomes. At the completion of the review, 31 studies were included (19 case reports and 12 case series), describing a total of 92 patients who underwent ascending aortic endovascular repair for TAAD (Figure 1).[13,22–51] The selected studies were published between 2000 and 2019.

Patients presented with acute ($n = 55$), subacute ($n = 10$), or chronic TAAD ($n = 27$), defined as 0–14 days, 15–90 days, and >90 days after the onset of symptoms, respectively. Fourteen studies reported on the timing of intervention for patients presenting with acute TAAD. Only four of these studies, describing a total of eight patients, reported patients who were treated within 24 h after the onset of symptoms.[32,33,39,39,51] Indications for endovascular repair were high and/or prohibitive in all but two cases; these patients refused high-risk open surgery or preferred endoluminal stent graft placement.[22,28] Preoperative demographics are reported in Tables 1 and 2 for the case reports and case series, respectively. Heterogeneity in reported literature precluded any meta-analysis of the data.

3.1 | Operative management and technique

The use of anesthesia was described in 23 studies, with 98% of cases performed under general anesthesia. Two main methods of blood pressure management to assure accurate stent graft deployment were used; rapid ventricular pacing (reduction of cardiac output by pacing the right ventricle at 180–220 beats per minute) in 77% of patients and medicine induced hypotension or cardiac arrest (use of sodium nitroprusside and adenosine to achieve controlled hypotension or intermittent cardiac arrest, respectively) in 22%.[52] Alternatively, one patient received venous inflow occlusion

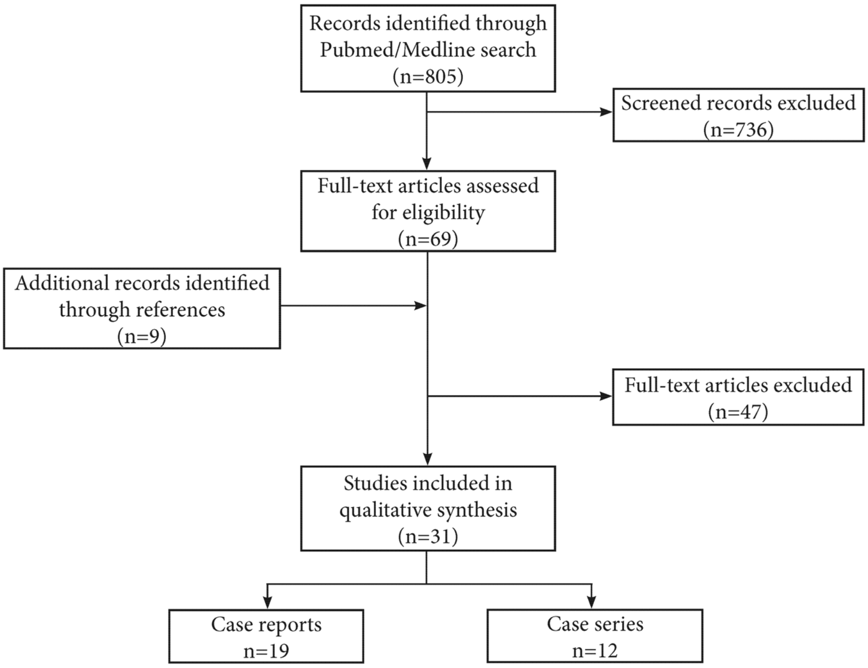

FIGURE 1 Flow chart of study selection process for eligible studies

and in one patient a TandemHeart (CardiacAssist, Inc.) was applied in addition to rapid ventricular pacing (Tables 3 and 4). Moreover, in 75% of cases, the procedure was performed under transesophageal echocardiogram (TEE) guidance. The endografts used in each study are reported in Tables 3 and 4. Out of all 31 studies, transfemoral access as a device delivery route was reported in 72 patients (78%; Tables 3 and 4). Other types of vascular access were transapical ($n = 14$, 15%), transcarotid ($n = 2$, 2%), or transaxillary ($n = 4$, 4%). Insufficient additional specifics were reported regarding the mode of access (i.e., cut-down or percutaneous). Overall technical success was 95.6%.

