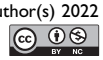
Innovations
2022, Vol. 17(4) 283–296



DOI: 10.1177/15569845221107011
journals.sagepub.com/home/inv


Management Strategies for Descending Thoracic Aortic Thrombus: A Review of the Literature

Quynh Nguyen[1], BSc, Xiya Ma[2], MD, MSc, Dominique Vervoort[3], MD, MPH, MBA, and Jessica G. Y. Luc[4], MD

Abstract

Descending thoracic aortic thrombus (DTAT) is an under-recognized source of systemic emboli with potential catastrophic consequences. Imaging modalities such as echocardiography, computed tomography, magnetic resonance imaging, and angiography can help identify and characterize the extent of embolic events. Established guidelines regarding the management of DTAT are currently lacking. Multiple treatment modalities are available; however, the effectiveness of each approach remains to be determined. In this study, we performed a review to examine the clinical presentation, diagnostic methods and findings, and outcomes of various treatment options for patients with DTAT. Medical management is the least invasive and most frequently chosen initial approach, offering a high reported success rate, whereas endovascular therapy can have a role in thrombus exclusion should conservative management fail.

Keywords

descending aortic thrombus, aortic thrombus, mural thrombus, floating thrombus

Central Message

Medical management is the least invasive and most frequently chosen initial approach for DTAT, whereas endovascular therapy can have a role in thrombus exclusion should conservative management fail.

Introduction

Descending thoracic aortic thrombus (DTAT) is a rare entity that can lead to systemic arterial thromboembolism, a serious and potentially life-threatening condition.[1] Therefore, early detection and treatment are critical for a good prognosis. Although DTAT could be detected incidentally, most cases present with peripheral embolic events, which makes early detection challenging.[2–6] Recent developments in diagnostic imaging have contributed significantly to the accurate diagnosis of various aortic pathologies such as DTAT, including echocardiography, computed tomography (CT), angiography, and magnetic resonance imaging (MRI).[7–11] Although thrombi in the ascending aorta, aortic arch, and abdominal aorta have all been previously described, reported thoracic thrombi were most commonly (38.0%) located in the descending thoracic aorta.[12] Currently, there are no established guidelines on the management of DTAT.[13–16] Different approaches have been reported with varying degrees of invasiveness and effectiveness, ranging from conservative medical management to endovascular intervention and open surgery.[1]

The present review aims to describe and summarize the clinical presentation, diagnostic methods, treatment, and reported outcomes for thrombi localized in the descending thoracic aorta.

Methods

Literature Search Strategy

Articles were identified following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines

[1]Faculty of Medicine and Dentistry, University of Alberta, Edmonton, AB, Canada
[2]Faculty of Medicine, Université de Montréal, QC, Canada
[3]Division of Cardiac Surgery, Department of Surgery, University of Toronto, ON, Canada
[4]Division of Cardiovascular Surgery, Department of Surgery, University of British Columbia, Vancouver, BC, Canada

Corresponding Author:
Jessica G. Y. Luc, Division of Cardiovascular Surgery, University of British Columbia, 1081 Burrard Street, Unit 486, Vancouver, BC, V6Z 1Y6, Canada.
Email: jessicagyluc@gmail.com

through electronic searches of Ovid Medline, Embase, Cochrane Database of Systematic Reviews, and Scopus databases, performed in August 2020. Studies describing DTAT were found using a combination of variations of the key terms "thrombus," "aorta," "descending thoracic aorta," "atheroma," "thromboembolism," "emboli," and relevant medical subject heading (MeSH) terms. A closely related but distinct condition termed "shaggy aorta" (SA) has been increasingly described in the literature.[17–19] SA refers to an aorta with irregular mural thrombus as demonstrated on imaging studies. Because of severe atherosclerotic process, the aorta becomes extremely degenerate and friable and likely to cause atheroembolism spontaneously or during procedural manipulations.[20,21] SA is a different entity from floating aortic thrombus in terms of etiology and management. Therefore, articles describing SA were not included in this study. In addition, relevant sources cited within retrieved articles were also reviewed for further identification of potentially relevant publications. After removal of duplicates, articles were screened by 2 independent contributors using the eligibility criteria, as described below.

Selection Criteria

Inclusion and exclusion criteria were determined before data collection. Articles were limited to those involving human subjects and written in English. We included only contemporary studies, defined as published in the year 2000 and onward, with clear descriptions of the management strategy used for the DTAT. Cases describing patients younger than 18 years and those with congenital heart lesions, structural heart problems, aortic dissection pathologies, or previous cardiac surgical operations were excluded. Our goal was to describe the clinical experience, management, and outcomes of patients with de novo DTAT rather than those with preexisting cardiac pathologies, as these complex cases are often managed on a case-by-case basis. Studies reporting intracardiac thrombi, or thrombi located in the ascending aorta, aortic arch, abdominal aorta or pulmonary artery were also excluded.

Data Extraction

All data were manually extracted from article texts, tables, and figures. Variables included study sample size, age, sex, cardiovascular risk factors, presence of coagulation disorders, symptoms at presentation, diagnostic modalities, thrombus characteristics, medical management, surgical management, follow-up, and early and late outcomes. Discrepancies were resolved by group discussion and consensus.

Descriptive statistics were performed using GraphPad Prism version 8.4.3 (GraphPad Software, La Jolla, CA, USA). Categorical variables were presented as counts (n) and frequency (%). Continuous variables were presented as mean ± standard deviation if normally distributed or median and interquartile range (IQR) if not normally distributed.

Results

A total of 1,611 articles were identified after removing duplicates, with 51 articles included in this study involving 64 patients.

Clinical Presentation

In terms of patient demographics, DTAT can present at various ages, ranging from 21 to 77 years. The median age at presentation was 54 years (Table 1). DTATs were more commonly reported in female patients (59% of cases) than in male patients.

Although patients with DTAT can be asymptomatic, most reported cases presented with manifestations of thromboembolism. Claudication symptoms such as extremity pain, ischemic rest pain, skin discoloration, gangrene, and necrosis were the most common initial presentation, accounting for 45% of the cases. Abdominal pain was also reported in 33% of patients, followed by neurologic deficits such as sudden visual impairment, dysarthria, aphasia, paraplegia, or paresthesia in 11% of cases. Less common initial presentations included chest pain, dyspnea, and back pain. Three percent of DTAT was identified in the context of traumatic events.

Hypercoagulable states can contribute to the occurrence of DTAT. Protein C deficiency and polycythemia vera have each been reported in 5% of cases. Other coagulation disorders that were identified in patients with DTAT include thrombophilia, protein S deficiency, antithrombin III deficiency, positive anticardiolipin antibody, and essential thrombocytosis.

As with other types of thromboembolic diseases, various risk factors for cardiovascular disease and arterial thrombosis were reported in patients with DTAT. Smoking (33%), hypertension (30%), obesity (22%), diabetes (14%), and dyslipidemia (13%) were the most commonly reported cardiovascular risk factors among the included cases. With regard to thrombosis risk factors, malignancy and chemotherapy were associated with 13% and 6% of DTAT cases, respectively. Other conditions such as previous thromboembolism, vasculitis, and steroid or drug use have also been described in the context of DTAT.

