Reviews

Advances in the Management of Thoracic Aortic Diseases

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The great majority of thoracic aortic pathologic entities involve the formation of a dilated segment of the aorta that is prone to rupture. Aneurysm is defined as a permanent localized dilation of the aorta with a diameter that is at least 50% greater than normal[1].

From a surgical standpoint, diseases of the thoracic aorta can be classified into the following broad categories[2]:

1. Aneurysm.
   a. Degenerative (atherosclerosis, cystic medial degeneration).
   b. Congenital or developmental (Marfan's syndrome, Ehlers-Danlos syndrome).
   c. Traumatic
   d. Inflammatory (Takayasu's arteritis, Kawasaki's disease).
   e. Mycotic (infectious).
   f. Mechanical or post-stenotic (aortic valve stenosis, coarctation).
   g. Anastomotic (post-arteriotomy, post patch aortoplasty repair)
2. Pseudoaneurysm.
3. Dissection (acute or chronic).
   a. Type A (DeBakey type I and II), involvement of ascending aorta.
   b. Type B (DeBakey type III), involvement of descending aorta.
4. Penetrating atherosclerotic ulcer
5. Intramural hematoma
6. Atherosclerotic disease (without aneurysm formation).

Aneurysmal aortic disease and acute aortic dissection account for most of aortic surgery performed. Other disease entities such as penetrating atherosclerotic ulcer and intramural hematoma have slowly emerged in the medico-surgical arena as new knowledge is accumulated[3-5]. In addition, non-aneurysmal atherosclerotic disease of the ascending aorta and the aortic arch has received attention lately as it may account for a significant proportion of embolic stroke[6-12].

Over the past few years, studies of the natural history of thoracic aortic aneurysms and dissections have allowed us to develop surgical intervention criteria[13]. In addition to size criteria, symptomatic states, organ compression and malperfusion, concomitant aortic insufficiency, and acute ascending aortic dissection are well-accepted general indications for surgical intervention regardless of aortic aneurysm size. These criteria however merely represent general guidelines and should be weighed against the patient's age, overall physical condition, and anticipated life expectancy.

Ascending aorta

The most frequent pathologic entity that results in aneurysms of the ascending aorta is cystic medial degeneration. In this condition, the wall of the aorta is depleted of smooth muscle cells and the elastic tissue is subject to microscopic fragmentation that eventually leads to aortic wall weakness and aneurysm formation. Patients with Marfan's syndrome suffer from defective synthesis of the glycoprotein fibrillin, an essential component of the elastic tissue of the aortic wall, which results in aneurysmal dilatation of the aorta as a result of reduced number of microfibrils.

The dilated segment of the ascending aorta is prone to rupture or dissection. Surgical intervention should optimally take place prior to the occurrence of such catastrophic event. Studies of the natural history of aneurysms of the ascending aorta indicate that patients should undergo elective replacement of the ascending aorta when the greatest diameter of the aneurysmal segment reaches 5.5 cm[13,14]. For patients with Marfan's syndrome, the surgical threshold is 5.0 cm, as these patients are more likely to develop dissection and rupture. In patients with Marfan's syndrome, replacement of the root of the aorta is also indicated, as the coronary sinuses are invariably aneurysmal. While supracoronary tube graft replacement of the ascending aorta frequently suffices in older non-Marfan patients, patients with the Marfan's syndrome require replacement of the root of the aorta and the ascending aorta with a composite conduit containing a Dacron graft and a mechanical valve prosthesis[15-17].

When aortic valve regurgitation is present, it should be determined whether this is secondary to loss of aortic root geometry due to aneurysmal dilatation or primary, due to degenerative changes of the aortic valve leaflets. Frequently, mild to moderate aortic regurgitation is corrected following supracoronary replacement of the ascending aorta with accurately sized Dacron graft. When the aortic valve leaflets are anatomically intact but do not fully oppose at the edges because of aneurysmal aortic root dilatation, it is possible to replace the aneurysmal aortic sinuses (usually the non-coronary sinus only or all three sinuses) with a scalloped graft while preserving the native aortic valve[18]. The intermediate-term results of this technique are satisfactory in the hands of experienced surgeons. Aortic valve-sparing operations have also been used successfully in Marfan patients[19]. Long-term follow-up data is lacking in this group of patients. Valve-sparing techniques applied to patients with Marfan's syndrome are generally less successful, as these patients have a higher likelihood of developing degeneration and eventually insufficiency of the aortic valve. For patients with Marfan's syndrome, composite graft replacement of the aortic root remains the gold standard[17].

