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Review article

Descending thoracic aortic emergencies: Past, present, and future

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ABSTRACT

The most important descending thoracic aortic (DTA) pathologies are aneurysms, dissections, and traumatic injuries. In acute settings, these conditions can constitute a significant risk of bleeding or ischemia of vital organs, resulting in a fatal outcome. Morbidity and mortality associated with aortic pathologies remain significant, despite improvements in medical therapy and endovascular techniques. In this narrative review, we present an overview of the transitions in the management of these pathologies and discuss current challenges and future perspectives. Diagnostic challenges include differentiating between thoracic aortic pathologies and cardiac diseases. Efforts have been made to identify a blood test that can rapidly differentiate these pathologies. Computed tomography is the cornerstone of diagnosing thoracic aortic emergencies. Our understanding of DTA pathologies has improved substantially due to the significant advancement in imaging modalities in the last 2 decades. On the basis of this understanding, the treatment of these pathologies has been revolutionized. Unfortunately, robust evidence from prospective and randomized studies is still lacking for the management of most DTA diseases. Medical management plays a crucial role in achieving early stability during these life-threatening emergencies. This includes intensive care monitoring, heart rate and blood pressure control, and considering permissive hypotension for patients presenting with ruptured aneurysms. Over the years, surgical

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management of DTA pathologies changed from open repair to endovascular repair with dedicated stent-grafts. Techniques in both spectrums have improved substantially.

1. Introduction

Descending thoracic aortic (DTA) pathologies include a range of diseases, the most important of which are aneurysms, dissections, and traumatic injuries. In the acute settings, these conditions can constitute a significant risk of bleeding or malperfusion of vital organs, resulting in a fatal outcome [1,2].

The incidence of thoracic aortic aneurysm (TAA) and type B aortic dissection (TBAD) is increasing due to better diagnostic imaging and increased life expectancy in the population [3,4]. Their mortality is likely to be underestimated, as many aortic-related deaths are attributed to other cardiovascular diseases, such as cardiac arrest, myocardial infarction, or cerebrovascular accidents [1,3,4].

Traumatic aortic rupture is less common than dissection or aortic aneurysm, but it remains one of the leading causes of death in young adults [5]. Blunt traumatic thoracic aortic injuries are associated with a high mortality rate and could be the second most common cause of death in trauma patients, preceded only by intracranial hemorrhage [6,7].

Despite improvements in both medical and surgical therapeutic options, overall mortality associated with aortic pathologies remains significant. Unfortunately, robust evidence from prospective and randomized studies is still lacking for management of most DTA diseases. Consequently, the recommendations in most of the guidelines are based entirely on low-level evidence [1,8,9].

During the past decades, surgical management of thoracic aortic emergencies has significantly shifted from major open surgery to minimally invasive thoracic endovascular aortic repair (TEVAR). In this narrative review, we present an overview of the change in management of these pathologies and discuss current challenges and future perspectives in the treatment of these pathologies. Given the broad subject of the review and multiple research questions, the format of a narrative rather than a systematic review was chosen.

2. Methodology

This narrative review of the literature focuses on the management of acute thoracic aortic pathologies with associated evolution of diagnostic and therapeutic options. MEDLINE and Cochrane Library databases have been used to search for articles discussing diagnosis of thoracic aortic emergencies, early experiences with thoracic aortic repair in an acute setting, field transition from open repair to endovascular repair, and articles that assess and compare the outcomes of each management approach. The database searches were limited to studies published in English in peer-reviewed journals, without date restriction (up to December 2022), and initial articles were also cross-referenced. The review also contains expected future developments and discusses the initial reports of some novel surgical techniques.

2.1. *Diagnosis and imaging of DTA emergencies*

The clinical diagnosis of aortic dissections and symptomatic aneurysms is challenging in the emergency setting due to the similarity of symptoms with cardiac ischemia. Unfortunately, sudden death can be the first and only sign of aortic pathologies. Considering the vast number of patients with chest and back pain presenting to emergency departments, and the low incidence of acute descending aortic pathologies in this cohort, detection of a biomarker or rapid blood test to distinguish aortic emergencies from other emergencies would be highly desirable.