Diagnosis

Echocardiography, CT, MRI, and angiography have all been used for the diagnosis of DTAT (Table 2). CT and CT angiography were the most frequently used imaging (78%), although the diagnosis of DTAT was often revealed on transesophageal echocardiography (TEE), which was used in 64% of the cases. Despite its great diagnostic value, TEE was unable to detect DTATs that were identified on CT imaging in 2 cases. In contrast, transthoracic echocardiography (TTE) was performed in 16% of patients as part of the initial workup for potential aortic sources of arterial embolism. Multiple imaging studies were often necessary to confirm the diagnosis of DTAT and to identify the extent of thromboembolic events.

DTAT can manifest in different shapes on imaging. DTAT was described as a mass, a filling defect, and a hypodensity

Table 1. Demographic and Clinical Presentation of Previously Described Cases of Thrombus in the Descending Thoracic Aorta.

Parameter	Initial treatment strategy			Overall ($N = 64$)
	Medical ($n = 32$)	Endovascular ($n = 22$)	Surgical ($n = 10$)	
Demographics				
Age, years	55 (50–62)	58 (48–63)	52 (48–56)	54 (50–62)
Female	15 (47)	16 (73)	7 (70)	38 (59)
Symptoms				
Asymptomatic	3 (9)	1 (5)	0	4 (6)
Trauma	1 (3)	1 (5)	0	2 (3)
Chest pain	3 (9)	1 (5)	2 (20)	6 (9)
Back pain	2 (6)	1 (5)	1 (10)	4 (6)
Abdominal pain	12 (38)	8 (36)	1 (10)	21 (33)
Dyspnea	2 (6)	1 (5)	2 (20)	5 (8)
Claudication	15 (47)	11 (50)	3 (30)	29 (45)
Neurological deficits	2 (6)	4 (18)	1 (10)	7 (11)
Others	6 (19)	5 (23)	2 (20)	13 (20)
Coagulation disorders				
Protein S deficiency	1 (3)	0	0	1 (2)
Protein C deficiency	2 (6)	0	1 (10)	3 (5)
Antithrombin III deficiency	0	0	1 (10)	1 (2)
Positive anticardiolipin antibody	1 (3)	0	0	1 (2)
Polycythemia vera	2 (6)	1 (5)	0	3 (5)
Essential thrombocytosis	1 (3)	0	0	1 (2)
Thrombophilia	0	2 (9)	0	2 (3)
Others	2 (6)	0	0	2 (3)
Risk factors				
Malignancy	7 (22)	1 (5)	0	8 (13)
Chemotherapy	4 (13)	0	0	4 (6)
Steroid use	0	1 (5)	0	1 (2)
Previous thrombus	5 (16)	1 (5)	1 (10)	7 (11)
Diabetes	4 (13)	2 (9)	3 (30)	9 (14)
Hypertension	7 (22)	8 (36)	4 (40)	19 (30)
Dyslipidemia	3 (9)	4 (18)	1 (10)	8 (13)
Vasculitis	0	0	1 (10)	1 (2)
Smoking	12 (38)	6 (27)	3 (30)	21 (33)
Drug use	1 (3)	1 (5)	0	2 (3)
Obesity	5 (16)	7 (32)	2 (20)	14 (22)
Coronary artery disease	1 (3)	2 (9)	0	3 (5)
Arrhythmias	0	2 (9)	0	2 (3)
Others	5 (16)	4 (18)	2 (20)	11 (17)

Data are presented as median (IQR) or *n* (%).

lesion in 13%, 8%, and 6% of cases, respectively. Delayed contrast enhancement was observed in 3% of the cases. Most reported DTAT cases were either mobile (38%) or floating (31%). The definition and characterization of the floating DTATs were not available on the reported cases. Mural thrombus was identified in 11% of patients.

Most reported DTAT cases were confined to the descending thoracic aorta (75%). Other thrombi were identified in 25% of cases. Distally, 38% were located in the iliac or femoral artery, 25% in the abdominal aorta, 19% in the superior mesenteric artery, and 13% in the celiac artery. Thrombi in the pulmonary artery were found in 13% of cases. Retrograde embolism was reported in 1 case with a thrombus identified in the cerebral artery.

With regard to thrombus size, 3% of reported DTATs were less than 1 cm, 36% were 1 to 5 cm, 11% were 6 to 10 cm, and 5% were greater than 10 cm. Aortic atherosclerosis was found in 13% of patients. In addition, 5% of patients also showed aortic intimal irregularity on imaging studies.

Management

Multiple treatment options with varying degrees of invasiveness are available for the management of DTAT, although established guidelines are lacking. Current treatment approaches include conservative management, endovascular intervention, and surgery. Most patients in this review received conservative medical management (50%) as the initial approach. Endovascular intervention was the treatment of choice in 34% of cases, whereas the remaining 16% were managed surgically.

Table 2. Diagnostic Findings in Previously Described Cases of Thrombus in the Descending Thoracic Aorta.

Parameter	Initial treatment strategy			Overall ($N = 64$)
	Medical ($n = 32$)	Endovascular ($n = 22$)	Surgical ($n = 10$)	
Imaging modalities				
TTE	6 (19)	4 (18)	0	10 (16)
TEE	20 (63)	12 (55)	9 (90)	41 (64)
CT/CTA	24 (75)	18 (82)	8 (80)	50 (78)
MRI/MRA	11 (34)	0	3 (30)	14 (22)
Angiography	1 (3)	2 (9)	0	3 (5)
Thrombus appearances				
Mass	5 (16)	0	3 (30)	8 (13)
Filling defect	3 (9)	1 (5)	1 (10)	5 (8)
Hypodensity lesion	2 (6)	1 (5)	1 (10)	4 (6)
Delayed contrast enhancement	1 (3)	0	1 (10)	2 (3)
Mobile	10 (31)	9 (41)	5 (50)	24 (38)
Mural	3 (9)	3 (14)	1 (10)	7 (11)
Floating	10 (31)	5 (23)	5 (50)	20 (31)
Thrombus characteristics				
Location				
Confined to descending thoracic aorta	26 (81)	14 (64)	8 (80)	48 (75)
Presence of other thrombi	6 (19)	8 (36)	2 (20)	16 (25)
Cerebral artery	0	1 (13)	0	1 (6)
Pulmonary artery	0	0	2 (100)	2 (13)
Abdominal aorta	1 (17)	3 (38)	0	4 (25)
Celiac artery	1 (17)	1 (13)	0	2 (13)
Superior mesenteric artery	1 (17)	2 (25)	0	3 (19)
Inferior mesenteric artery	0	0	0	0
Iliac/femoral artery	2 (33)	3 (38)	1 (50)	6 (38)
Others	3 (50)	2 (25)	0	5 (31)
Size, cm				
<1	2 (6)	0	0	2 (3)
1–5	10 (31)	9 (41)	4 (40)	23 (36)
6–10	4 (13)	2 (9)	1 (10)	7 (11)
>10	1 (3)	1 (5)	1 (10)	3 (5)
Presence of aortic atherosclerosis	5 (16)	3 (14)	0	8 (13)
Presence of intimal irregularity	0	1 (5)	2 (20)	3 (5)

Abbreviations: CT, computed tomography; CTA, computed tomography angiography; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.
Data are presented as *n* (%).

