Endovascular Management of Acute Complicated Type B Aortic Dissection in North America

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The management of patients with complicated acute type B aortic dissection is challenging. Thoracic endovascular aortic repair has shown promising results in small series; however, using nonstandard definitions and improper inclusion criteria confounds the published results. This article reviews the techniques and outcome of patients who underwent endovascular treatment for complicated acute type B aortic dissection in North America. Primary stent grafting for treatment of complicated acute type B aortic dissection compares favorably with the surgical outcome. Thoracic aortic endovascular repair can be offered with a relatively low postoperative morbidity and mortality in experienced hands. It also appears to have a favorable outcome in mid-term follow-up. Longevity of the repair and durability of the stent grafts in the thoracic aorta are yet to be established.

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KEY WORDS

Aortic dissection • Acute aortic syndrome • Thoracic endovascular aortic repair

Acute type B aortic dissection is a catastrophic event, and part of the group of aortic pathologies termed *acute aortic syndrome*. This also includes ruptured or symptomatic aortic aneurysm, intramural aortic hematoma, penetrating atherosclerotic ulcer, and traumatic aortic transection. Although most patients with acute type B aortic dissection can be treated with anti-impulsive and antihypertensive therapy,[1] up to 20% of these patients may have complicated acute type B aortic dissection (cATBAD). They will present with or develop early in their hospital stay severe complications such as rupture, impending rupture, or branch vessel malperfusion.[2] These challenging patients are usually offered open surgical or endovascular management.

The open surgical replacement of a dissected descending thoracic aorta has been the standard of care for treatment of cATBAD over the past 40 years; however, surgical management and outcomes have been challenging even in centers of excellence (Table 1).[3-12] Over the past decade, primary thoracic endovascular aortic repair (TEVAR) in patients with cATBAD has shown promising results in experienced endovascular centers.[13-15] However, little is published about the current procedural details and multicenter results. This article reviews the technical aspects of the intervention and analyzes the outcome of the patient cohort in North America using standard definitions and commonly accepted inclusion and exclusion criteria.

Over the past decade, primary thoracic endovascular aortic repair (TEVAR) in patients with cATBAD has shown promising results in experienced endovascular centers.

Patients and Methods

A search using PubMed and Medical Subject Heading keywords was limited to English language publications after 1995 that involved human subjects. The articles were assessed for their validity, correct pathology, and patient cohort. The methods and statistical analysis were also critically reviewed for appropriateness and accuracy. The publications were analyzed and clinically important data were collected and incorporated based on the following inclusion and exclusion criteria: all patients had complicated acute type B aortic dissections, and were candidates for TEVAR based on adequacy of proximal and distal landing zone and access vessels. The exclusion criteria included type A, uncomplicated acute type B, and chronic type B aortic dissections; penetrating ulcer or intramural hematoma of the descending thoracic aorta; patients treated outside of the United States; and studies with nine or fewer subjects.

For accurate comparison, standard definitions in reporting outcomes of patients with type B aortic dissection were applied[16]; aortic dissection is categorized as acute or chronic depending on the onset of symptoms or dissection. If the symptoms or dissection occurred within 14 days, the aortic dissection was termed acute. Conversely, if the symptoms or dissection occurred beyond 14 days, the dissection was termed chronic. The Stanford classification system for aortic dissection was applied: type A refers to dissections that involve the ascending aorta regardless of the site of origin. Type B refers to dissections that involve only the descending aorta. Rarely, dissections that start in the descending aorta can also extend proximally into the aortic arch and the ascending aorta. In this special case, the type B dissections were called retro-A dissections. The term *cATBAD* was used for patients who present with, or during the hospital course develop, the following symptoms: rupture, malperfusion syndromes, unrelenting pain, refractory hypertension, or impending rupture (acute aortic expansion to 4.5 cm or false lumen expansion to 2.5 cm). Primary technical success was defined as complete exclusion of the primary tear site by the stent-graft without procedural endoleak, death, or conversion to open repair. Treatment failure was defined according to the Stanford criteria as aortic rupture, device mechanical fault, reintervention, aortic-related death, or sudden or unexplained late death.[17] A standard definition for endoleaks was adopted for this analysis.[18]