3.2 | Hospital stay and follow-up

The hospital stay was described in 11 case reports with a median of 5 days (range: 1.5–12 months). In only two out of 12 case series, hospital stay was described, averaging 8.7 days over a total of 23 patients. Follow-up was described in 10 case reports with a median of 6 months (range: 1–25 months). In the case series, follow-up was described in 7 studies (32 patients), averaging 14 months (range: 18–39 months).

3.3 | Complications

Early endoleak, within 30 days, occurred in 17 out of 92 patients (18%), and 4 patients required additional management using stent graft extensions.[35,37,51] One patient received an Amplatzer plug to treat type 1 A endoleak.[49] This was achieved through transapical access, after which the plug was used to eliminate residual flow across the entry tear at the proximal aspect of the stent graft. Late endoleak occurred in nine patients (10%). Most patients with endoleak developed no major complications, other than additional endovascular procedures. Subdividing the occurrence of endoleaks into proximal and distal leaks was impossible, as the location was not explicitly reported in all studies. However, most of the bird-beak signs (i.e., the wedge-shaped gap between endograft and aortic wall due to incomplete apposition of the proximal portion of the endograft) were seen in the distal landing zone, as can be expected from its curved geometry.[53]

Rare complications included stent graft induced new entry-tears (SINE; $n = 2$), accidental covering of branch vessels ($n = 1$), iatrogenic dissection ($n = 1$), and retained delivery systems ($n = 1$), all of which required open surgical repair.[35,36,45]

Overall, 30-day mortality was 9% (Table 5), with breakdowns of 11%, 0%, and 4% for acute, subacute, and chronic type A dissection, respectively. The 30-day event-free survival (i.e., freedom from death, reintervention, or major complication) was 71%. Short-term mortality was 16%. Short-term event-free survival at a 2-year follow-up could not be reported. The stroke rate was 6% (6 out of 92).

3.4 | Additional procedures

With the exception of one study describing concomitant PCI in the setting of coronary artery disease (CAD), no studies reported on the treatment of CAD.[46] Eight patients (9%) required arch vessel debranching before TEVAR, while intraoperative aortic arch branching procedures were performed in six cases (7%; Table 6), using a chimney, fenestration, or branched stent graft. Additional stenting or ballooning for endoleak or aortic valve entrapment was performed in six cases (7%). Two patients (2%) required direct open conversion.

TABLE 1 Demographics and comorbidities of selected case reports

Author	Year	Indication	Mean age	Gender	Comorbidities	Relevant surgical history	Significant aortic insufficiency	Hospital stay (days)	Average follow-up (months)
Dorros[13]	2000	Chronic TAAD	56	Female	CAD	CABG, open TAAD repair	N/S	N/S	0.75
Zhang[22]	2004	Subacute TAAD	46	Female	CAD	None	N/S	N/S	12
Ihnken[33]	2004	Acute TAAD	89	Female	None	None	N/S	12	N/S
Zimpfer[44]	2006	Acute TAAD	84	Male	DM, CVA, and RF	None	N/S	7	1
Senay[46]	2007	Acute TAAD	66	Male	Lung cancer	Open lobectomy	N/S	5	N/S
Palma[47]	2008	Chronic TAAD	63	Male	COPD, RF, HTN, DM, and CVA	None	No	N/S	N/S
Metcalfe[48]	2012	Acute TAAD	68	Female	HTN and RF	None	N/S	N/S	N/S
Shabaneh[49]	2013	Acute TAAD	70	Male	AEF, CAD, COPD, and RF	AAA repair, EVAR, esophagectomy, and CABG	No	4	1
Pontes[50]	2013	Acute TAAD	84	Female	COPD, DM, CHF, and RF	None	N/S	N/S	N/S
McCallum[51]	2013	Ruptured chronic TAAD	77	Male	CAD	Post heart transplant, sternotomy x4	N/S	N/S	25
Kölbel[23]	2013	Acute TAAD	67	Male	COPD, CHF, and RF	None	No	10	5
Luo[24]	2014	Acute TAAD	56	Female	CAD and RF	Heart-transplant	No	N/S	6
Atianzar[25]	2014	Acute TAAD	79	Male	N/S	None	No	1.5	N/S
Wilbring[26]	2015	Acute TAAD	82	Male	AoS, RF, COPD, DM, and CVA	None	No	N/S	6
Berfield[27]	2015	Acute TAAD	95	Female	CHF and AoS	TAVR	Yes	7	2
Rohlffs[28]	2016	Chronic TAAD	72	Male	CAD and COPD	fEVAR for TAAA	N/S	4	N/S
Muetterties[29]	2017	Acute TAAD	48	Female	HTN and RF	None	No	4	24
Kong[30]	2019	Chronic TAAD	65	Male	N/S	Mitral valve repair and aortic valve repair	No	5	N/S
Wamala[31]	2019	Acute TAAD	91	Male	CAD, DM, RF, COPD, and HTN	EVAR	N/S	7	12