Conservative management. Conservative management was frequently used as the initial treatment strategy in patients diagnosed with DTAT. This approach was also recommended for patients who were not surgical candidates or those who did not wish to receive invasive treatment. Antithrombotic agents were administered in most patients, namely, 30 of the 32 cases (94%; Table 3). All 30 patients (100%) received anticoagulant medication, whereas 5 patients (17%) additionally received an antiplatelet drug. Thrombolytic therapy using streptokinase or alteplase was reported in 2 of the 32 cases (6%). Information on maintenance therapy was scarce, with only 5 of 32 cases (16%) explicitly mentioning long-term antithrombotic therapy using anticoagulants after initial treatment. The length of hospital stay ranged from 14 to 28 days, with a median of 16 days.

Endovascular management. Indications for endovascular intervention were mentioned in 12 cases (Table 4). Among these cases, most DTATs were managed with an endovascular intervention to prevent embolic events (58%, 7 of 12 cases). The stability of the patient's clinical condition, such as having multiple embolic events or a rapidly deteriorating condition, was an indication for intervention in 2 cases (17%). Thrombus location and mobility were also taken into consideration when deciding upon the most appropriate treatment approach (17%, 2 of 12 cases). In some cases, failure of conservative management or recurrent thrombus after surgical thrombectomy necessitated further intervention (25%, 3 of 12 cases). Endovascular management was also selected in cases in which antithrombotic therapy was contraindicated and the patient was not fit for surgery (8%, 1 of 12 cases). In some situations, the lack of

Table 3. Conservative Treatment and Outcomes of Thrombus in the Descending Thoracic Aorta.

No.	Reference	Year	Antithrombotic	Thrombolysis	Complications	Hospital LOS (d)	Follow-up time	Follow-up findings
1	Yagyu et al.[2]	2019	IV unfractionated heparin, followed by warfarin	—	—	—	2 wk, 8 mo	2 wk: complete resolution of thrombus; 8 mo: no embolic events, asymptomatic
2	Yagyu et al.[2]	2019	IV unfractionated heparin, followed by warfarin	—	—	—	2 mo, 8 mo	Complete resolution of thrombus; 8 mo: no recurrence
3	Kim et al.[3]	2016	IV unfractionated heparin × 3 d	—	—	—	2 wk	CT: thrombus decreased in size, asymptomatic
4	Kim et al.[3]	2016	IV unfractionated heparin	—	Occluding thrombi in distal vessels, lower limb claudication requiring catheter-directed thrombolysis	—	2 wk	CT: resolution of descending aortic thrombus, L kidney infarction, total occlusion of L proximal run-off vessels, pain and swelling of L lower limb; Angiography: complete occlusion of L tibioperoneal trunk, proximal tibial artery, and peroneal artery
5	Abissegue et al.[4]	2015	Heparin × 10 d, followed by acenocoumarol in hospital; antiplatelet and oral anticoagulant at discharge	—	—	28	2 mo, 10 mo	2 mo, CT: resolution of thrombus; 10 mo: no recurrence
6	Fukuhara et al.[5]	2015	Heparin	—	Worsening of symptoms requiring endovascular intervention	—	—	—
7	Dingli and Dhingra[6]	2014	—	—	Rapid clinical deterioration, switching to comfort care	—	—	—
8	Celikyay et al.[7]	2013	Enoxaparin sodium	—	Respiratory distress, sepsis, and visceral ischemia requiring ICU admission, intubation, hemodialysis, cardiac arrest and death	—	—	—
9	Saranteas et al.[8]	2012	Unfractionated heparin	—	—	—	1 wk, 3 wk	1 wk, TEE: minimal residual of thrombus; 3 wk, TEE: complete resolution of thrombus
10	Montero-Tinnirello et al.[9]	2012	Acenocumarol	—	—	—	—	—
11	Namura et al.[10]	2011	IV heparin	—	—	—	7 d	CT: no changes in masses/thrombi size, requiring surgery
12	Martens et al.[11]	2010	Warfarin, aspirin	—	—	—	—	—

(continued)

Table 3. (continued)

No.	Reference	Year	Antithrombotic	Thrombolysis	Complications	Hospital LOS (d)	Follow-up time	Follow-up findings
13	Lainez et al.[22]	2009	Oral anticoagulant	—	Peripheral recurrent embolisms requiring amputation	—	—	—
14	Catapano et al.[23]	2009	Warfarin × 6 mo, followed by long-term anticoagulant	—	—	—	6 mo	Complete resolution of thrombus
15	Luaces et al.[24]	2009	IV heparin	—	—	—	—	No changes in mass/ thrombus size, requiring surgery
16	Iyer et al.[25]	2009	Heparin, followed by warfarin	—	—	—	1 mo, 6 mo, 2 y	1 m, MRI: partial thrombus resolution; 6 m, MRI: almost complete thrombus resolution; 2 y: patient remained asymptomatic
17	Zhang et al.[26]	2008	Heparin, followed by aspirin and warfarin	—	Peripheral embolisms requiring endovascular intervention	—	1 wk	Acute pain and cyanosis of R first and third toes
18	Sari et al.[27]	2008	—	Streptokinase	Sudden and severe low back pain, loss of lower extremity pulses within 3 h, progressed to cardiopulmonary arrest and death within 1 h	—	—	—
19	Loffroy et al.[28]	2007	SC LMWH × 6 d	—	—	16	2 d	CT: complete resolution of thrombus
20	Durdil et al.[29]	2007	Anticoagulant × long term	IV alteplase	Hematoma at central venous catheter insertion site	—	4 mo	TEE: no signs of thrombosis in thoracic aorta
21	Yoon et al.[30]	2006	Dalteparin, followed by phenprocoumon	—	Big toe necrosis requiring amputation	—	6 wk	TTE: complete resolution of thrombus
22	Slabbekoorn et al.[31]	2006	IV anticoagulant	—	—	14	2 mo	TEE: resolution of thrombus
23	Mark et al.[32]	2005	Warfarin × long term	—	—	14	9 mo	No further ischemic symptoms
24	Mirza et al.[33]	2005	Warfarin	—	—	—	3 mo	TEE: resolution of thrombus
25	Rocco et al.[34]	2004	IV heparin, followed by warfarin	—	—	—	3 d, 1 mo, 6 mo	TEE: resolution of thrombus, patient remained asymptomatic
26	Hazirolan et al.[35]	2004	Warfarin, followed by heparin × 6 wk	—	—	—	6 wk	MRI: no changes in thrombus morphology or size, requiring surgery
27	Auer et al.[36]	2004	Anticoagulant × long term	—	—	—	3 mo	Patient remained asymptomatic
28	Mochizuki et al.[37]	2003	IV heparin, followed by warfarin at discharge × long term	—	—	15	13 d	CT, TEE: complete resolution of thrombus, patient remained asymptomatic

(continued)

Table 3. (continued)