There has been a significant focus on detection of a biomarker for aortic disease in the past decade. Although several biomarkers have been investigated, to date none has reached adequate accuracy. D-dimer was proposed as a biomarker that could aid in ruling out acute aortic dissection [10]. The issue is that D-dimer levels increase with multiple medical conditions, including acute aortic dissections, venous thromboembolism, systemic inflammatory state, and malignancy. Thus, its specificity in detecting certain diseases is low. Using a cutoff of 500 ng/mL to rule out acute dissection, D-dimer has a sensitivity of 95% to 98% and low to moderate specificity in low-risk patients [10]. To optimize the diagnostic value of this test, an integration between Aortic Dissection Detection Risk Score (Table 1) with D-dimer test results has been recommended [11–13]. The score was initially developed from a large international registry of acute aortic dissection and has been externally validated. The European Society of Cardiology guideline has adopted the Aortic Dissection Detection Risk Score in their diagnostic algorithms for patients presenting with acute chest pain [12]. Although implementation of such complex diagnostic algorithms in clinical practice has been difficult to date, future work in this field may entail integration of biomarkers with artificial intelligence–based algorithms to evaluate risk scores in the acute setting. Artificial intelligence–based triage of emergency patients with chest pain is being developed and may also be applicable to reduce the risk of missed or delayed diagnosis in patients with acute aortic syndromes [14].

Detection of DTA pathologies has improved substantially due to the improvements in imaging modalities in the last 2 decades. Currently, multidetector computed tomography (CT) scanning with three-dimensional reconstruction capability is considered the “gold standard” for evaluating patients with aortic diseases. Older-generation CT scans provided poor-quality images; examinations were conducted using only a single-detector scanner [15]. Multidetector spiral CT with 64 detectors was introduced in the first decade of the millennium

Table 1 – Aortic Dissection Detection Risk Score items.

High-risk conditions	High-risk pain features	High-risk examination features
• Marfan syndrome or other connective tissue disease • Family history of aortic disease • Known aortic valve disease • Known thoracic aortic aneurysm • Recent aortic manipulation	• Chest, back, or abdominal pain described as: ∘ Abrupt onset ∘ Severe intensity ∘ Ripping or tearing	• Evidence of perfusion deficit: ∘ Pulse deficit ∘ Systolic blood pressure difference ∘ Focal neurologic deficit (with pain) • Murmur of aortic insufficiency • Hypotension or shock

For each risk category, 1 point is assigned if one or more risk factors are present. The Aortic Dissection Detection Risk Score ranges from 0 to 3 [12].

and, with the increasing sophistication of CT scanners, images are acquired at <1-mm slice thickness [15]. Conjointly, gantry rotation time decreased significantly from 1 second to 0.4 seconds, which led to a tremendous reduction in examination time and motion artifacts [16]. Today, high-resolution imaging of the entire aorta can be obtained in a single breath-hold [15].

CT has become the cornerstone of diagnosing thoracic aortic emergencies, as it is readily available in most hospitals and aids in rapid assessment of aortic anatomy. Post-acquisition image processing with multiplanar reformation can generate sagittal, coronal, and oblique images, as well as three-dimensional renderings that can be used to determine suitable repair (Fig. 1). Often the confirmation of a diagnosis depends on different views of the aorta and both noncontrast and contrast slices. CT angiography also visualizes occlusive disease in branch vessels, dissections, and mural thrombus. Using dedicated software with centerline reconstructions aids procedure planning [15].

Although radiation dose during CT has been reduced significantly over the past several decades, the need for iodine-based contrast for aortic imaging remains [15,17]. Manipulation of x-ray tube voltage to reduce radiation and contrast dose is a possible way forward for individualized CT protocols to optimize image quality and reduce these risks [17].

Magnetic resonance angiography (MRA) is an alternative imaging modality that can be considered when evaluating aortic pathologies. Although MRA provides better contrast resolution, its spatial resolution is poorer than multidetector CT [18]. Multidetector CT can reach a spatial resolution of 0.5 mm and the best MR resolution is 1 mm [19]. There was initial enthusiasm for the use of MRA in patients with renal insufficiency, but established concerns of nephrogenic systemic fibrosis over the use of gadolinium in patients with glomerular filtration rate < 30 mL/min has made the use of MRA less attractive [20]. Also, MRA is not a practical option for patients with emergent aortic disease, given the increased image acquisition times and limited availability (Table 2).

Trauma is a unique challenge for physicians, establishing a standardized CT trauma protocol expedites identification of both life-threatening and minor injuries [21,22]. High-quality images shaped the classification scheme of blunt traumatic aortic injuries (BTAIs) that we use today (Table 3) [23–25]. It differentiates minor aortic injuries from major injuries that require urgent attention.

Following the same path, aortic dissection classifications evolved on the basis of anatomic location of the primary entry tear and dissection propagation. In 1965, DeBakey described the original classification based on the location of the primary entry tear and extension of the dissection [26]. A few years later, the widely adopted Stanford classification came out as a simplified version, as it focused on the location of the primary entry tear only [27]. One important limitation with these classifications is that they do not address dissections that orig-

Table 2 – Comparison of MDCT and MRA [18,19].