Abbreviations: AEF, aorto-esophageal fistula; AoS, aortic stenosis; CAD, coronary artery disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; DM, diabetes mellitus; fEVAR, fenestrated endovascular aortic repair; HTN, hypertension; N/S, not specified; RF, renal failure; TAAA, thoraco-abdominal aneurysm; TAAD, type A aortic dissection; TBAD, Type B aortic dissection.

TABLE 2 Demographics and comorbidities of selected case series

Author	Year	N (TAAD)	Indication	Mean age	Male, n (%)	Comorbidities	Relevant surgical history	Significant aortic insufficiency, n (%)	Hospital stay (days)	Average follow-up (months)
Ye[32]	2011	10	6 acute TAAD, 4 chronic TAAD	51	9 (90)	HTN	None	N/S	N/S	N/S
Ronchey[34]	2013	4	4 acute TAAD	70	2 (50)	HTN, DM, and COPD	AVR, open TAAD repair	N/S	N/S	15
Bernardes[35]	2014	3	2 acute TAAD, 1 chronic TAAD	54	0	HTN and CAD	Open TAAD repair	N/S	N/S	2.5
Roselli[36]	2015	11	11 acute TAAD, 2 chronic TAAD	74	6 (55)	HTN, CAD, DM, COPD, RF, CVA, and CHF	Cardiovascular Surgery	N/S	N/S	N/S
Vallabhajosyula[37]	2015	2	2 acute TAAD	84	0	HTN, CAD, CVA, and HCC	None	N/S	N/S	9
Khoynezad[38]	2016	2	1 acute TAAD, 1 chronic TAAD	86	1 (50)	HTN and deep vein thrombosis	Cardiovascular Surgery	N/S	N/S	8
Li[39]	2016	15	1 acute TAAD, 7 subacute TAAD, 7 chronic TAAD	65	12 (80)	COPD and RF	Sternotomy	2 (13%)	9.4	N/S
Nienaber[40]	2016	12	6 acute TAAD, 6 chronic TAAD	81	9 (75)	CAD, COPD, and RF	None	None	N/S	19
Murakami[41]	2017	1	1 subacute TAAD	66	0	HTN, CAD, RF, and CVA	None	1 (100%)	N/S	N/S
Grieshaber[42]	2018	4	3 acute TAAD, 1 subacute TAAD	63	3 (75)	CAD, COPD, RF, and CVA	Open TAAD repair	None	N/S	N/S
Hsieh[43]	2019	1	Acute TAAD	79	0	CVA	None	N/S	1	10
Ghoreishi[45]	2019	8	7 acute TAAD, 1 chronic TAAD	69	N/S	CAD, COPD, and RF	CABG	2 (25%)	7.5	12

Abbreviations: CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; DM, diabetes mellitus; HCC, hepatocellular carcinoma; HTN, hypertension; N/S, not specified; RF, renal failure; TAAD, type A aortic dissection.

