Review Article

Acute Type-B Aortic Dissection: The Treatment Strategy

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Despite progress in cardiovascular surgery, postoperative complications and surgical mortality remain high after operation in the case of acute aortic dissection type B (AAD-B).[1] Thoracic endovascular aortic repair (TEVAR), in the treatment of AAD-B is becoming commonplace despite some controversies.[1-3] AAD-B (Stanford classification) or type III (De Bakey classification) represents one third of all the cases of AAD.[4] The first 2 weeks from the onset of symptoms are considered acute dissection.[1] However, AAD-B is an insidious disease, because the occlusion of the aortic branches owing to the expansion of the dissection complicates the clinical presentation, and also deadly, because of the tremendous ischaemic complications, requiring in these cases immediate and intensive management.[5] In addition, the chronic phase (after two weeks from the onset of symptoms) of the dissection of the descending thoracic aorta contributes to a significant percentage of the prevalence of thoracic and thoracoabdominal aneurysms. Medical therapy is the treatment of choice for uncomplicated cases, but in case of complicated acute (impeding or frank rupture and malperfusion syndrome) or chronic (degeneration) dissection TEVAR is nowadays indicated,[1] taking into consideration that open surgical repair is associated with nearly 30% perioperative mortality, 25% composite neurological morbidity, and a renal failure rate of 20%.[6]

Treatment strategy

The aim of the treatment is to prevent death and irreversible ischaemic damage of the involved organs of the abdomen, as well as of the lower limbs. In contrast to the patients with acute aortic dissection type A (or type I and II) who almost always need urgent surgery, medical therapy is chosen for the majority (>90%) of AAD-B cases.[7-9] The reasons for the adoption of the medical therapy are as follows:[4,10]

- The optimal results of conservative management. In fact, almost two thirds of approximately 85% to 90% of patients who are discharged from the hospital after medical therapy are in good condition with no complications after aggressive antihypertensive medical therapy alone.[11]
- Avoiding the risk of an emergency operation.
- The similar long-term outcome for survivors after either medical or surgical therapy.

However, a few patients with life-threatening complications of AAD-B require emergency surgical or interventional management (aortic graft replacement, endovascular stent-graft placement, flap fenestration, catheter

reperfusion, and surgical bypass). All of these techniques aim, on the one hand, to prevent the proximal primary intimal tear and preclude or remove all aneurysmal disease so as to reduce the risk of dissection-related death, and on the other hand, to maintain the perfusion to all distal organs and major aortic branches.[11] Endovascular techniques with stent-grafts have been applied in numerous studies since 1999.[12-18] Despite the success of medical therapy in the acute management of non-complicated aortic dissection, long-term morbidity and mortality are high. TEVAR has been associated with reductions in morbidity and mortality in the treatment of complicated dissections. There are limited data regarding TEVAR for acute uncomplicated dissections.[19] Also, stent-grafts have been used in combination with open surgical repair.[20,21]

Medical treatment

Initial medical therapy

As soon as AAD-B is suspected, urgent and intensive medical therapy should be initiated, the cornerstone of which is the reduction of the systolic (optimal: 100-120 mmHg), mean, and diastolic blood pressures and their rise rate.[8,22] The same therapy, with an antihypertensive and negative inotropic action, is also administered to patients who have an indication for emergency operation or intervention. The criterion of successful antihypertensive management is relief from the pain, while if the pain persists it may be due to an extension of the dissection or impending rupture. Arterial hypertension predisposes patients to early reappearance of the dissection or early rupture of the persisting false lumen.[23] The patient is monitored in an intensive care unit, with recording of electrocardiogram, blood pressure, central venous pressure, blood gas analysis and urine volume production hourly.[5] Basically, the indicated drugs are β-adrenergic antagonists (e.g. esmolol, metoprolol), vasodilators (e.g. nitroglycerine or sodium nitroprusside) and calcium channel antagonists (e.g. diltiazem, nifedipine), which also produce a beneficial bradycardia.[5] An alternative to the combination of β-blockers with a vasodilator drug could be labetalol, an α_1-adrenergic and nonspecific β-blocker.[5]

Long-term medical therapy

No matter which is the indicated initial type of treatment (medical, surgical or intraluminal), during the hospitalisation the same drugs (antihypertensive and negative inotropic action) continue to be provided and are gradually transitioned from intravenous to oral agents. Specifically, oral β-blockers (e.g. metoprolol, atenolol), calcium channel antagonists and angiotensin-converting enzyme inhibitors (such as lisinopril) are continued indefinitely.[5] Recently, it was suggested that angiotensin-converting enzyme inhibitors have a positive impact on the increase rate of the aortic diameter in patients with Marfan syndrome, whereas it is in doubt whether β-blockers actually have a positive effect.[24] To sum up, as far as the goal of medical management is concerned, steady and optimal blood pressure control is highly important and is believed to decrease the incidence of aneurysms due to a persisting false lumen.[23]