Feature	MDCT	MRA
Acquisition time	Few seconds	Few minutes
Availability	24-hour	Limited
Applicability	Acute setting and follow-up	Follow-up, to decrease the radiation exposure
Contrast resolution	Lower than MRA	High
Spatial resolution	Higher than MRA, 0.5 mm	Lower than MDCT, 1 to 2 mm
Movement artifact susceptibility	Low movement artifact susceptibility	High movement artifact susceptibility
Radiation Exposure	Yes	No
Contrast	Iodinated contrast	Gadolinium contrast
Renal complications	Risk of contrast-induced nephropathy in patients with GFR < 30 mL/min	Risk of nephrogenic systemic fibrosis in patients with GFR < 30 mL/min
Other limitations/risks	Iodinated contrast induced anaphylaxis	Avoided in patients with claustrophobia and patients with ferromagnetic implants

Abbreviations: GFR, glomerular filtration rate; MDCT, multidetector computed tomography; MRA, magnetic resonance angiography.

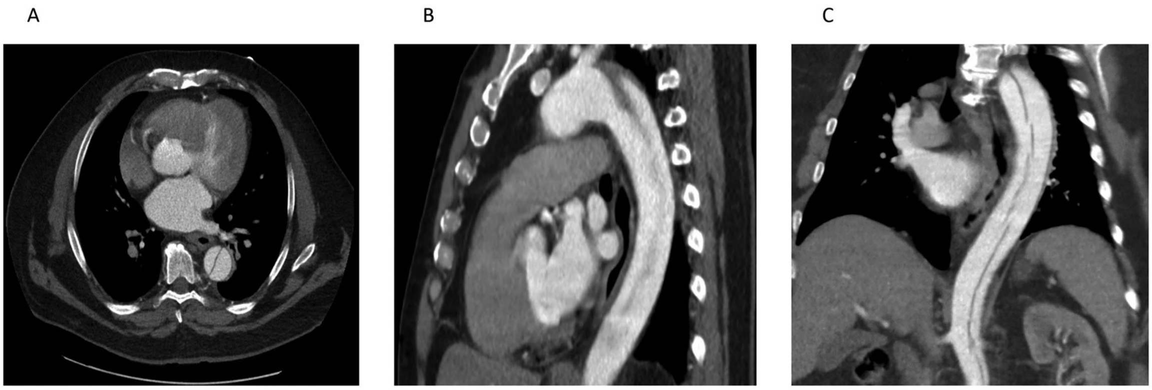


Fig. 1 – Multi-planar reformatting (MPR) of acute type B dissection. Axial view (A), Sagittal view (B), Coronal view (c).

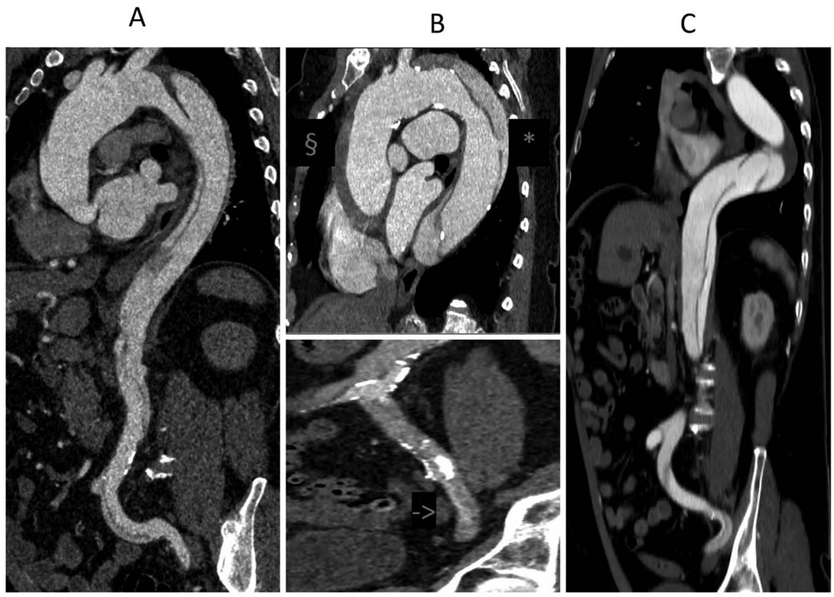
Table 3 – SVS classification for blunt thoracic aortic injury (BTAI) and Harborview BTAI grading system.