No.	Reference	Year	Antithrombotic	Thrombolysis	Complications	Hospital LOS (d)	Follow-up time	Follow-up findings
29	Stollberger et al.[38]	2001	IV heparin × 3 wk, followed by oral anticoagulant	—	—	28	4 wk, 6 wk, 30 mo	4 wk, TEE: thrombus decreased in size; 6 wk, MRI: complete resolution of thrombus; 30 mo, TTE, MRI: no recurrence, patient remained asymptomatic
30	Kolvekar et al.[39]	2001	Anticoagulant	—	—	—	2 wk	MRI: no changes in thrombus morphology or size, requiring surgery
31	Schwartzbard et al.[40]	2000	IV heparin, followed by warfarin and aspirin × 6 wk and at discharge	—	Abdominal wall bleeding	—	6 wk, 8 mo	6 wk, TEE, MRA: no evidence of thrombus; 8 mo: no embolic events
32	Filipek et al.[41]	2000	IV heparin and aspirin	—	Chest pain	—	3 mo	CT: resolution of thrombus

Abbreviations: CT, computed tomography; ICU, intensive care unit; IV, intravenous; L, left; LMWH, low-molecular-weight heparin; LOS, length of stay; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; R, right; SC, subcutaneous; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.

underlying aortic pathology may favor an endovascular approach as opposed to open surgery (8%, 1 of 12 cases). In addition, endovascular management was performed in cases of diagnostic uncertainty, for example, when aortic dissection could not be ruled out (8%, 1 of 12 cases).

Thoracic endovascular aortic repair (TEVAR) using stent graft was reported in 21 of 22 cases (95%) to exclude DTAT. Mechanical endovascular thrombectomy without stent graft implantation was used in only 1 patient (5%). Antiembolization devices in the forms of occlusion balloons (3 cases) or introducer sheaths (1 case) were used in 4 of 22 cases (18%). Left carotid-subclavian artery bypass was performed in 1 case to correct a blockage of the left subclavian artery by the stent graft. Antithrombotic use was reported in 15 cases (68%). Patients who underwent endovascular intervention spent 3 to 25 days in the hospital, with a median stay of 5 hospital days.

Surgical management. Common indications for surgical management included failure of conservative management (40%, 4 of 10 cases), thrombus size and mobility (40%, 4 of 10 cases), patient clinical presentation (20%, 2 of 10 cases), prevention of embolic events (20%, 2 of 10 cases), and for diagnostic purposes (20%, 2 of 10 cases; Table 5). Surgery was also chosen in 1 case (10%) because of the perceived lower embolic risk compared with endovascular intervention, as well as the lack of experience with the endovascular approach.

Thoracotomy was the surgical approach of choice for all the reported cases. Once access to the descending thoracic aorta is established, the aorta is opened, the thrombus is removed, and the aortotomy is closed by direct suture or patch repair. In 2 cases (20%), the thoracic aortic segment that contained the thrombus was resected, and the aorta was reconstructed with an interposition graft. Moderate hypothermia was reported in 1 case (10%). Central cardiopulmonary bypass (CPB) strategy via left atrium and distal thoracic aorta cannulations was performed in 1 case (10%). Peripheral CPB via left femoral artery and vein were reported in 3 cases (30%). Adjunctive antithrombotic therapy was described in 8 cases (80%). Patients who underwent surgical intervention spent 5 to 14 days in the hospital, with a median stay of 12 hospital days. Pathological studies confirmed the presence of a thrombus in 4 cases (40%) and indicated an inflammatory process of the aortic wall in 2 cases (20%).

Outcomes and Prognosis

Information on treatment outcomes was available for 94% of patients who received conservative treatment, 73% of patients who received endovascular treatment, and 40% of patients who received surgical treatment, resulting in an overall 78% of patients in this study (Table 6). Complications were described in 26% of all cases with outcomes reported. The most common complication in patients diagnosed with DTAT was recurrent embolism, which was identified in 7 cases (14%). Among these 7 patients, 5 were managed conservatively (17%), 1 was managed with endovascular treatment (6%), and 1 was managed surgically (25%). Other reported complications for patients who were managed conservatively include bleeding (3%, 1 of 30 cases), hematoma at the central venous catheter insertion site for thrombolysis (3%, 1 of 30 cases), and chest pain (3%, 1 of 30 cases). In patients who received endovascular

Table 4. Endovascular Treatment and Outcomes of Thrombus in the Descending Thoracic Aorta.

No.	Reference	Year	Indication for treatment	Method of repair	Antithrombotic	Complications	Pathology/ histology	Hospital LOS (d)	Follow-up time	Follow-up findings
1	Battocchio et al.[42]	2019	Clinical presentation	Embolectomy by Fogarty catheters, followed by aortic balloon angioplasty, and implantation of a BeGraft balloon-expandable covered stent; occlusion balloon at common iliac artery to prevent distal embolization	—	Ischemic-reperfusion syndrome	—	25	15 d	CTA: good positioning of aortic endograft, patent visceral vessels
2	Jamjoom et al.[43]	2019	—	TEVAR with a covering stent	Anticoagulant × 3 mo, antiplatelet × lifelong	—	—	—	3 mo, 35 mo	CTA: complete resolution of thrombus, no recurrence
3	Choi et al.[44]	2019	—	Mechanical endovascular thrombectomy with reperfusion	Heparin × 10 d, dalteparin × 4 d, warfarin	—	Thrombus	—	2 mo	CTA: almost complete resolution of thrombus
4	Desouza et al.[45]	2018	Suspected aortic dissection	TEVAR	—	—	—	—	—	Complete resolution of thrombus
5	Knight et al.[46]	2018	—	EXCLUDER extension cuff for descending aortic thrombus, stent graft for abdominal aorta and iliac thrombi	—	—	—	—	—	—
6	Knight et al.[46]	2018	—	Conformable GORE TAG stent graft deployment	—	—	—	—	—	—
7	Knight et al.[46]	2018	—	EXCLUDER extension cuff for descending aortic thrombus, thrombectomy and endovascular graft deployment for mesenteric thrombus	—	—	—	—	—	—
8	Khan and Vasudevan[47]	2018	Prevent embolic events	TEVAR; occlusion balloon at distal thoracic aorta to prevent distal embolization	Warfarin	—	—	3	26 mo	Asymptomatic
9	Sivakumaran et al.[48]	2018	Prevent embolic events	Zenith TX2 thoracic aortic stent graft deployment, SMA cannulation with Cobra 2 catheter and Armada balloon to prevent embolization to SMA, common femoral artery clamped to prevent distal embolization	Heparin postop, warfarin prior to discharge	—	—	—	—	—
10	Siani et al.[49]	2016	Prevent embolic events; high risk for open surgery; contraindicated for anticoagulant therapy	Thoracic aortic stent graft (TAG, Gore-Tex) placement with Prostar XL closure system, and aspiration of deployment-related emboli in abdominal aorta	Unfractionated low-dose heparin	—	—	—	12 mo	No recurrence
11	Fukuhara et al.[5]	2015	Failure of conservative management	Thoracic aortic stent graft deployment (TAG, Gore-Tex)	Anticoagulant	Multiple distal vessels embolization, ischemic anoxic brain injury, eventually dead	—	12	—	—

(continued)

Table 4. (continued)