Surgical treatment

Indications and contraindications

It has already been clarified that surgical treatment is not the treatment of choice and only a minority of patients with AAD-B should be operated on. The indications are not absolutely defined; nevertheless, some commonly accepted ones are presented in Table 1.[6,25,26] On the other hand, there are contraindications, which are also not utterly defined; however, high mortality and complication rates have been estimated under the following circumstances:[7,10,27-30] older patients; and coexistent severe diseases, e.g. ischaemic heart disease, chronic pulmonary disease, extended atherosclerosis, or malignant neoplastic disease.

Table 1. Surgical treatment is not the treatment of choice and only a minority of patients with acute type B aortic dissection should be operated on. The indications are not absolutely defined; nevertheless, some commonly accepted ones are presented in this table.

Indications for Surgical Treatment	
1)	Distal ischaemia: viscera, kidneys, lower limbs
2)	Drug resistant pain
3)	Drug resistant hypertension
4)	Rupture / imminent rupture
5)	Expansion in length
6)	Diameter increase >5 cm
7)	Emergence in a pre-existing aneurysm
8)	Pseudoaneurysm
9)	Aortic arch participation
10)	Relatively younger patients without severe comorbidity
11)	Marfan syndrome
12)	Paraplegia? Indication during the first hours

Surgical procedure

The main concept of the operation in AAD-B is to replace with a graft the site of the "primary intimal tear" (or "entry site")[8] and maintain adequate peripheral perfusion.[11] However, the removal of the portion of aorta at risk for rupture does not eliminate the risk of subsequent aneurysmal degeneration of the residual distal aortic false lumen.[11] Special effort is made to resect the smallest aortic part possible, in order to avoid spinal cord ischaemia. Nonetheless, some techniques have been developed and are applied, alone or in combination, so as to prevent ischaemia of the spinal cord and kidneys during the operation.[11] These techniques are presented briefly in Table 2.[11,23,31-34] Full or partial cardiopulmonary bypass is always used. Full cardiopulmonary bypass combined with deep hypothermia, with or without circulatory arrest, is used if the distal aortic arch is replaced or if extensive resection of the descending thoracic or thoracoabdominal aorta is required.[33] If placing clamps is inadvisable, or in the case of retrograde dissection in the aortic arch, total cardiopulmonary bypass with hypothermic circulatory arrest is used for better cerebral protection.[33,35] Additional care for the protection of the phrenic nerve, the vagus nerve, and the recurrent laryngeal nerves is taken.[33] After proximal and distal occlusion of the affected aorta, it is opened longitudinally, thrombi are removed from the false lumen, and the true lumen is entered. Orifices of the intercostal or segmental arteries above the level of the sixth intercostal space and any bronchial or oesophageal arteries are ligated.[33] Intercostal or segmental arteries below the level of the sixth intercostal space, from which the artery of Adamkiewicz (major anterior segmental medullary artery) is generated, are crucial for the adequate perfusion of the spinal cord. These arteries should be selectively perfused until their implantation into the graft. The aorta is completely transected and the corresponding proximal and distal cuffs are reinforced with strips of polytetrafluoroethylene (PTFE) or bovine pericardium on the external aortic surface.[23,33] A hermetic proximal anastomosis with a graft is constructed first, using a continuous 4-0 polypropylene suture. The intercostal arteries between the levels of the T6 and L2 vertebrae should be reimplanted in the posterior surface of the graft.[33,36-38]

Table 2. Summary of some techniques that have been developed and are applied, alone or in combination, so as to prevent ischaemia of the spinal cord and kidneys during the operation.