SVS Classification for BTAI			
Grade I	**Grade II**	**Grade III**	**Grade IV**
• Intramural hematoma	• Intimal tear	• Pseudoaneurysm	• Rupture
Harborview BTAI Grading System			
Minimal	**Moderate**	**Severe**	
• No external contour abnormality • Intimal tear and/or thrombus is <10 mm	• External contour abnormality or intimal tear >10 mm	• Active extravasation • Left subclavian artery hematoma >15 mm	
<u>No intervention</u> • Optional follow-up imaging	<u>Semi-elective repair</u> • Stabilization of concomitant injuries • Impulse control	<u>Immediate repair</u> • BTAI takes first priority	

inate in the arch. Recently, the Society for Vascular Surgery and Society of Thoracic Surgeons published a new classification to address the previously mentioned limitation (Fig. 2). In this classification, the distinction between type A and type B is predicated on the primary entry tear location alone. The distal extent of a type A aortic dissection is then characterized by the involved aortic zone. TBAD includes any aortic dissection with an entry tear originating in zone 1 or beyond. Subsequently, TBAD is further characterized by the proximal and distal dissection extension in each aortic zone. If the origin of the primary entry tear is not obvious, the dissection will be marked as “indeterminate” with the designation I [9]. This new classification is tailored to meet the needs of modern endovascular treatment and has potential to aid our future understanding of the best treatment option for specific dissections.

Some remaining challenges in terms of preoperative planning include the uncertainties regarding sizing in the acute setting, and evaluation of entry tears and presence of artifacts. Hypovolemia may underestimate the true aortic size in trauma patients and minor dissections or intramural hematomas may be mistaken for motion artifacts or vice versa.

Electrocardiography (ECG)-gated CT diminishes this problem. This technique was proposed in the early 1980s as a solution for motion artifacts and to optimize the diagnostic accuracy of cardiac CT [28]. With time, this technique evolved into two different acquisition techniques during multiple phases of the cardiac cycle, which include prospective ECG triggering and retrospective ECG gating [29]. The former uses the ECG signal to control scanning so that x-rays are generated and projection data are acquired during the selected cardiac phase only [30]. In the latter, volumetric CT data are acquired throughout the cardiac cycle during the simultaneous recording of the ECG signals, followed by retrospective reconstruction of the data, referencing the ECG signal to generate im-



Panel	DeBakey Classification	Stanford Classification	SVS/STS Classification
A	Type IIIB	Type B	Type $B_{3,11}$
B	Type IIID	Type A	Type $B_{0,12}$
C	Type IIIB	Type B	Type $B_{5,12}$

Fig. 2 – Example of aortic dissections and their classification based on DeBakey, Stanford and SVS/STS. In panel B, § notifies proximal extension of the dissection into the ascending aorta; * notifies the primary entry tear, and -> notifies the distal entry tear at the external iliac level. Please note that DeBakey IIID in panel B is based on the modified DeBakey classification (Reul GJ, Cooley DA, Hallman GL, et al. Dissecting aneurysm of the descending aorta. Arch Surg. 1975;110:632-640).

ages with the least motion artifacts [30]. The prospective ECG-triggering technique is more simplified and requires a lower dose of radiation, but it cannot be used in patients with arrhythmia and does not provide any information regarding cardiac functionality in the same way as a retrospective ECG-gating scan [29,30].

2.2. *Medical management*

Medical management is widely accepted as definitive management for patients with uncomplicated TBAD and minor BTAI (grade 1 and 2), it is also considered the initial management for patients with complicated TBAD and major BTAI [23–25,31]. The key elements of this approach are intensive care monitoring with anti-impulse therapy to reduce the hemodynamic forces that have initiated the intimal tear [23,24,31].

In contemporary practice, a combination of IV β-blockers and vasodilators are the standard of care [31]. β-Blockers should be initiated before vasodilators, otherwise a reflex sympathetic stimulation could increase the shearing stress on the aortic wall. It is recommended to first target heart rate between 60 and 80 beats/min and then systolic blood pressure < 120 mm Hg [31]. The intensive medical treatment in aortic dissection has been challenged in recent years, considering that rapid lowering of blood pressure carries risks for renal, cerebral, and coronary ischemic events [32].

The survival benefit of permissive hypotension protocol is well established in trauma patients and ruptured abdominal aortic aneurysms [33,34]. The protocol restricts fluid resuscitation before achieving surgical control of the bleeding source. Resuscitation should be sufficient to maintain consciousness, minimize organ ischemia, and maintain systolic pressures of 70 to 90 mm Hg [35]. Implementation of this protocol in managing patients with ruptured DTA aneurysm (rDTAA) seems reasonable, even though the supporting evidence is lacking.

2.3. *Operative management*

Historically life-threatening DTA emergencies were treated with open surgery and interposition grafting. Today, open surgery in most centers is reserved for highly selected cases, if any. The scientific dilemma remains in some settings, such as patients with connective tissue disorder [36] or chronic dissection aneurysms. The rapid shift from open to endovascular treatment has occurred because of the lower morbidity and short-term mortality associated with endovascular repairs [37,38]. The debate continues on the long-term durability of the repairs.