No.	Reference	Year	Indication for treatment	Method of repair	Antithrombotic	Complications	Pathology/ histology	Hospital LOS (d)	Follow-up time	Follow-up findings
12	Scott et al.[50]	2014	Thrombus characteristics; clinical presentation	Thoracic aortic stent graft deployment	Clopidogrel at discharge	—	—	3	3 d, 9 mo	3 d: no additional embolic events; 9 mo: good positioning and function of stent graft, patency of distal vessels
13	Habib et al.[51]	2013	—	Thoracic aortic stent graft deployment, L carotid artery–subclavian artery bypass to correct a blockage of the L subclavian artery by the stent graft	Heparin in hospital, warfarin at discharge	Occlusion of bypass graft resulting in neurological deficits in upper extremities	—	14	3 mo	Symptoms partially resolved
14	Trindade et al.[52]	2012	—	Thoracic aortic stent graft deployment	—	—	—	—	30 d	CT: good positioning of stent graft, complete exclusion of thrombus
15	Alla et al.[53]	2011	—	Thoracic aortic stent graft deployment	Heparin in hospital, clopidogrel at discharge	—	—	—	—	—
16	Martens et al.[11]	2010	—	Percutaneous transluminal angioplasty and stenting of L subclavian artery with a 10–40 smart stent, thoracic aortic stent graft (TAG, Gore-Tex) deployment	Heparin in hospital, antiplatelet at discharge	—	—	—	—	CT: good positioning of stent graft, patency of L subclavian artery
17	Saratzis et al.[54]	2008	—	Thoracic aortic stent graft EndoFit deployment	Clopidogrel × lifelong	—	—	—	30 d, 2.5 y	30 d, CT: good positioning of stent graft; 2.5 y: patient remained asymptomatic
18	Luebke et al.[55]	2008	Prevent embolic events; thrombus characteristics; patient characteristics	Thoracic aortic stent graft EXCLUDER deployment	—	—	—	—	—	—
19	Zhang et al.[26]	2008	Failure of conservative management	Thoracic aortic stent graft (TAG, Gore-Tex) deployment, bilateral common iliac arteries were temporarily sealed by introducer sheaths	Oral anticoagulant and aspirin at discharge	—	—	—	9 mo	CT: good positioning of stent graft, complete exclusion of thrombus, patient remained asymptomatic
20	Piffaretti et al.[56]	2007	Prevent embolic events	Thoracic aortic stent graft deployment	Warfarin at discharge	—	Thrombus	5	6 mo	CTA: complete resolution of thrombus, no recurrence
21	Fueglistaler et al.[57]	2005	Prevent embolic events	Thoracic aortic stent graft deployment (TAG, Gore-Tex)	Oral anticoagulant × lifelong	—	—	—	3 mo	CT: exclusion of thrombus
22	Criado et al.[58]	2004	Prevent embolic events; recurrent thrombus post-surgical thrombectomy	PTFE graft deployment with Palmaz stents placed and balloon expanded at proximal and distal half of the graft	Oral anticoagulant at discharge	—	—	3	9 mo	CT: good positioning of stent graft, patient remained asymptomatic

Abbreviations: CT, computed tomography; CTA, computed tomography angiography; L, left; LOS, length of stay; postop, postoperative; SMA, superior mesenteric artery; TEVAR, thoracic endovascular aortic repair.

Table 5. Surgical Treatment and Outcomes of Thrombus in the Descending Thoracic Aorta.

No.	Reference	Year	Indication for treatment	Approach	Method of repair	DHCA	Antithrombotic	Complications	Pathology/ histology	Hospital LOS (d)	Follow-up time	Follow-up findings
1	Mirza et al.[59]	2019	Thrombus characteristics; potential distal embolization; definitive treatment; diagnostic purposes; lower embolic risk compared to endovascular intervention	Thoracotomy; L atrium and distal thoracic aorta bypass	Aortotomy, segmental thoracic aortic resection, and interposition reconstruction	—	Heparin × 3 d preop	—	Aortic wall inflammation	5	—	—
2	Lok et al.[60]	2016	Thrombus characteristics	Thoracotomy; L femoral artery and vein bypass	Aortotomy, segmental thoracic aortic resection, and interposition reconstruction	—	Aspirin & warfarin at discharge	—	—	—	—	—
3	Namura et al.[10]	2011	Failure of conservative treatment; diagnostic purposes	Thoracotomy; L femoral artery and vein bypass	Aortotomy and thrombectomy	Moderate hypothermia	Warfarin × 1y postop, followed by aspirin	—	Thrombus	—	1 y, 4 y	CT: no recurrence, no dilatation of aorta
4	Krishnamoorthy et al.[61]	2011	Thrombus characteristics; presence of distal emboli	Thoracotomy	Aortotomy, thrombectomy, and small patch graft closure	—	Heparin periop, followed by anticoagulant × lifelong	Pulmonary embolism	—	—	—	—
5	Martens et al.[11]	2010	Clinical presentation; limited evidence and experience of an endovascular approach for emergency procedures	Thoracotomy	Aortotomy, segmental thoracic aortic resection, and interposition reconstruction	—	Antiplatelet at discharge	—	Thrombus, aortic wall showed mild inflammation of vasa vasorum	—	3 wk	Improvement of neurological symptoms, residual scotoma of R eye
6	Luaces et al.[24]	2009	Failure of conservative treatment	Thoracotomy	Aortotomy and thrombectomy	—	Anticoagulant	—	—	—	—	—
7	Makaryus and Fan[62]	2009	Prevent embolization	—	Thrombectomy	—	—	—	Thrombus	—	—	—
8	Hazirolan et al.[35]	2004	Failure of conservative treatment	—	Aortotomy and thrombectomy	—	—	—	—	—	—	—
9	Criado et al.[58]	2004	Thrombus characteristics	Thoracotomy	Aortotomy, thrombectomy, and suture closure of aorta	—	Heparin periop, followed by warfarin at discharge	Hemothorax	—	12	1 mo	TEE: recurrent mobile thrombus at the previous surgical area, requiring endovascular intervention
10	Kolvekar et al.[39]	2001	Failure of conservative treatment; prevent embolization	Thoracotomy; L femoral artery and vein bypass	Aortotomy and thrombectomy	—	Warfarin at discharge	—	Thrombus	14	—	—

Abbreviations: CT, computed tomography; d, day; L, left; LOS, length of stay; m, month; periop, perioperative; postop, postoperative; R, right; TEE, transesophageal echocardiography; w, week; y, year.

Table 6. Summary of Outcomes for Different Treatment Approaches for Thrombus in the Descending Thoracic Aorta.