TABLE 3 Operative details of selected case reports

Author	Endograft specification	Device delivery	Anesthesia	Device deployment approach	TEE
Dorros[13]	OSD, Lacteba	Transfemoral	General	Adenosine induced cardiac arrest	No
Zhang[22]	Gianturco Z, Cook Medical	Transfemoral	Epidural	N/S	No
Ihnken[33]	Excluder Endoprosthesis, W.L. Gore	Transfemoral	General	N/S	Yes
Zimpfer[44]	CMD, Jotec	Transfemoral	General	Rapid pacing	Yes
Senay[46]	Valiant, Medtronic	Transfemoral	General	N/S	No
Palma[47]	CMD, Braile Biomedical	Transfemoral	General	Rapid pacing	No
Metcalfe[48]	Zenith Ascend Dissection, Cook Medical	Transfemoral	General	Rapid pacing	No
Shabaneh[49]	Zenith TX2, Cook Medical	Transfemoral	General	Rapid pacing + tandem heart	Yes
Pontes[50]	N/S	Transfemoral	General	Induced hypotension	No
McCallum[51]	Talent, Medtronic	Transfemoral	N/S	Adenosine induced cardiac arrest	No
Kölbel[23]	Zenith TX2, Cook Medical	Transapical	General	Rapid pacing	Yes
Luo[24]	Valiant, Medtronic	Transapical	General	Rapid pacing	Yes
Atianzar[25]	Valiant, Medtronic	Transfemoral	Spinal	Induced hypotension	No
Wilbring[26]	Relay NBS, Bolton Medical	Transfemoral	N/S	Rapid pacing	Yes
Berfield[27]	Modified Zenith TX2, Cook Medical	Transfemoral	General	Rapid pacing	Yes
Rohlffs[28]	Scalloped Zenith Ascend TAA, Cook Medical	Transfemoral	N/S	Venous inflow occlusion	Yes
Muetterties[29]	Excluder Endoprosthesis, W.L. Gore	Transaxillary	General	Adenosine induced cardiac arrest	Yes
Kong[30]	W.L. GORE	Transfemoral	N/S	Induced hypotension	No
Wamala[31]	Jotec Evita	Transfemoral	General	Rapid pacing	Yes

Abbreviations: CMD, custom made device; N/S, not specified; OSD, off the shelf device; TEE, transesophageal echocardiogram.

3.5 | Reinterventions

Ten patients (11%) underwent open reintervention, whereas four patients (4%) underwent endovascular reintervention (Table 6). Open reinterventions were performed SINE ($n = 3$),[35,39] Type I endoleak ($n = 1$),[36] severe AI ($n = 1$),[22] PAU ($n = 1$),[38] iatrogenic femoral artery dissection ($n = 1$),[45] pseudoaneurysm ($n = 2$),[32,36] and pericardial effusion ($n = 1$).[45] Endovascular reinterventions were performed for Type I endoleak ($n = 3$)[35,36] and severe AI ($n = 1$).[45]

4 | DISCUSSION

Over recent years, endovascular interventions to treat TAAD have proven to be a feasible treatment modality. We report a 30-day mortality of 9% and a short-term mortality of 16%. When compared to literature data on in-hospital mortality for open surgical repair of TAAD, ranging between 16% and 20%, these results suggest that endovascular repair is an acceptable alternative for patients who are deemed unfit to undergo open surgical repair for type A dissection.[2,54] It is important to note that, similar to type B aortic dissection, acuity of disease in TAAD impacts both patient presentation and outcome.[55] Patients presenting with subacute/chronic TAAD have better short- and long-term survival rates when compared to acute TAAD patients.[3] Stroke incidence with endovascular treatment of TAAD of 6% was no higher than previous reports from arch TEVAR[56–58] and open TAAD repair.[4,54,59]

Given the novelty of this procedure and the lack of long-term outcomes, there remain several topics of concern that must be adequately considered: patient selection, vascular access, stent graft design, and aortic valve involvement. These topics will be addressed below.

4.1 | Patient selection

When considering endovascular repair in TAAD, rigorous patient selection is of paramount importance, based on both clinical and radiological characteristics. As of current, only patients who are considered too frail to undergo open surgical repair are considered for TEVAR. Patients with prohibitive fragility warrant a minimally invasive approach and require careful planning. TAAD patients presenting with visceral malperfusion syndrome represent just such a population, with increased in-hospital mortality (71%) compared to medically treated patients (57%).[2,60–62] Sustained positive outcomes using a treatment approach of initial endovascular malperfusion management (i.e., fenestration of the intimal flap and/or true lumen stenting), followed by delayed open repair have been