In early years, open surgery of the thoracic aorta suffered from lack of cardiopulmonary bypass and risk of spinal ischemia. In 1950, Lam and Aram [39] reported one of the earliest experiences with symptomatic DTAA open repair using aortic homograft. In 1958, the use of Dacron grafts by DeBakey and colleagues [40] resulted in a revolution for surgeons in the repair of aortic aneurysms. The advert of endovascular aortic repair was initiated with experimental studies in Charkov, Ukraine by the vascular surgeon Nikolai Volodos [41]. He performed the first TEVAR in 1987 in a patient with a post-traumatic descending aortic pseudoaneurysm, with insertion of a self-fixating stent-graft. In the Western world, endovascular aortic repair was introduced by Parodi in the abdominal aorta and Dake in thoracic aorta in the early 1990s [42,43]. Dake et al [43] reported the treatment of 13 patients affected by DTA pathologies using endovascular stent-grafts. In their experience, all endografts were deployed successfully. Twelve patients achieved complete thrombosis of the aneurysm sac during follow-up. Two patients required endograft extension for Type I endoleak.

From then on, TEVAR was considered as an attractive alternative to open repair, especially in unfit patients. Concerns about durability have been the opponent of endovascular technologies. Nevertheless, these technologies evolved dramatically. The newer TEVAR generations have lower profiles, better manufacturing quality, and improved deployment precision. These improvements overcame many shortcomings from the early days, including access-related complications, conformity to aortic anatomy, endoleaks, and misdeployment.

The international market offers only a few approved stent-grafts, each with its own unique properties. The newest generation Gore Conformable Thoracic Graft stent-grafts, constructed using an expanded polytetrafluoroethylene tube reinforced with expanded polytetrafluoroethylene/fluorinated ethylene propylene film and an external nickel-titanium (nitinol) self-expanding stent, are equipped with an Active Control System that allows it to conform to the aortic wall, ensuring better apposition and minimizing the risk of proximal bird-beaking. Furthermore, the Conformable Thoracic Graft is designed with staged deployment, which prevents windsock effect at the proximal fixation [44]. Medtronic's Valiant Captivia is composed of a monofilament woven polyester graft attached to sinusoidal nitinol springs that are placed on the outside of the graft, which provides flexibility and conformability. The modular design consists of an eight-peaked bare-metal proximal FreeFlo configuration that evenly distributes radial force across the proximal aortic neck to optimize aortic wall opposition. Its tip capture provides controlled deployment and placement when navigating through the thoracic aorta [45]. Similarly, the Terumo Aortic Relay stent-graft platform is based on polyester graft combined with nitinol stents and is available in configurations with and without proximal bare stent. Cook Zenith TX2 with Pro-Form consists of woven Dacron fabric sewn to self-expanding stainless-steel Z-stents. The Pro-Form modification uses a trigger-wire release mechanism that improves proximal conformity and wall apposition. During device deployment, the proximal stent remains in a trifold configuration, which improves deployment accuracy and avoids a windsock effect. Active fixation is provided by barbs on both ends to prevent migration and component separation. A dissection specific stent-graft design exists on the TX2 platform, without proximal barbs and with extensive tapering, as well as with availability of bare-metal stent for distal extension [46]. Cook Zenith Alpha was proposed as a lower-profile TEVAR option (16Fr to 20Fr) to overcome access-related complications. It consists of external nitinol stents and woven polyester fabric sewn together. Similar to the TX2, the Alpha uses active fixation to minimize the risk of migration [47].

2.4. DTAA repair

Comparison of open repair and TEVAR in the treatment of DTAA and rDTAA mainly comes from systematic reviews and meta-analysis of retrospective series and nonrandomized controlled or population-based studies [37,38,48–52].

In an assessment of long-term outcomes after TEVAR for TAA at Uppsala University, including intact and rDTAA, 77 patients were included. Forty-nine patients (64%) were treated for intact TAA and 28 (36%) for ruptured TAA (rTAA). Survival after intact TAA repair was 95.9% at 30 days, 91.8% at 90 days, and 62.5% at 5 years. However, the survival rate after ruptured TAA repair was 71.4% at 30 days, decreased to 57.1% at 90 days, and only 1 patient was alive at 5 years. Clearly, TEVAR for intact TAA was associated with an acceptable 5-year survival rate in contrast to the results for rTAA. This analysis suggests that it is important to improve the selection process to identify patients who likely will benefit from rTAA repair [53].