Parameter	Initial treatment strategy			Overall ($N = 64$)
	Medical ($n = 32$)	Endovascular ($n = 22$)	Surgical ($n = 10$)	
Outcomes reported	30 (94)	16 (73)	4 (40)	50 (78)
Complications				
Bleeding	1 (3)	0	0	1 (2)
Stroke	0	0	0	0
Recurrent embolism	5 (17)	1 (6)	1 (25)	7 (14)
Ischemic reperfusion syndrome	0	1 (6)	0	1 (2)
Others	2 (7)[a]	1 (6)[b]	1 (25)[c]	4 (8)
Follow-up				
Follow-up available	25 (78)	15 (68)	3 (30)	43 (67)
Follow-up time, days	42 (14–180)	135 (53–293)	198 (28–639)	60 (25–240)
Success rate				
Follow-up imaging	22 (88)	12 (80)	2 (67)	36 (84)
Thrombus resolution	16 (73)	3 (25)	1 (50)	20 (56)
Thrombus regression	2 (9)	1 (8)	0	3 (8)
Thrombus exclusion	0	8 (67)	0	8 (22)
No changes/recurrent thrombus requiring further intervention	4 (18)	0	1 (50)	5 (14)
Death	3 (10)	1 (6)	0	4 (8)

[a]Hematoma at central venous catheter insertion site; chest pain.
[b]Occlusion of the left carotid artery–subclavian artery bypass graft to correct a blockage of the left subclavian artery by the endovascular stent graft.
[c]Hemothorax requiring exploration of the chest and evacuation of the hematoma.

intervention, ischemic reperfusion syndrome and occlusion of the left carotid artery–subclavian bypass graft after TEVAR, which was conservatively managed, were each reported in 1 of 16 cases (6%). For surgically treated patients, hemothorax requiring exploration of the chest and evacuation of the hematoma was reported in 1 of 4 cases (25%). Mortality was reported in 4 of 50 patients with information on outcomes (8%). Of these 4 patients, 3 received medical treatment, 1 had endovascular intervention, and all 4 patients died of multiorgan failure secondary to ischemia.

Follow-up information regarding patient survival, resolution/recurrence of thrombus and symptoms, or graft positioning was available in 67% of patients in our review, of whom 78% received conservative treatment, 68% received endovascular treatment, and 30% received surgical treatment. The median duration of follow-up was 42 days (IQR: 14 to 180 days) in conservatively managed patients, 135 days (IQR: 53 to 293 days) in those treated with the endovascular approach, and 198 days (IQR: 28 to 639 days) in those who had surgical treatment—overall, 60 days (IQR: 25 to 240 days) in all included cases.

Follow-up imaging was mentioned in 84% of all patients with follow-up information. Successful management, as defined by thrombus resolution, regression, or exclusion, was achieved in 82% of patients receiving medical treatment, 100% receiving endovascular treatment, 50% receiving surgical treatment, and 86% overall. The rest of the cases either showed no changes in thrombus size or a recurrent thrombus requiring further endovascular or surgical intervention (14% overall).

The proposed algorithm for the management of DTAT is included in Figure 1.

Discussion

Overall, the main predisposing factors for DTAT include (1) hypercoagulability either genetically or acquired, such as in the case of malignancy, and (2) risk factors for vasculopathy such as smoking, hypertension, obesity, diabetes, and dyslipidemia. The median age of presentation was mid-50s, and DTAT was more commonly found in females than in males. DTAT could be identified incidentally or from manifestations of downstream embolization causing gut ischemia and claudication symptoms or retrograde embolization causing neurologic symptoms. The natural course of untreated DTAT is either asymptomatic or symptomatic systemic embolization, multiorgan failure, and eventually death, which further emphasizes the importance of early diagnosis and treatment.

There are 3 major treatment modalities for managing DTAT: conservative management with thrombolysis or antithrombotic agents, endovascular with TEVAR or thrombectomy, and open surgery. It is important to take into account the clinical presentation, characteristics of the DTAT, patient comorbidities, and patient preference, as well as center-specific experience, before deciding on the best treatment approach. Conservative treatment is the most common initial approach. It is easily accessible, noninvasive, and does not require technical expertise. This approach is suitable for stable patients, those with

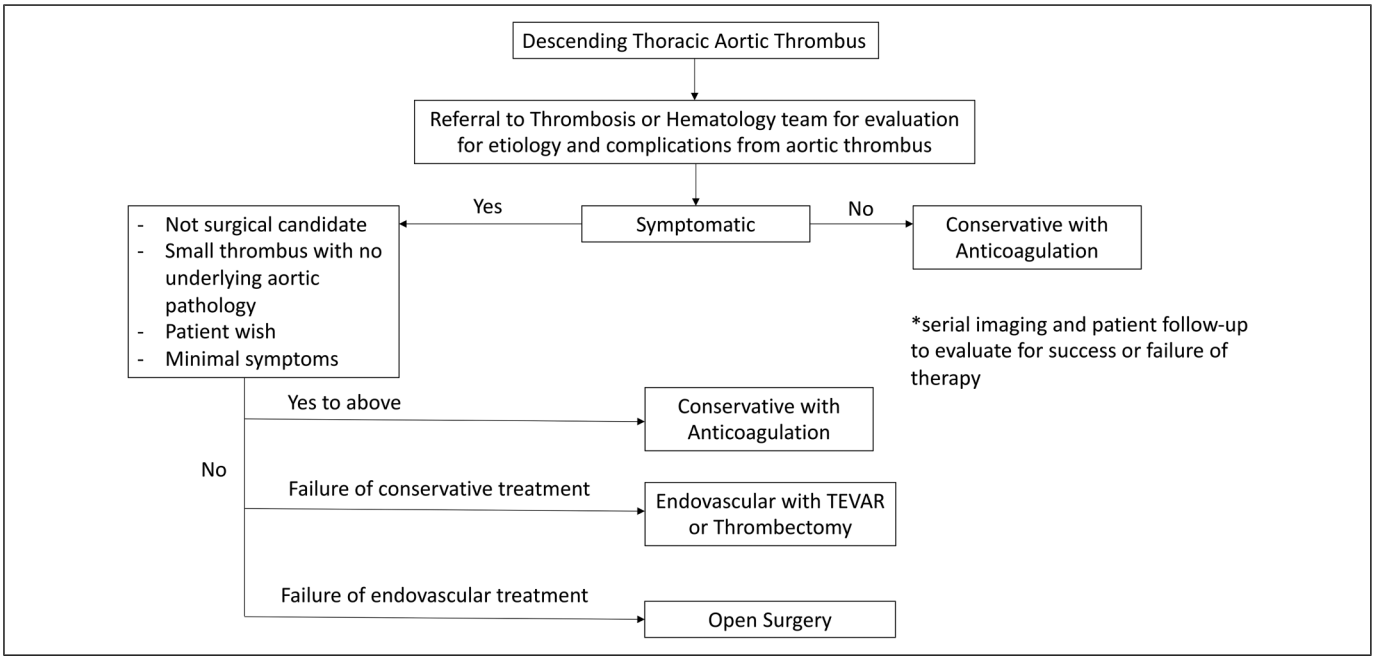


Fig. 1. Proposed algorithm for the management of descending thoracic aortic thrombus. TEVAR, thoracic endovascular aortic repair.

small DTAT and no underlying aortic pathology, those who are not surgical candidates, or who do not wish to undergo more invasive treatment. Endovascular stenting or thrombectomy have been indicated in patients with worsening clinical course, failure of conservative treatment, and recurrent thrombus after surgical treatment. This treatment modality is also suitable for patients who are not surgical candidates or for those in whom antithrombotic therapy is contraindicated. The endovascular approach can be used for both therapeutic and diagnostic purposes in cases of diagnostic uncertainty. Open surgery is often used as the last resort when other less invasive approaches fail or in cases of diagnostic uncertainty when a concomitant surgical pathology cannot be ruled out.