Results

Endovascular Techniques

For potential TEVAR candidates, after initiation of appropriate antiimpulsive and antihypertensive medication,[19-21] adequate imaging is the next step. The procedural planning is based on the preoperative imaging. The study of choice is a multislice computed tomography (CT) angiogram (preferably electrocardiography gated) from the base of the skull down to femur head. This allows for evaluation of proximal landing zone, evidence of visceral malperfusion, location and number of proximal and large intimomedial tears, dominance of left vertebral artery, vertebrobasilar abnormalities, evidence of rupture or contained rupture, and adequacy of access to vessels, including distal extension of dissection in iliofemoral vessels. Transesophageal echocardiogram and intravascular ultrasound (IVUS) may offer additional information intraoperatively. Details of pre- and postoperative imaging and surveillance have been elucidated previously.[22]

Patients are divided into a "malperfusion" or "rupture" pathway based on physical examination, laboratory results, and imaging findings. This triage changes primary endpoints of intervention. Transcranial Doppler, motor-evoked potentials, and cerebrospinal fluid drainage are recommended to reduce adverse neurologic events. Cut-down is performed on the largest and nondissected femoral artery. Systemic heparinization is performed aiming for an activated clotting time of 250 sec throughout the endovascular procedure. True lumen wire access into the ascending aorta is verified using IVUS. IVUS interrogation will

TABLE 1

A Sample of Contemporary Surgical Outcomes of Complicated Type B Aortic Dissection

Study	Patients (N)	Patients With Malperfusion (N)	Postoperative Reoperations	Postoperative Spinal Cord Injury	Early Mortality	1-Year Survival (%)	Average Follow-up (Mo)
Bozinovski and Coselli[6]	76	n/a	2 (3%)	5 (7%)	11 (15%)	n/a	1
Elefteriades JA et al[8]	31	17 (55%)	n/a	6 (19%)	n/a	n/a	n/a
Gysi T et al[11]	38	13 (34%)	9 (30%)	5 (14%)	8 (21%)	n/a	48
Kouchoukos NT et al[9]	20	n/a	n/a	0	8 (40%)	n/a	n/a
Lansman SV et al[7]	34	6 (18%)	9 (26%)	1 (3%)	0	100	70
Roseborough G et al[10]	22	9 (41%)	5 (23%)	1 (5%)	4 (18%)	75	40
Trimarchi S et al[12]	82	33 (40%)	5 (7%)	4 (5%)	24 (29%)	n/a	1
All studies	303	78 (38%)	30 (12%)	22 (7%)	55 (20%)	86	32

also visualize accurately all intimomedial tears, evaluate adequacy of access vessels, and allow a more accurate measure of the proximal healthy aorta. Intraoperative diagnosis of true lumen cannulation throughout the entire aorta is based on four criteria: preoperative CT scan findings (that may have changed since the CT acquisition), acute angle between flap and the outer wall of the false lumen, three-layer appearance of the intact true lumen outer wall, and presence of thrombus or cobweb in the false lumen. Alternatively, the "embracement of pigtails" technique may be applied from the right radial and femoral arteries to ensure true lumen advancement of the guidewire. A 4F pigtail catheter advanced over the guidewire via the right radial or brachial artery picks up the femoral pigtail catheter in the true lumen of the abdominal aorta and pulls it into the aortic arch. This procedure ensures definitive placement of the stiff guidewire and the femoral pigtail in the true lumen, which is essential for primary endovascular repair of cATBAD. The stent graft is chosen based on CT and ultrasound findings. This is usually less generously oversized (by maximal 10%) in patients with cATBAD, compared with those with aneurysmal disease, where appropriate oversizing is critical to avoid type I endoleaks. A pigtail is then placed via the contralateral femoral artery or the right radial artery approach for predeployment angiogram.

In cases of (impending) aortic rupture, the patient is managed preoperatively with principles of permissive hypotension. Just prior to stent graft deployment, the rate of rise of left ventricular pressure (dP/dt) is reduced by right ventricular pacing, high-dose adenosine, or short-acting β-blockers or calcium channel antagonists.[23] Once the desired portion of the descending thoracic aorta is covered with the stent graft, the patient is maintained hyperdynamic and hypertensive (sometimes with pharmacologic interventions) to improve spinal cord perfusion pressure and reduce the possibility of postoperative paraplegia/paraparesis. Complete coverage of the descending thoracic aorta, usually from the left common carotid artery to just above the celiac artery, is normally necessary for the patients in the "rupture" pathway, because the location of the tear is frequently not visualized on imaging. Indications for preoperative subclavian artery revascularization are a patent left internal mammary artery as a coronary artery bypass conduit, dominant left vertebral artery, functional left dialysis fistula, professional/athletic "heavy use" of left arm, and rare cerebrovascular anomalies that are associated with posterior circulation malperfusion if the left subclavian artery is covered without revascularization (eg, absent posterior cerebral or basilar artery, both vertebral arteries arising from left subclavian artery). If the patient has 1 to 2 cm of healthy landing zone distal to the left subclavian artery, the subclavian artery coverage is omitted. Rarely, the entry tear is within 1 cm of the left common carotid artery. In these cases, a carotid-carotid bypass is necessary in preparation for a zone I stent graft deployment (covering the origin of the left common carotid artery). No balloon molding of the stent graft is performed to avoid the possibility of dissection flap rupture or retrograde aortic dissection. A postdeployment angiogram will demonstrate exclusion of the false lumen of the descending thoracic aorta. The same approach is applied to patients with unrelenting pain and refractory hypertension.