- Distal perfusion of the aorta
- Systemic hypothermia, so as to lower the metabolism rate during surgery
- Cerebrospinal fluid drainage, preserving the pressure under 10 mmHg
- Partial cardiopulmonary bypass without circulatory arrest

Surgical management of peripheral ischemia

Surgical repair of the dissected portion of the aorta frequently eliminates the need for reperfusion of the peripheral arteries.[39] Inadequate visceral, renal or lower limb perfusion has been associated with a very high risk of death.[23]

Complications of surgical treatment

Apart from the prominent early mortality affecting the operated patients, many of them, up to 78%,[40] suffer from early complications. The most important early complications of surgical treatment are the following:[31,32,40-47]

1. Spinal cord ischaemia, which can lead to paraplegia (2.3-6.6%) or paraparesis (0-3.1%). The extent of repair, the aortic clamp time, the postoperative renal complications, and gastrointestinal complications have been identified ($p<0.05$) as independent predictors of spinal cord injury, supporting the notion that the degree and duration of ischaemia of the spinal cord and the reimplantation of the critical intercostal arteries are crucial.[46]
2. Renal ischaemia, with acute renal failure as a result (overall: 19.7%), which can be either temporary (9.2%), or permanent (10.5%).[42] The use of atriofemoral bypass for distal perfusion and the prevention of other complications are important for reducing the risk of renal failure.[44]
3. Cardiac complications (43.4%), including mostly atrial dysrhythmias.[46]
4. Stroke (2.7-6.6%).[11,42]
5. Acute postoperative respiratory failure.
6. Left vocal cord paralysis (39.5%), requiring tracheostomy in 13.2% of the patients.[42]
7. Visceral ischaemia or peritonitis.
8. Sepsis.
9. Lower limb ischaemia resulting in tissue necrosis.

Unfortunately, these complications may cause the multiple organ failure syndrome (MOF).

Endovascular treatment

The modern trend

Recently, the application of endovascular methods using endo-stents or stent-grafts for the management of descending aortic dissection has been a significant advance. Since 1999, successful outcomes with these techniques have been published and have encouraged their use in younger and healthier patients, too.[12-18] However, it has to be stressed that the endovascular treatment of AAD-B is still at an early stage. The main goal is to cover the primary intimal tear, relieve the lower body malperfusion, and prevent rupture, so that the patient can be resuscitated and then followed closely for an indefinite period.[11,12,14,17] Using the endovascular treatment on an emergency basis for acute complicated AAD-B can save the patient if applied judiciously and quickly, but should not be considered as a definitive "curative" intervention.[1,11] The advantages of endovascular treatment may be the following:[8,12,19,20,50]

a) The endovascular technique is minimally invasive, safe, shorter, and effective.
b) All the complications related to extracorporeal circulation and thoracotomy are avoided.
c) The reduced blood loss.
d) The shorter hospitalisation.
e) The probable lower incidence of postoperative paraplegia, because stents are usually short, and rarely extend beyond the 6th intercostal space.
f) The avoidance of any clamping in the friable thoracic aortic wall.
g) Probably, better late results regarding the incidence of late aneurysms and/or rupture. Indeed, according to some studies, the false lumen is eliminated in up to 80% of cases.[13,49,50]

The rationale behind endovascular therapy is that covering the area of the primary intimal tear with a stent-graft promotes false lumen thrombosis and subsequent aortic remodelling by eliminating antegrade (or occasionally retrograde) flow into the false lumen.[5,11] However, according to the INSTEAD study (INvestigation of STEnt grafts in patients with type B Aortic Dissection),[51,52] stent-graft treatment of patients with chronic aortic dissection offers no benefit in terms of reducing the risk of aortic rupture or enhancing life expectancy. On the other hand, the disadvantages of interventional management might be the following:[5,11,13-15,23,53-55]

a) Complications from the stent itself, such as angulation, dislodgement, "peri-stent-leaks", branch obstruction, etc., and
b) Complications of the endovascular treatment in AAD-B, both described in the relevant paragraph.
c) Complications from femoral, internal inguinal arteries or abdominal aorta, and
d) Complications of chronic aortic dissection, such as critical branches perfused both by true and false lumen, and the presence of multiple communications between the true and false lumen.

Thoracic aortic endografting for complicated acute type B aortic dissection can be performed with relatively low postoperative morbidity and mortality by an experienced team. The endovascular approach to life-threatening complications of acute type B aortic dissection seems to have a favourable outcome in midterm follow up.[56] According to a study conducted by Mastroroberto et al,[57] of 51 consecutive patients with AAD-B, 11 underwent open surgery and 13 TEVAR; the TEVAR group had significantly better mortality and postoperative complications. No significant differences were found in terms of cumulative survival at follow up. On this basis TEVAR could be considered an option in the treatment of these complex cases, with all proper reservations, especially in relation to the small sample sizes examined.[57]

Indications for endovascular treatment

While the feasibility of stent-graft placement in the descending thoracic aorta is now firmly established for various pathologies,[30,58,59] the indications for intervention remain to be fully defined. Today, the indications for emergency stent-grafting include those presented in summary in Table 3.[12,13,15,17,30,60-62] The presence of Marfan syndrome or a connective tissue disorder has been a strict exclusion criterion in all commercial thoracic aortic stent-graft trials.[11]

Types of vascular occlusion

As far as AAD-B is concerned, the concept of endovascular therapy can be more completely understood by dividing the vascular occlusion into two types: "dynamic" and "static".[23,63,64] In "dynamic-type" obstructions, the true lumen is compressed by the false, and the blood flow to the former lumen is compromised.