DTAT is a rare condition, and information on the prevention of DTAT or recurrent DTAT is very limited. Anticoagulant after initial treatment was the only prevention strategy mentioned in all of the included case reports. However, the effectiveness of anticoagulants in this context remains to be determined because of the lack of long-term data.

Limitations

This study has several key limitations. Our study was limited by the available parameters reported in previous case reports and case series. Important data such as characteristics of the aorta or whether the thrombus was acute or chronic were mostly lacking. The heterogeneity in our study population due to center experience, interventional and surgical techniques, and other center-specific practices may affect treatment approaches and patient outcomes. Furthermore, treatment outcomes were unspecified in 22% of all patients and particularly in 70% of surgical patients, coupled with a lack of follow-up information in an already small population of patients. Therefore, pooled results of therapeutic outcomes may not comprehensively reflect the true outcomes. Given that our review article includes only published articles, it may also be subject to publication bias.

Conclusions

DTAT is a rare condition that can result in significant morbidity and mortality with therapeutic options including conservative management with antithrombotic or thrombolytic agents, endovascular intervention with thrombectomy or TEVAR, and surgical treatment with thrombectomy or segmental aortic resection. Medical management is the least invasive and most frequently chosen initial approach, offering a high reported success rate, whereas endovascular therapy can have a role in thrombus resolution, regression, or exclusion should conservative management fail.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Quynh Nguyen https://orcid.org/0000-0003-1330-9026

References

1. Meyermann K, Trani J, Caputo FJ, et al. Descending thoracic aortic mural thrombus presentation and treatment strategies. *J Vasc Surg* 2017; 66: 931–936.
2. Yagyu T, Naito M, Kumada M, et al. Aortic mural thrombus in the non-atherosclerotic aorta of patients with multiple hypercoagulable factors. *Intern Med* 2019; 58: 381–385.
3. Kim JH, Jeon YS and Cho SG. Successful management of four unusual cases of acute aortic thrombus induced by chemotherapy. *Clin Imaging* 2016; 40: 224–227.
4. Abissegue YG, Lyazidi Y, Chtata H, et al. Acute systemic embolism due to an idiopathic floating thrombus of the thoracic aorta: success of medical management: a case report. *BMC Res Notes* 2015; 8: 1–5.
5. Fukuhara S, Tyagi S, Clarke-Pearson E, et al. Endovascular stent graft repair of thoracic aortic mural thrombus in a patient with polycythemia vera: a word of caution. *Vascular* 2015; 23: 89–92.
6. Dingli K and Dhingra V. Thoracic aortic mural thrombus as a cause of multiorgan failure. *Minerva Anestesiol* 2014; 80: 121–122.
7. Celikyay F, Yuksekkaya R, Yilmaz A, et al. A fatal condition in the thoracic aorta: what's your diagnosis? Floating aortic thrombus. *Ann Saudi Med* 2013; 33: 508–509.
8. Saranteas T, Kostopanagiotou G and Panou F. Transesophageal echocardiographic examination in the diagnosis of bowel ischemia due to thoracic aorta thrombosis. *J Cardiothorac Vasc Anesth* 2012; 26: e14–e15.
9. Montero-Tinnirello J, Vilar-Freire M and Delgado Sánchez-Gracián C. Leriche's syndrome and thoracic aortic mural thrombus. *Rev Esp Cardiol (Engl Ed)* 2012; 65: 1133.
10. Namura O, Sogawa M, Asami F, et al. Floating thrombus originating from an almost normal thoracic aorta. *Gen Thorac Cardiovasc Surg* 2011; 59: 612–615.
11. Martens T, Van Herzeele I, Jacobs B, et al. Treatment of symptomatic mobile aortic thrombus. *Acta Chir Belg* 2010; 110: 361–364.
12. Fayad ZY, Semaan E, Fahoum B, et al. Aortic mural thrombus in the normal or minimally atherosclerotic aorta. *Ann Vasc Surg* 2013; 27: 282–290.
13. Erbel R, Aboyans V, Boileau C, et al. 2014 ESC guidelines on the diagnosis and treatment of aortic diseases: document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). *Eur Heart J* 2014; 35: 2873–2926.
14. Boodhwani M, Andelfinger G, Leipsic J, et al. Canadian Cardiovascular Society position statement on the management of thoracic aortic disease. *Can J Cardiol* 2014; 30: 577–589.
15. Appoo JJ, Bozinovski J, Chu MWA, et al. Canadian Cardiovascular Society/Canadian Society of Cardiac Surgeons/Canadian Society for Vascular Surgery joint position statement on open and endovascular surgery for thoracic aortic disease. *Can J Cardiol* 2016; 32: 703–713.
16. Hiratzka LF, Bakris GL, Beckman JA, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: executive summary. A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. *Catheter Cardiovasc Interv* 2010; 76: E43–E86.
17. Hollier LH, Kazmier FJ, Ochsner J, et al. "Shaggy" aorta syndrome with atheromatous embolization to visceral vessels. *Ann Vasc Surg* 1991; 5: 439–444.
18. Williams GM, Harrington D, Burdick J, et al. Mural thrombus of the aorta: an important, frequently neglected cause of large peripheral emboli. *Ann Surg* 1981; 194: 737–744.
19. Reber PU, Patel AG, Stauffer E, et al. Mural aortic thrombi: an important cause of peripheral embolization. *J Vasc Surg* 1999; 30: 1084–1089.
20. Serra R, Bracale UM, Jiritano F, et al. The shaggy aorta syndrome: an updated review. *Ann Vasc Surg* 2021; 70: 528–541.
21. Maeda K, Ohki T, Kanaoka Y, et al. A novel shaggy aorta scoring system to predict embolic complications following thoracic endovascular aneurysm repair. *Eur J Vasc Endovasc Surg* 2020; 60: 57–66.
22. Lainez B, Ruiz V, Ramallal R, et al. Recurrent embolism due to thoracic aortic thrombus detected by transesophageal echocardiography: which treatment is currently the most appropriate? *Rev Esp Cardiol* 2009; 62: 1335–1337.
23. Catapano Minotti G, Corsonello A, Guadalupi G, et al. A thrombotic snake in the thoracic aorta. *Intern Emerg Med* 2009; 4: 515–516.
24. Luaces M, Rodríguez-Benavente AM, Vilacosta I, et al. Thrombosis of an apparently normal thoracic aorta: another case, another conundrum. *Rev Esp Cardiol* 2009; 62: 576–577.
25. Iyer AP, Sadasivan D, Kamal U, et al. Resolution of large intra-aortic thrombus following anticoagulation therapy. *Heart Lung Circ* 2009; 18: 49–50.
26. Zhang WW, Abou-Zamzam AM, Hashisho M, et al. Staged endovascular stent grafts for concurrent mobile/ulcerated thrombi of thoracic and abdominal aorta causing recurrent spontaneous distal embolization. *J Vasc Surg* 2008; 47: 193–196.
27. Sari I, Davutoglu V, Bayram N, et al. Fatal giant aortic thrombus presenting with pulmonary edema in a patient with chronic obstructive pulmonary disease. *Clin Appl Thromb* 2008; 14: 486–488.
28. Loffroy R, Boussel L, Farhat F, et al. Isolated floating thrombus of the thoracic aorta: a rare sign of traumatic aortic injury managed with anticoagulant therapy. *Ann Thorac Surg* 2007; 84: 1766.
29. Durdil V, Fiedler J, Alan D, et al. Multiple mobile aortic thrombosis treated by thrombolysis: a case report. *J Thromb Thrombolysis* 2007; 24: 315–316.
30. Yoon S, Schmassmann-Suhijar D, Zuber M, et al. Chemotherapy with bevacizumab, irinotecan, 5–fluorouracil and leucovorin (IFL) associated with a large, embolizing thrombus in the thoracic aorta. *Ann Oncol* 2006; 17: 1851–1852.
31. Slabbekoorn M, Henneman ODF, Geelhoed-Duijvestijn PHLM, et al. Mural aortic thrombus and peripheral embolisation in a patient with hyperhomocysteinaemia. *Neth J Med* 2006; 64: 20–22.