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In patients with malperfusion, initially the most prominent proximal intimomedial tears are covered with a stent graft. An IVUS revealing stagnation of the false lumen (smoke effect) in the descending thoracic aorta is a surrogate for a successful rerouting of the perfusion into the true lumen (Figure 1).

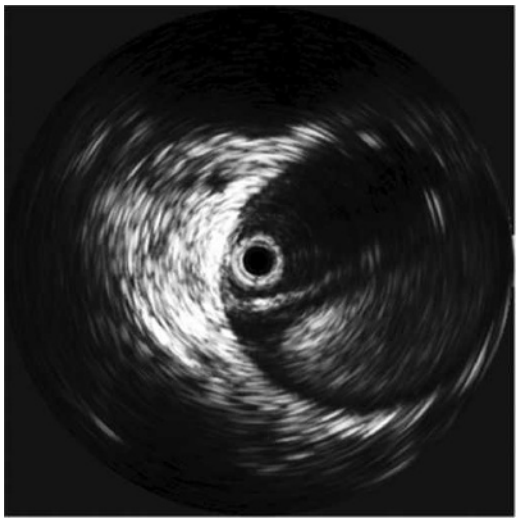

Figure 1. Intravascular ultrasound of the distal descending thoracic aorta after stent-graft-exclusion of the first two dominant intimomedial tears. The false lumen is more echogenic than the true lumen due to stagnation of the blood.

The patients with dynamic obstruction (true lumen collapse or dissection flap opposition to the branch vessel orifice) are usually treated by proximal stent-grafting to redirect the cardiac output toward the true lumen. The arteries are reassessed for malperfusion using angiograms, IVUS interrogations, and interluminal manometry. On rare occasions, the dynamic obstruction will persist. In these cases, IVUS-guided balloon fenestration will perfuse the true lumen at the level of the branch vessels. In patients with static obstruction (clot or dissection flap within the orifice of branch vessels), treatment with a self-expanding stent or fenestration may become necessary. A completion manometry in these patients is recommended to document alleviation of the gradient between the branch vessel and the nondissected aorta.

Connective tissue disorders such as Marfan syndrome have been a contraindication for endovascular repair due to dilatation of the proximal and distal landing zones and subsequent type I endoleak. The only exceptions are patients in whom proximal and distal landing zones were fixated with polyethylene terephthalate tube grafts. However, if a patient with a connective tissue disorder presents with cATBAD and in extremis, TEVAR may be offered with the understanding that this patient will require elective open repair at a later stage to replace the stent graft with traditional surgical repair. This has been the strategy of some aortic centers of excellence (personal communication: panel discussion, Houston Aortic Symposium, March 26-28, 2009).

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Review of North American Studies

The literature search revealed five publications on endovascular management of cATBAD that met the aforementioned inclusion and exclusion criteria (Table 2). A total of 155 patients underwent primary TEVAR for cATBAD. The primary technical success rate was 94% (146 patients). Primary indications for TEVAR were malperfusion in 72 (46%), franc rupture in 41 (26%), impending rupture in 15 (10%), persistent pain in 12 (8%), and uncontrollable hypertension in 15 (10%); 59% of patients had more than one indication for operation. Postoperative temporary or permanent paraplegia or paraparesis was present in 15 patients (10%). Early mortality and 1-year survival were 13% and 81%, respectively. Treatment failure according to Stanford criteria was present in 39 patients (25%).