In a meta-analysis of 44 studies, outcomes of TEVAR and open repair for ruptured descending aortic pathologies was assessed. TEVAR was associated with a significantly lower risk of in-hospital mortality compared with open repair (11% *v* 22%) (risk ratio [RR] = 0.63; 95% CI, 0.57–0.70). Also, it was associated with lower renal failure (RR = 0.87; 95% CI, 0.77–0.98), cardiac complications (RR = 0.54; 95% CI, 0.47–0.62), and peripheral vascular injuries (RR, 0.79; 95% CI, 0.66–0.94). The risk of stroke rate was not statistically different between TEVAR and open approach (RR = 0.86; 95% CI, 0.62–1.19), but TEVAR exerted benefits on the risk of postoperative paraplegia (RR = 0.70; 95% CI, 0.55–0.91). Interestingly, the late mortality (hazard ratio = 0.84; 95% CI, 0.63–1.13) and reintervention (RR = 1.48; 95% CI, 0.80–2.74) rates were not significantly different between TEVAR and open repair [37].

Another meta-analysis evaluated the outcomes of TEVAR versus open repair for the management of rDTAA. A total of 28 articles reporting on 224 patients with rDTAA, of which 143 patients (63.8%) were treated with TEVAR and 81 (36.2%) were treated with open repair. The 30-day mortality rate was significantly lower in the patients treated with TEVAR (19%) compared with open repair (33%) (odds ratio [OR] = 2.15; $P = .016$). Myocardial infarction was also significantly lower in patients treated with TEVAR (3.5% *v* 11.1%; OR = 3.5; 95% CI, 1.02–13.37; $P = .047$). Stroke (10.2% *v* 4.1%; OR = 2.67; $P = .117$) and paraplegia (5.5% *v* 3.1%; OR = 1.83; $P = .405$) were more frequent after open repair versus TEVAR, but without statistical significance. Reliable data regarding deaths during follow-up were insufficient for comparison [38].

Although high-quality evidence is lacking to show the superiority of TEVAR, it is considered the first line of treatment in patients with DTA pathologies, given its lower 30-day mortality and morbidity.

Endovascular devices and techniques are rapidly evolving. DTAA that encroaches proximally into the arch or distally into the visceral aorta can be treated simultaneously or in a staged fashion using custom-made devices. In an emergency, simple coverage of the left subclavian artery or the celiac artery is increasingly being avoided due to better understanding of the risks and new technical developments [54]. Furthermore, off-the-shelf devices come into existence to suit different aortic anatomies, aiming to extend the sealing into both the arch and visceral aorta safely [55,56]. The emerging in situ laser fenestration technique can overcome sealing zone limitations and provide us with a wider range of repairs. In this technique, a Dacron stent-graft is deployed to cover the left subclavian artery and visceral vessels, followed by penetrating the fabric of the endograft to access target vessels using laser probe [57], and subsequently deploying a balloon-expandable covered stent as a bridge between the endograft and the target vessels [58,59].

Challenges going forward consist of the issue of spinal cord ischemia, which is a relatively common complication after rD-TAA repair due to the hypotension and need for extensive coverage without staging [37,38]. How to identify this early, or identify patients at risk, remains a challenge. Biomarkers previously used in patients with traumatic spinal cord ischemia and brain injury have been tested [60], but so far no clinical biomarker is in use. In the future, biomarkers may be the way to identify patients at risk of spinal ischemia during aortic intervention early.

Another dilemma in patients with ruptured thoracic aorta is managing hemothorax, there are different schools of thought on when and if the hematoma should be evacuated, with some studies suggesting that early evacuation has beneficial results, and the concern is the risk for endoleak resulting in uncontrollable bleeding through the chest tube. More work is needed to guide this practice [61,62].

2.5. *TBAD repair*

In the past, medical management was the mainstay for TBAD; open surgical intervention had dismal outcome at that time. TEVAR has changed this landscape in favor of intervention for specific groups of patients. Multiple investigational trials were conducted to assess the safety and effectiveness of TEVAR in patients with noncomplicated TBAD, these include INSTEAD, INSTEAD XL, and ADSORB trials [63–65]. Generally, these trials showed the superiority of TEVAR with best medical treatment over the best medical treatment alone in terms of aortic remodeling and aortic-related mortality, but they failed to show the superiority in the all-cause mortality.

Although we lack level 1 evidence, there is consensus that TEVAR is the best option for treatment of patients with truly complicated TBAD, that is, rupture and malperfusion [1,8,9]. Areas of uncertainty where future research is required is the evaluation of new techniques, such as the PETTICOAT (Provisional Extension to Induce Complete Attachment) and STABILISE (Stent Assisted Balloon Induced Intimal Disruption and Relamination in Aortic Dissection Repair) techniques [66–71]. Although the ambition has been that these techniques would result in aortic remodeling and avoid future aneurysmal degeneration of the dissected aorta, this needs further evaluation.