TABLE 4 Operative details of selected case series

Author	Endograft specification	Device delivery	Anesthesia	Device deployment approach	TEE
Ye[32]	Talent, Medtronic; Zenith, Cook Medical; Ancure II, XianJuan; Aegis, Microport	Transfemoral Transcarotid	General	Induced hypotension	No
Ronchey[34]	Zenith TX2 TAA, OSD, Cook Medical	Transfemoral	General	Rapid pacing	Yes
Bernardes[35]	Zenith, Cook Medical; TAG, W.L. Gore; Valiant, Medtronic	Transfemoral	General	Induced hypotension	No
Roselli[36]	W.L. Gore; Medtronic; Cook Medical	Transfemoral Transapical Transaxillary	General	Rapid pacing	Yes
Vallabhajosyula[37]	Zenith TX2 TAA, Cook Medical	Transapical	N/S	Rapid pacing	Yes
Khoynezad[38]	Valiant PS-IDE, Medtronic	Transfemoral	N/S	Rapid pacing	Yes
Li[39]	Zenith TX2 TAA, Cook Medical	Transfemoral	General	Rapid pacing	Yes
Nienaber[40]	Zenith TX2 TAA, Cook Medical; Relay NBS, Bolton; C-TAG, W.L. Gore; Nitinol Stent, Optimed	Transfemoral	General	Rapid pacing	Yes
Murakami[41]	Zenith TX2 TAA, Cook Medical	Transapical	General	Rapid pacing	Yes
Grieshaber[42]	CMD, Bolton Medical	Transfemoral Transapical	General	Rapid pacing	Yes
Hsieh[43]	Medtronic	Transfemoral	General	N/S	No
Ghoreishi[45]	W.L. Gore TAG or Excluder	Transfemoral Transaxillary	General	Raped pacing	Yes

Abbreviations: CMD, custom made device; N/S, not specified; OSD, off the shelf device; TEE, transesophageal echocardiogram.

demostrated.[63,64] A recent publication by Omura et al.[65] demonstrates the feasibility of TEVAR and concomitant true lumen stenting in acute retrograde type A dissection with renal malperfusion. However, no cases of endovascular TAAD repair with concomitant endovascular visceral malperfusion treatment have been reported yet.

ECG-gated computed tomography (CT) scan technique is highly recommended given the requirement for motion-artifact free images for accurate measurements. Retrospective ECG-gating technique is optimal for quantification of morphometric changes of the aorta over the cardiac cycle, and for dynamic evaluation of the entry tear anatomy, particularly in acute/subacute TAAD given higher degrees of intimal flap motion.[66] As of recent, various studies have explored imaging characteristics in type A dissection patients to assess feasibility of endovascular aortic repair.[11,12] Ideally, 2 cm of nondilated and nondissected aorta can be identified at both proximal and distal landing zones. Complex hemodynamics encountered in the thoraco-abdominal aorta leads to increased displacement forces on the stent graft and accentuate the need for a robust seal.[67,68]

4.2 | Vascular access

When treating most proximal aortic disease, transfemoral delivery may be more limited as a result of inadequate delivery system length and higher degrees of aortic arch angulation. The iliofemoral arteries require a caliber of at least 6.5–7 mm, as most conformable thoracic endografts have a minimal profile of 20 French.[69–72] Retrograde delivery routes carry an increased risk if true lumen access is not obtained at both landing zones. Wire location in the true lumen can be confirmed by IVUS examination before delivery of the endograft. Furthermore, accurate deployment may be complicated by increased spring-back forces or decreased conformability (i.e., increased rigidity) of the delivery device.[73,74]

Alternatively, a transapical, transcarotid, or transaxillary approach offer deployment strategies closer to the ascending aorta when compared to the transfemoral approach. Nonetheless, each of these approaches carry distinct risks. Transapical delivery is incompatible with previous implanted prosthetic mechanical valves and may potentially induce long-term complications, such as formation of left ventricular pseudoaneurysm, as reflected in this review.[36,39] This approach, however, offers the unique advantage of antegrade deployment, ensuring true lumen access. Furthermore, the more in-line approach and shorter distance to the sinotubular junction (STJ) provides a lower dependence on delivery device conformability.[12] Transcarotid and transaxillary access have been rarely described for proximal aortic TEVAR. In the two patients where transcarotid delivery was performed, stroke occurred within 3 weeks and 1 years postoperatively.[32]