Conrad and colleagues[24] reviewed their experience with endovascular management of cATBAD in 33 patients between August 2005 and October 2007; 14 patients were treated at Massachusetts General Hospital (Boston, MA) and 19 patients were included from other institutions as part of an industry-sponsored trial.[24] One patient died of postprocedural aortic rupture. Three other patients died early, four others by the 1-year follow-up. No endoleaks or reinterventions were observed in the follow-up. A partial or complete thrombosis of the false lumen along the treated aortic segment was recorded in 93% and 88% at 1-month and 1-year scans, respectively; however, imaging was missing in four other surviving patients.

Feezor and coworkers[25] published data on 33 patients with cATBAD. They painted a bleaker perspective on the outcome of these patients. Six patients underwent aortic banding for type I endoleak or persistent false lumen perfusion. Three patients underwent open replacement of the descending thoracic aorta for persistent false lumen perfusion; 14 procedures for adjunctive stenting in the iliac and visceral arteries were performed. The in-hospital mortality was 21% (n = 7). From this cohort, one patient had aortic rupture; another was found to have retrograde aortic dissection with hemopericardium on autopsy. Seven patients showed endoleak in follow-up imaging.[25]

Khoynezhad and colleagues reviewed 28 consecutive patients with cATBAD who underwent TEVAR between August 1999 and July 2007.[26] Upon including patients in the previous 2 years, there were 38 patients in all. Indications for TEVAR were rupture or impending rupture in 11 (29%), malperfusion in 20 (53%), unrelenting pain in five (13%), and refractory hypertension in two (5%) patients. Four (11%) patients died early. Six patients died during follow-up predominantly due to non–aorta-related causes (unknown cause in one patient). Overall survival was 81% and 72% at 1- and 5-year follow-up, respectively. Complete or partial thrombosis of the false lumen in the thoracic aorta was achieved in 25 (89%) members of the surviving cohort. The rate of treatment failure according to Stanford criteria was 18% (n = 7) at 5 years.

Szeto and coauthors[27] examined the results of TEVAR in 35 patients presenting with rupture (n = 18) or malperfusion syndrome (n = 17). Coverage of the left subclavian artery was required in 25 patients (71.4%). Primary technical success as defined earlier was achieved in

TABLE 2

Review of North American Results on Primary Endografting for Complicated Acute Type B Aortic Dissection

Study	Patients (N)	Patients With Malperfusion (N)	Primary Technical Success Rate (%)	Postoperative Spinal Cord Injury	Early Mortality	1-Year Survival (%)	Average Follow-up (Mo)	Treatment Failure in Follow-up	Reverse Aortic Remodeling of the Descending Thoracic Aorta
Conrad MF et al[24]	33	17 (53%)	32 (97%)	2 (6%)	4 (12%)	76	12	8 (24%)	19 (88%)[a]
Feezor RJ et al[25]	33	11 (33%)	30 (91%)	8 (24%)	7 (21%)	n/a	6	14 (42%)	15 (75%)[b]
Khoynezhad A et al[26]	38	20 (53%)	35 (92%)	1 (3%)	4 (11%)	81	38	7 (18%)	25 (89%)
Szeto WY et al[27]	35	17 (49%)	33 (94%)	3 (9%)	1 (3%)	93	13	5 (14%)	20 (74%)[c]
Verhoye JP et al[28]	16	7 (44%)	16 (100%)	1 (6%)	4 (25%)	73	36	5 (31%)	10 (63%)
All studies	155	72 (46%)	146 (94%)	15 (10%)	20 (13%)	81	21	39 (25%)	89 (78%)

[a]Defined as thrombosis along the treated aorta at 1 year (four patients are missing postoperative imaging).
[b]At 1 month (six patients are missing postoperative imaging).
[c]Four patients are missing postoperative imaging.

33 patients. One patient underwent successful endovascular treatment for persistent type II endoleak. The early mortality was superb, at 2.8%. One-year survival was also above average, at 93.4%. There were no open conversions. Two patients did require repair in the ascending aorta; another required carotid-subclavian bypass. One patient developed stroke (2.8%), and three others had spinal cord ischemia (5.7% transient and 2.8% permanent). Complete reverse aortic remodeling of the descending thoracic aorta was achieved in 74%, taking into account that four survivors were missing surveillance imaging.

Finally, Verhoye and colleagues[28] reported data on 16 patients with cATBAD at Stanford University (Stanford, CA), who underwent TEVAR using customized or commercially available devices. Four patients required concomitant branch-vessel stenting. One patient underwent reintervention for type Ia endoleak at 3 months. This patient required open conversion, but recovered uneventfully. Early mortality was 25% (n = 4), with no late deaths. No new neurologic complications occurred, with the exception of temporary paraparesis in one patient. According to the latest scan, four patients (25%) had complete thrombosis of the false lumen; the lumen was partially thrombosed in six patients (38%). Distal aortic diameter was increased in only one patient. Actuarial survival at 1 and 5 years was 73%.[28] With follow-up to 9 years, this study reports one of the longest follow-ups of patients with cATBAD in the literature.