Table 3. Indications for emergency stent-grafting in acute type B aortic dissection.

- Rupture
- Severe visceral or lower limb malperfusion
- Persistent refractory back pain
- Uncontrollable hypertension

In these cases, endovascular stent-graft coverage of the primary intimal tear is indicated, so as to redirect flow into the true lumen.[13,65] "Static-type" obstructions are due to the enfoldment of the intima at intimal tears near or at the branch vessel ostium, and the branches may also be thrombosed. Those obstructions require endovascular stenting of the branch vessel orifice, either alone, or in addition to fenestration of the dissection septum.[39,66]

Complications of endovascular treatment

Early first-generation devices suffered from numerous problems, such as stroke with insertion, ascending aortic dissection or aortic penetration from struts, vascular injury, graft collapse, endovascular leaks, graft material failure, aneurysm expansion or rupture, and migration or kinking.[11] Although the newer products coming into clinical use have been considerably improved, some significant complications after stenting of the aorta have been reported. Overall the complications are the following:

1. Cerebral vascular accident, owing to catheter manipulation in the ascending aorta and/or aortic arch, affected by atherosclerosis.[5,14,15] Stroke is the most serious and commonly experienced complication after endovascular stent-grafting, with an incidence of 3-10%.[11,14,15]
2. Excluding or obstructing highly significant branches, such as the left subclavian artery (acute ischaemia of the left upper arm), the intercostal arteries below the 6th intercostal space (paraplegia) and/or the visceral arteries.[13,48,53]
3. Failure to exclude the aneurysm sac from the blood flow, the so called "endoleaks".[67,68]
4. Chronic progression of dilatation of the true and the false lumen.[11]
5. Angulation, dislodgement, lumen obstruction, stent-graft migration.[11]
6. Aortic rupture during implantation, after perforation of the outer adventitial layer of the aortic wall.[23]
7. False aneurysm formation of the proximal or distal end of the stent, secondary to erosion from an uncovered stent-graft.[54]
8. Graft erosion or fracture, secondary to movement between the stent-body and the overlying fabric, or to fatigue.[23]

Comparison of the treatment modes

Strict comparison and interpretation of the results between medical and surgical, or medical and interventional management is difficult. The reasons for that are, on the one hand, because there is a considerable dissimilarity in risk factors between the two populations, and on the other hand because there are no randomised comparative studies, but only some comparative retrospective analyses.[10,11] These studies involved a small number of patients, or a short follow-up period. The 36-year "Stanford experience" included 142 patients, 111 treated medically and 31 treated surgically, and compared the two groups with respect to mortality, reoperation, and late complications.[10] The results for those three factors were found to be similar. The early mortality in the last 30 years for patients treated medically did not change significantly, ranging from 7.4% to 19%,[10,67] in contrast to the surgical mortality rate, which decreased from 57% in the 1960s to 6-31% in the 1990s.[4,10,69] Several recent studies have demonstrated that operative mortality is between 2% and 26% and depends largely on urgency, the extent of comorbid conditions and the operator's experience.[70-78]

The overall actuarial survival is similar between medical and surgical treatment and is estimated at 71%, 60-84%, 35% and 17% at 1, 5, 10, and 15 years, respectively.[10,67,79-80] Although primary medical therapy for uncomplicated type B dissection may improve hospital survival, it has not changed long-term survival.[18] Most deaths are related to comorbid conditions, but late complications from distal aortic dissection are estimated to occur in 20% to 50% of patients.[81-85] Such sequelae include new dissection, with associated new complications, rupture of a weak false channel, and, most commonly, saccular or fusiform aneurysmal degeneration of the thinned walls of the false channel, which can lead to rupture and exsanguination.[16,89,90,91]

According to 1898 reported cases, in the hands of experienced surgeons, an average lower extremity paralysis rate of 3.4%, stroke rate of 2.7%, and mortality rate of 4.8% can be expected for open surgical procedures today.[11] Analysis of the midterm results of

endovascular stent-graft management demonstrates a 3- to 8-year survival varying from 25% to 90% across a wide range of operative indications.[72,78,89-95] Another study, with 16 patients treated with stent-graft management and up to 36 months' follow up, reported that mortality was 25 ± 11% with no late deaths.[96] Actuarial survival at 1 and 5 years was 73 ± 11%, while the actuarial freedom from treatment failure was 67 ± 14% at 5 years.[96]