TABLE 5 In-hospital and short-term outcomes of selected case reports and case series

	Case reports No. of patients (%)	Case series No. of patients (%)
Early outcomes	**Total *n* = 19**	**Total *n* = 73**
Technical success	19 (100)	69 (95)
Endoleak	4 (21)	13 (18)
Stroke	1 (5)	5 (7)
Myocardial infarction	1 (5)	1 (1)
Respiratory failure requiring prolonged ventilation or intubation	1 (5)	0 (0)
Renal failure requiring dialysis	0 (0)	1 (1)
Aortic insufficiency	1 (5)	1 (1)
30-day mortality	2 (11)	6 (8)
30-day event-free survival	9 (75)[a]	51 (71)[b]
Short-term outcomes	**Total *n* = 17**	**Total *n* = 67**
Endoleak	1 (6)	5 (7)
Short-term mortality	0	11 (16)
Stent graft-induced new-entry tears	0	3 (4)

[a]Seven patients were excluded due to a follow-up of less than 30 days.
[b]One patient was excluded due to a follow-up of less than 30 days.

4.3 | Stent graft design

Most cases reports describe stent grafts that were originally designed for the descending thoracoabdominal aorta. Consequently, these devices are often too long for use in the ascending aorta, frequently measuring over 10 cm in length, whereas the normal length of the ascending aorta is 8–10 cm.[75] Potential solutions include customizing existing descending stent grafts or using commercially approved shorter segment devices. The first option comes with significant shortcomings, as the newly exposed cut-end of the endograft may cause damage to the adjacent aortic tissue and increase risk of SINE. Furthermore, unloading and reloading the device may lead to failure during deployment. The latter option has the advantage of accounting for the higher angulation through modular grafting and the preloaded market-approved devices. However, when using shorter segment stent grafts, there is often need to deploy multiple overlapping stents to ensure coverage of the ascending aorta, with a corresponding increased risk of type IIIa endoleak (i.e., leak between endograft components) or migration. Metcalfe et al.[48] were the first to describe the use of a stent graft specifically designed for the ascending aorta, with excellent results.

Stent graft design and deployment techniques need to account for the hemodynamic forces present in the ascending aorta, by ensuring adequate landing zone length and seal to withstand the displacement forces and ultimately prevent stent migration.[76–78] A computational fluid dynamics study by Figueroa et al.[79] evaluated net thoracic aortic stent graft displacement, demonstrating that the more proximal the endograft is implanted, the greater the cranial component of displacement.

In conventional endovascular aneurysm repair outer-to-outer-wall diameter is used for stent graft sizing and 10%–20% oversizing is generally accepted.[80] However, in dissection and IMH the size of the true lumen relative to the outer-wall diameter may be discrepant, difficult to measure and variable over time. Additionally, the tissue strength of the dissected segment may be unable to bear the radial force imposed by the oversized endograft. To this extent, tissue fragility in the dissected ascending aorta must be taken into account, and stent graft oversizing of 10%–20% may be excessive, potentially causing further wall injury or rupture. Predominantly in acute dissections, oversizing of 5%–10% is advocated, whereas the amount of oversizing in chronic dissections may be higher.[81–83] These oversizing rates have been based on TEVAR for descending

TABLE 6 Additional procedures and reinterventions

		Case reports (*n* = 19) *n* (%)	Case series (*n* = 73) *n* (%)
Intraoperative procedures	Arch vessel debranching	0 (0)	8 (11)
	Branching procedures	2 (11)	4 (5)
	Additional stenting	1 (5)	3 (4)
	Additional ballooning	1 (5)	1 (1)
	Open conversion	0 (0)	2 (3)
	Coronary stenting	1 (5)	1 (1)
Reinterventions	Open	1 (5)	9 (12)[a]
	Endovascular	0 (0)	4 (5)

[a]Three out of nine reinterventions were related to vascular access complications.

thoracic aortic pathology, as limited ascending endovascular repair has not yet been described.