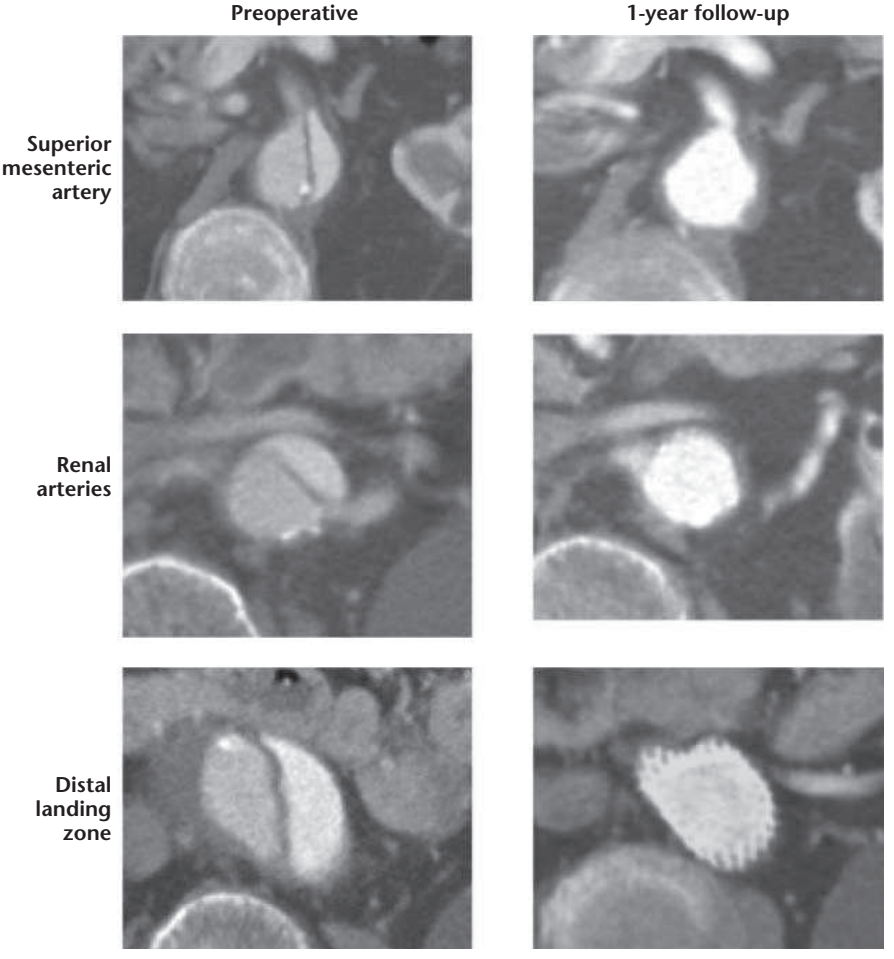
Discussion

Endovascular management for cATBAD has gained increased interest as a primary treatment option.[13-15,24-29] This was stimulated by the Stanford group's initial report in 1999.[13] The goal of the therapy is to exclude the primary entry site, obliterate the false lumen, prevent aortic rupture, and relieve visceral and lower body malperfusion.

The endovascular treatment of patients with cATBAD is complex and requires an algorithmic approach. Primary endpoints of treatment are different in patients with malperfusion versus rupture. In patients with malperfusion, balloon fenestration was the primary method of treatment in the past; there is now a clear shift toward primary stent grafting of the proximal descending thoracic aorta in these patients. If performed accurately, this usually relieves malperfusion in up to 90% of patients with dynamic or mixed dynamic-static obstruction. Furthermore, the possibility of complete thrombosis of the false lumen in the thoracic aorta and reverse aortic remodeling is significantly increased (Figure 2). In this review, 78% of survivors had partial or complete thrombosis of the descending thoracic aorta (Table 2). Transcatheter (or open surgical) fenestration equalizes the arterial pressure in both lumens, and hinders thrombosis of the false lumen. Therefore, fenestration should be used only as bailout, when other techniques of reperfusion are unsuccessful.