The INvestigation of STEnt grafts in patients with type B Aortic Dissection (INSTEAD) trial was designed to compare covered stents with medical therapy alone for uncomplicated type B dissection.[52,97] Preliminary results suggested equivalent mortality in patients with uncomplicated acute type B dissection who were treated medically or by endovascular stents and medical therapy at 1 year.[52,97,98] Despite reasonably low early operative morbidity and mortality, late complications, including endoleaks, graft migration, stent fractures, and aneurysm-related death, are much more common than those reported for the gold standard procedure, namely, open aortic surgery.[11,99] Until now it is uncertain whether the trend toward more aggressive endovascular treatment will influence prognosis or offer improved long-term survival or freedom from aortic complications compared with conventional open surgical repair or medical management alone. During the 5-year postoperative follow up, operation was necessary in 14% of the medical group and 13% of the surgical patients, which is similar; at 10 years operation was necessary in 17% of both groups.[10] The only independent predictor of late aortic reoperation was Marfan syndrome, stressing the fragility of the dissected aorta in these patients.[23]

False lumen patency is an especially important factor for late mortality. This patency leads to aneurysm formation and at a later time to rupture of a contiguous or remote aortic part, with a great possibility of death. False lumen patency, particularly in the acute phase, and also an aortic diameter over 40 mm, have been reported by Marui et al, in a retrospective analysis of 101 patients with uncomplicated AAD-B, as two significant factors that predispose to late aneurysm formation, and it was suggested that such patients should be considered for early operation.[29]

Follow up

Regardless of the approach used, as long as patients have residual dissected aorta, they remain at risk for late aneurysmal degeneration and rupture of the false lumen and require indefinite serial imaging surveillance and close blood pressure monitoring. Lifelong rigorous arterial blood pressure control and cerebral, cardiac and renal function are critical factors.[8] Hence, definitive negative inotropic therapy is administered for the rest of their lives, even in normotensive patients, and it is considered to lower the possibility of aneurysmal degeneration of the false lumen.[23] Imaging should be performed regularly in order to monitor the development of late complications, which are estimated to occur in 25% to 33% of patients.[11] Gradual aortic enlargement is variable, and predisposing conditions as well as choice of antihypertensive therapy may play a role in the progression of aneurysmal false lumen degeneration. Both open surgical and endovascular stent-graft treatment may slow the disease, but neither reverses its natural history unless the entire extent of dissection is either resected or excluded, and that can be achieved only by surgical intervention.[11] In patients with AAD-B, independently from the initial therapy, an early pre-discharge computed tomography angiography (CTA) or magnetic resonance (MRI) scan is mandatory in order to exclude early complications and to serve as a baseline imaging study. Over the first year following AAD-B, an imaging examination with CTA or MRI is necessary at 1, 3, 6 and 12 months, and thereafter annually.[5] Patients with Marfan syndrome should be examined at 6- to 12-month intervals for the remainder of their lifetime.[33] Transoesophageal echocardiography provides valuable information regarding flow and thrombosis in the false lumen. It should be noted that the method used to measure aortic size can influence the recorded diameter: CT measures external diameter, echocardiography, MRI, and CTA measure intraluminal diameter, whereas aortography can overestimate the luminal diameter.[11]

Conclusions

The increasing understanding of AAD-B during the last two decades has led to a more clarified and improved treatment strategy with better results. Medical therapy is the treatment of choice for the majority (>90%) of patients with AAD-B.[7,8] Nevertheless, new drugs aiming at prevention of the occurrence and the slowdown of the aortic destruction have to be added to those already existing. A few patients with life-threatening complications of AAD-B need emergency surgical or endovascular management.

Those techniques aim, on the one hand, to avoid the proximal primary intimal tear and preclude or remove all aneurysmal disease so as to reduce the risk of dissection-related death, and on the other hand, to maintain the perfusion to all distal organs and major aortic branches.[16] Since AAD-B remains a devastating disease, it clearly highlights the need for substantial advances in enlightenment regarding pathophysiology (molecular and genetic biology), diagnosis (e.g. biomarkers),[100] and of course management, reflected already in the promising advances and rigorous research concerning endovascular treatment.[12-18]

Complications of surgical and endovascular treatment remain a frustrating problem. There are many questions concerning the comparison of the three treatment modes and the management of peripheral ischaemia, requiring more clinical studies. Regardless of the approach used, these patients require indefinite serial imaging surveillance and close blood pressure monitoring.[8]

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