32. Mark HK, Ho NS, Tse CCW, et al. Recurrent lower limb embolism from thoracic aortic mural thrombus: a rare presentation of occult malignancy. *Hong Kong Med J* 2005; 11: 299–302.
33. Mirza IH, Mitchell ARJ and Timperley J. Transoesophageal echocardiography for the identification of a giant aortic thrombus. *Heart* 2005; 91: 778.
34. Rocco D, Scardia M, Cazzato M, et al. Floating thrombus in the thoracic aorta: what should be done? *Ital Heart J* 2004; 5: 632–634.
35. Hazirolan T, Perler BA and Bluemke DA. Floating thoracic aortic thrombus in "protein S" deficient patient. *J Vasc Surg* 2004; 40: 381.
36. Auer J, Berent R, Weber T, et al. Bilateral intermittent claudication and the aorta. *Heart Vessels* 2004; 19: 103–104.
37. Mochizuki Y, Zhang M, Golestaneh L, et al. Acute aortic thrombosis and renal infarction in acute cocaine intoxication: a case report and review of literature. *Clin Nephrol* 2003; 60: 130–133.
38. Stollberger C, Kopsa W and Finsterer J. Resolution of an aortic thrombus under anticoagulant therapy. *Eur J Cardiothorac Surg* 2001; 20: 880–882.
39. Kolvekar SK, Chaubey S and Firmin R. Floating thrombus in the aorta. *Ann Thorac Surg* 2001; 72: 925–927.
40. Schwartzbard A, Freedberg RS and Kronzon I. The value of repeat transesophageal echocardiography in the evaluation of embolism from the aorta. *J Am Soc Echocardiogr* 2000; 13: 1124–1126.
41. Filipek MS, Primack SL, Hronas TN, et al. Transient aortic thrombus in a sickle-cell patient with chest pain: CT and MR findings. *AJR Am J Roentgenol* 2000; 175: 1287–1288.
42. Battocchio C, Dezi T, D'Andrea A, et al. Acute occlusion of descending thoracic aorta. *Ann Vasc Surg* 2019; 60: 477.e15–477.e19.
43. Jamjoom R, Zagzoog MM and Sait S. Outcome of endovascular approach for management of thoracic aortic thrombus. *Ann Vasc Surg* 2019; 59: 307.e7–307.e12.
44. Choi V, Kim DD, Fridman S, et al. Pearls & Oy-sters: giant descending aortic arch donut sign: retrograde embolism as a cause of acute ischemic stroke. *Neurology* 2019; 92: 443–445.
45. Desouza N, Sood A, Baciewicz FA, et al. Traumatic aortic mural thrombus diagnosed echocardiographically before thoracic endovascular aortic repair. *Tex Heart Inst J* 2018; 45: 188–189.
46. Knight JB, Chaer RA and Gelzinis TA. Transesophageal echocardiography for guidance of endovascular stent exclusion of thoracic aortic thrombi: a case series. *J Cardiothorac Vasc Anesth* 2018; 32: 1333–1336.
47. Khan A and Vasudevan T. Hybrid technique for the management of thoracoabdominal aortic thrombosis and symptomatic transatlantic inter-society consensus "C" aorto-iliac disease. *Vascular* 2018; 26: 331–334.
48. Sivakumaran Y, Bullen AS and Leslie GJ. Endovascular stent grafting of a thoracic aortic mobile thrombus with embolic phenomenon. *ANZ J Surg* 2018; 88: 933–935.
49. Siani A, Accrocca F, De Vivo G, et al. Endovascular treatment of symptomatic thrombus of the descending thoracic aorta. *Ann Vasc Surg* 2016; 36: 295.e13–295.e16.
50. Scott DJ, White JM and Arthurs ZM. Endovascular management of a mobile thoracic aortic thrombus following recurrent distal thromboembolism: a case report and literature review. *Vasc Endovascular Surg* 2014; 48: 246–250.
51. Habib H, Hsu J, Jo Winchell P, et al. Mural thrombus in the normal-appearing descending thoracic aorta of a chronic smoker. *Tex Heart Inst J* 2013; 40: 619–622.
52. Trindade VD, Bettio J and Albuquerque LC. Endovascular treatment of a mobile thrombus of the thoracic aorta: in association with ulcerative colitis. *Tex Heart Inst J* 2012; 39: 592–593.
53. Alla VM, Thota R, Mathias S, et al. Mobile thoracic aortic thrombus in a methamphetamine user after cardiac arrest *Tex Heart Inst J* 2011; 38: 445–447.
54. Saratzis N, Melas N, Saratzis A, et al. Minimally invasive endovascular intervention in emergent and urgent thoracic aortic pathologies: single center experience. *Hellenic J Cardiol* 2008; 49: 312–319.
55. Luebke T, Aleksic M and Brunkwall J. Endovascular therapy of a symptomatic mobile thrombus of the thoracic aorta. *Eur J Vasc Endovasc Surg* 2008; 36: 550–552.
56. Piffaretti G, Tozzi M, Caronno R, et al. Endovascular treatment for mobile thrombus of the thoracic aorta. *Eur J Cardiothorac Surg* 2007; 32: 664–666.
57. Fueglistaler P, Wolff T, Guerke L, et al. Endovascular stent graft for symptomatic mobile thrombus of the thoracic aorta. *J Vasc Surg* 2005; 42: 781–783.
58. Criado E, Wall P, Lucas P, et al. Transesophageal echo-guided endovascular exclusion of thoracic aortic mobile thrombi. *J Vasc Surg* 2004; 39: 238–242.
59. Mirza AK, Saran N, Warrington KJ, et al. Isolated thoracic aortic Takayasu arteritis presenting as presumed mobile aortic thrombus. *Vasc Endovascular Surg* 2019; 53: 267–270.
60. Lok SY, Bhagwat K, Smith JA, et al. Giant aortic mural thrombus. *J Card Surg* 2016; 31: 351.
61. Krishnamoorthy V, Bhatt K, Nicolau R, et al. Transesophageal echocardiography-guided aortic thrombectomy in a patient with a mobile thoracic aortic thrombus. *Semin Cardiothorac Vasc Anesth* 2010; 15: 176–178.
62. Makaryus AN and Fan D. Dangerous feather! *J Cardiovasc Comput Tomogr* 2009; 3: 182–183.