Current stent grafts available in North America are primarily

Figure 2. Preoperative and 1-year follow-up axial computed tomography scans of a patient with mesenteric malperfusion. In 1-year follow-up, the patient had complete aortic remodeling in the entire thoracoabdominal aorta. The false lumen is completely obliterated, and the true lumen is supplying the superior mesenteric artery and both renal arteries.



designed for aneurysmal pathology. Future generations of stent grafts will include covered areas for exclusion of intimomedial tears, and bare metal stents for the rest of the thoracoabdominal aorta. The distal bare components will compress the false lumen in cATBAD, and may be used safely across the visceral arteries. Some of these novel devices are already available for investigational use in Europe. In North America, on the other hand, the TEVAR of cATBAD remains off label, as the stent grafts are approved for fusiform and saccular aneurysms and penetrating ulcers. At least two of the three currently approved stent-graft companies are in the process of starting clinical trials on patients with cATBAD. It is probable that the outcome of these trials will result in approval of TEVAR on cATBAD.

There has been poor adherence to accepted definitions of cATBAD in most published series. For example, a cohort of 69 patients from the University of Michigan (Ann Arbor, MI) was found to include asymptomatic acute type B dissection patients without end-organ dysfunction but with CT evidence of true lumen collapse.[29] This paper was excluded from review because there was no segregation between the asymptomatic dissection group and the patients with clinical evidence of true cATBAD. Similar criticism applies to many other published studies on cATBAD,[13,30,31] including the largest meta-analysis on this topic involving 942 patients in various European centers.[31] The authors included patients with uncomplicated acute type B aortic dissection, chronic dissection, intramural hematoma, or penetrating aortic ulcer.[25] These eclectic patients comprised approximately half of the entire patient population included in the analysis. Admixture of various pathologies will not allow for comparison of "apples to apples" when reporting outcomes of patients with cATBAD.[16] Therefore, this study concentrated on manuscripts with clearly defined cATBAD and limited to North America. By having a homogeneous cohort, we strive to obtain more meaningful data that may be used as a benchmark for upcoming clinical trials.

This analysis shows that endovascular repair of cATBAD is associated with relatively low morbidity and mortality and may be considered as a primary treatment for patients with cATBAD in centers experienced with advanced endovascular techniques. Early mortality of 13% in this study (Table 2) compares favorably with open surgical results in this complex patient cohort (Table 1). A complete or partial reverse aortic remodeling in 78% of survivors is also encouraging. This may obviate the need for future treatment due to chronic aneurysmal degeneration of the false lumen.

Spinal cord injury rate of 10% (Table 2) is concerning and higher than in other larger TEVAR trials.[32] A higher rate of paraplegia/paraparesis may be due to the fact that many patients with cATBAD have intended stent graft coverage of the left subclavian artery, a prominent supplier of the spinal cord arterial network. The European registry revealed increased spinal cord injury rate associated with zone II deployment, when the left subclavian artery was not revascularized.[32]

This study has many limitations associated with retrospective review; the patient cohort is relatively small due to the incidence of this pathology and geographic boundaries. Therefore, the term *meta-analysis* was avoided, as a meaningful statistical analysis is not possible with the current number of patients. Some centers performing large-volume primary TEVAR for cATBAD in North America may have been overlooked, if they have not published the results in peer-reviewed journals indexed by PubMed. This study also lacked a direct comparison group treated primarily by surgical means. This is best accomplished with a randomized controlled trial of both surgical and endovascular approaches, and is not the aim of this manuscript. Long-term results of TEVAR are still being investigated.

Conclusions

The management and outcome of cATBAD is challenging. Surgical management has a significant rate of morbidity and mortality, and TEVAR as a primary method compares favorably with the surgical outcome. The endovascular procedure is complex, and may be performed as a primary treatment modus in experienced centers that are prepared to treat patients with acute aortic syndromes. TEVAR may become the therapy of choice for patients with cATBAD who are undesirable surgical candidates, if larger industry-sponsored clinical trials confirm its superiority. Long-term durability of TEVAR for patients with cATBAD is yet to be established. ■

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MAIN POINTS

- Most patients with acute type B aortic dissection can be treated with anti-impulsive and antihypertensive therapy, but up to 20% of these patients may have complicated acute type B aortic dissection (cATBAD) and are usually offered open surgical or endovascular management.
- Over the past decade, primary thoracic endovascular aortic repair (TEVAR) in patients with cATBAD has shown promising results in experienced endovascular centers.
- TEVAR may become the therapy of choice for patients with cATBAD who are undesirable surgical candidates.