4.4 | Aortic valve involvement

A major limitation of endovascular approach of type A repair is the limited ability to address aortic valve insufficiency (AI), either secondary to STJ malalignment or valve injury due to a proximal entry tear. In open repair for TAAD, AI can be treated using a valve resuspension technique or complete aortic valve replacement. As suggested previously by Kreibich et al.[84] and more recently demonstrated by Gaia et al.,[85] an "endo-Bentall" approach might allow for treatment of AI in the setting of TAAD. The authors describe a transapical approach, in which a TAVR valve is deployed simultaneously with an ascending aortic stent graft, successfully extending the proximal landing zone of the stent graft to the aortic annulus. The valve is connected to an uncovered portion of the stent graft, to allow for free diastolic coronary blood flow. In the case of an entry tear at the level of the sinus of Valsalva or lower; however, this approach may not fully exclude the entry tear, the primary goal of any TAAD repair technique. Currently, a proven endovascular solution to address significant AI is not available.

4.5 | Limitations

This systematic review is limited by the quality of the existing literature, characterized by an overall lack of large cohort studies and prospective trials. Given the estimated incidence of acute type A dissection of 3–5 per 100,000 patients and the observation that approximately 9%–14% of patients are deemed inoperable, one would expect a broad application of novel endovascular techniques. However, in the past two decades, we have identified a total of only 92 type A dissection patients managed with TEVAR. It is therefore important to recognize the potential for publication bias in the studies reviewed in this paper, warranting caution in interpreting these early results. Further, we recognize the distinct differences in outcomes between patients presenting with acute and chronic TAAD, and the lack of a sub analysis for these cohorts is dissatisfying. Therefore, current results may not be fully generalizable to the entire TAAD population. Open repair for TAAD is still recognized as the gold standard and endovascular repair as a treatment modality still under development. Patients undergoing endovascular aortic repair represent a small subpopulation of all type A dissection patients, and thus most conclusions drawn from the current reports of endovascular TAAD repair are likely premature. To fully ascertain the role of TEVAR in the treatment of TAAD, larger studies with long-term follow-up are clearly needed. Given the heterogeneity and the small sample size of all reports, we were unable to apply more advanced statistical techniques (e.g., random-effects meta-analysis model), and are thus limited to descriptive and pooled analyses.

5 | CONCLUSION

This systematic analysis presents a comprehensive review of isolated TEVAR management of type A dissection. Our review confirms that TEVAR is a feasible treatment option for high-risk TAAD patients and current reported mortality rates are favorable over medical treatment. However, this review also highlights the urgent need for technical advances in disease-specific device design, delivery methods, and hybrid endovascular techniques to address the need for concomitant valve replacement and/or arch endografting. Most importantly, our analysis emphasizes the significant need for larger studies with long-term results and more complete reporting of negative results before the endovascular intervention may widely proposed as an alternative to the gold standard open repair.

CONFLICT OF INTERESTS

David M. Williams: Medical advisory board for Boston Scientific; Himanshu J. Patel: Consultancy activities for W.L. Gore, Medtronic Inc., and Terumo Inc.; Joost A. van Herwaarden: Consultancy activities for Cook Medical, W.L. Gore, Medtronic Inc., and Terumo Inc; Other authors declare that there are no conflict of interests.

ORCID

Yunus Ahmed https://orcid.org/0000-0002-6036-8929
Ignas B. Houben https://orcid.org/0000-0001-8975-528X
C. Alberto Figueroa https://orcid.org/0000-0002-3934-6506
Nicholas S. Burris https://orcid.org/0000-0002-5198-4383
Joost A. van Herwaarden https://orcid.org/0000-0003-1165-5179

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APPENDIX

Medline search

(Endovascular OR Transluminal OR "endovascular procedures"[MeSH Terms] OR endovascular repair OR Endovascular treatment OR Endovascular approach OR endovascular stent graft OR Trans-luminal stent graft OR TEVAR OR Thoracic endovascular aortic repair OR thoracic endovascular repair) AND ("type A dissection" OR "acute type A dissection" OR "type A aortic dissection" OR "acute type A aortic dissection" OR ascending aortic dissection) AND ("ascending aorta" OR "ascending" OR "aorta"[MeSH Terms] OR "zone 0").