The PETTICOAT technique involves deployment of bare stents in the thoracoabdominal aorta distal to the stent-graft to expand the true lumen; thus treating dynamic malperfusion and stabilizing the intima. In the short term, the PETTICOAT technique is an excellent method to increase the true lumen diameter, but some degree of perfusion to the false lumen is still maintained and, as a result, the aorta still has a tendency to grow [66–69]. The STABILISE technique is considered an evolution of the PETTICOAT technique, consisting of

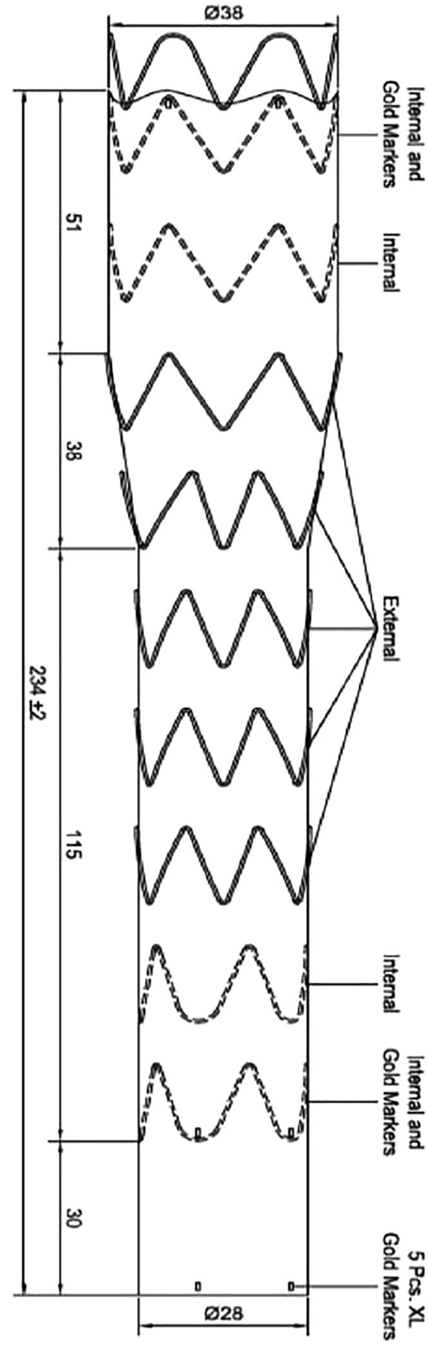


Fig. 3 – Dissection-specific stent graft design This graft is based on the Cook Alpha stentgraft platform, with several modifications: the proximal barbs are removed to reduce risk for intimal injury, the graft is significantly tapered to accommodate for change in true lumen diameter, the distal two stents have reduced radial force, and the final stent is removed resulting in an endovascular unsupported elephant trunk.

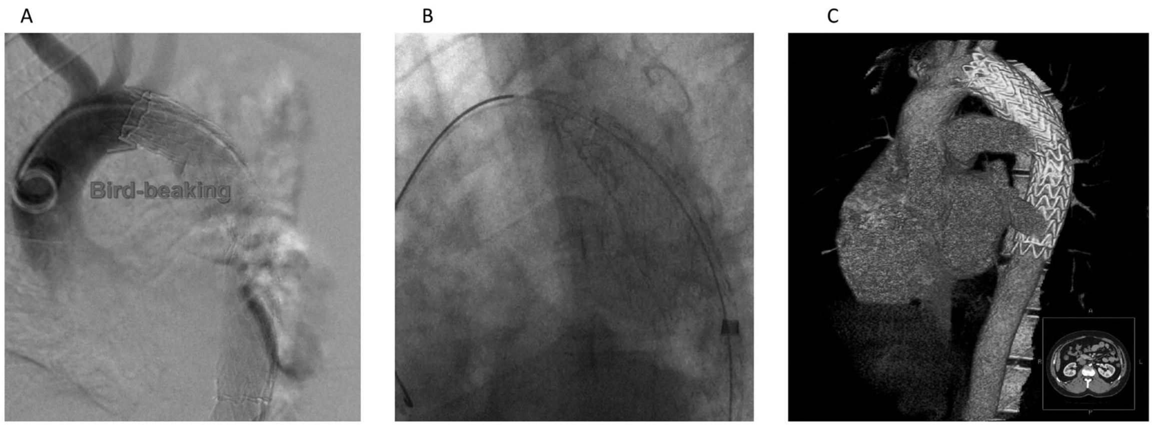


Fig. 4 – Intraoperative aortogram of patient treated with TEVAR for BTAL. Aortogram showing bird-beaking effect post TEVAR deployment (A). Proximal TEVAR collapse on follow-up (B). 3-D reconstruction of TEVAR after proximal relining with palmaz stent (C).

ballooning of the true lumen within the covered stent-graft and the deployed bare stents to rupture the dissection septum, allowing for full expansion of the stents and creating a single-channeled aorta [70,71].

A certain group of noncomplicated TBAD can be considered as high-risk dissection with significant risk of subsequent complications, such as rupture in the subacute period and aneurysmal degeneration in the future. This group includes patients with refractory pain or hypertension and those with high-risk radiographic features [9].

Refractory pain and hypertension correlate to poor short- and long-term outcomes [72]. Persistence of severe pain despite adequate blood pressure control, pain medications, and anxiolytic medications should place a patient in the high-risk category. Refractory hypertension is usually defined as high blood pressure persisting despite more than three different classes of antihypertensive medications. Persistence of pain or refractory hypertension more than 12 hours is considered a failure of medical treatment and surgical intervention should be considered [9].

Throughout the literature, there are many radiographic features considered as malignant findings. Importantly, maximum aortic diameter of > 40 mm, false lumen diameter of > 22 mm, primary entry tear > 10 mm, and primary entry tear located in the inner curve of the aorta. These radiological findings also carry the hazard of rapid aneurysmal degeneration [73,74].

Aortic dissection is a unique pathology at multiple levels, starting from its pathophysiology to the treatment and the outcomes. Stent-graft manufacturing engineers understood the differences between aortic aneurysms and dissections by dint of the collaboration with creative surgeons that resulted in the development of dissection-specific stent-grafts. Subsequently, stent-grafts with and without proximal bare stents, barbs, and various radial strengths are being developed and are available on the market. However, retrograde type A dissection and distal stent-graft–induced new tears remain unsolved clinical problems. Our group has developed a dissection-specific stent-graft to reduce the risk for distal stent-graft–induced new tears with reduced distal radial force (Fig. 3) [75,76].

2.6. *Blunt thoracic aortic injury repair*

Similar to the previous two pathologies, BTAI management shifted from open repair toward endovascular rapidly due to the minimally invasive nature of this procedure. Still, there have been significant early failures related to the unavailability of adequate stent-grafts for the aorta in young patients. Some of these challenges include stent-graft collapse (Fig. 4), early stent thrombosis, and stent fractures, which resulted in withdrawal of some grafts for this group of patients. Other technical issues include uncertainty in aortic size development in patients who receive a stent-graft at young age and the difficulties of adequate sizing in the acute setting in a possibly hypotensive patient. These issues create many opportunities for thriving forward, especially in three-dimensional planning software and stent-grafts designs.

Intravascular ultrasound (IVUS) is one of the devices that came into existence in an attempt to find a solution for sizing difficulties and deployment accuracy in both TBAD and BTAI. A study of patients with BTAI with equivocal CT angiography found that IVUS was more sensitive than angiography in these cases; 3 of 25 patients who had a negative angiogram were diagnosed using IVUS [77]. The benefit of IVUS is most clearly seen in its ability to accurately measure aortic diameter, identify the true and false lumens and guide the wire, identify the entry tear, and assist in accurate placement of the stent-graft in relation to adjacent side branches. The use of IVUS does add additional cost to a procedure and requires training for accurate use and interpretation.

2.7. *Surveillance*

Success in the endovascular era is not defined by procedural success only; it usually encompasses early postoperative care, adequate follow-up, and early diagnosis and management of adverse events. Although the pathophysiological process differs among the various DTA pathologies, patient surveillance follows a similar protocol after a TEVAR. Surveillance intervals are based on several reported experiences, as no definitive evidence exists [8]. Meena et al [78] proposed a more strict surveillance protocol for TBAD in comparison with the other aortic pathologies, as it associates with higher rate of aorta-related complications [78]. Multiple guidelines suggested that CT scans should be the modality of choice for surveillance at 1 month, 12 months, and yearly thereafter [1,79]. The accumulated radiation dose from the lifelong surveillance could, however, place young patients at an increased risk of radiation-induced cancer [80]. Magnetic resonance imaging comes into play as an attractive alternative to minimize the radiation-related risks for these patients [81]. Unfortunately, it is only compatible with nitinol-based endografts, given that the presence of stainless steel causes significant artifacts [81]. Establishing a standardized surveillance protocol based on high-quality evidence is a valuable area of research for these patients.

3. Conclusions

DTA pathologies carry high lethal risks, especially during emergencies. In the past 2 decades, the management has undergone substantial evolution, allowing us to minimize their risks remarkably. Nonetheless, more work must be done to fill the evidence gap aiming for higher-quality evidence during decision making.

Declaration of Competing Interest

None.

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