Aortic Arch

Perhaps the most challenging, from a surgical perspective, segment of the aorta is the segment extending from the proximal origin of the innominate artery to the distal origin of the left subclavian artery. Operations on the aortic arch require the use of hypothermic cardiopulmonary bypass and a period of circulatory arrest[20-26]. The surgical challenge is mostly related to adequate cerebral protection and avoidance of postoperative cerebrovascular accidents[27,28]. With techniques currently applied, a period of circulatory arrest of up to 40 minutes at a body temperature of 15 to 18°C is well tolerated by the majority of patients. Focal or diffuse neurologic deficits occur in up to 18% of patients undergoing resection of aneurysms of the aortic arch. Because of the relatively high morbidity, elective surgery is generally advised for patients with symptoms attributable to the aneurysm (tracheal compression, recurrent laryngeal nerve compression, pain) and patients with documented progressive enlargement to a size of more than 5.5 to 6.0 cm.

Most patients undergoing aortic arch operations are subjected to partial arch resections including the proximal one-third or half of the aortic arch, usually in conjunction with resection of aneurysm of the ascending aorta[29]. In this situation, a varying segment of the undersurface of the arch is replaced. The morbidity of this operation is much lower than that of procedures of total arch replacement. A short period of circulatory arrest is usually required for construction of the aortic arch anastomosis, adding little additional time and risk to the operation. With this technique, the extent of the aneurysm is precisely defined and the incidence of subsequent development of aneurysmal disease in the proximal arch is reduced.

Patients requiring total arch replacement usually also require replacement of varying segments of the ascending or the descending thoracic aorta. Adequate surgical exposure in this situation can be challenging. In the presence of favorable anatomy, such operations can be performed in two stages, with the ascending aorta and arch replaced initially and the descending aorta at a subsequent time. The "elephant trunk" technique has been a popular surgical technique for staged replacement of the thoracic aorta[30]. In other situation, such as when a surgical neck is absent or the patient is symptomatic or the size of the aneurysm is large placing the patient in increased risk of rupture while waiting for the second stage of the operation, single stage replacement of the thoracic aorta is indicated[31].

Improved results in surgery of the aortic arch are related to refinement in cerebral protection strategy[32]. Modern imaging techniques such as Magnetic Resonance Imaging and Transesophageal Echocardiography allow accurate depiction of the anatomy involved. Chronic atherosclerotic changes in the thoracic aorta are easily recognized, allowing appropriate modification of the surgical strategy. Continuous intraoperative EEG monitoring helps to define the adequate depth of systemic hypothermia for best cerebral perfusion. Avoidance of retrograde aortic perfusion via the femoral artery and the use of cannulation techniques involving the axillary artery or the proximal aorta has also helped to reduce the incidence of embolic strokes[33,34]. Cannulation of the Dacron graft following aortic arch reconstruction and establishment of antegrade aortic perfusion during the period of rewarming is now a standard surgical technique. The role of retrograde cerebral perfusion is more difficult to define[27,35-40]. Although it does not appear to meaningfully extent the safe interval of hypothermic circulatory arrest, it certainly helps in removal of air and atheromatous debris that can be trapped in the head vessels during arch reconstruction. Retrograde cerebral perfusion via the superior vena cava is now mostly used intermittently to assist in graft deairing and flushing during the final stage of aortic arch reconstruction.

The presence of atheromatous plaques in the arch with a thickness of more than 4 mm has been shown to be an important predictor of recurrent brain infarction. Since such plaques represent a source of embolization to other organs, endarterectomy or graft replacement of the involved segment of the arch should be considered when severe disease is detected in patients undergoing operations on the heart or the ascending aorta[6,7,10,11,41-48].

Descending Thoracic and Thoracoabdominal aorta

Aneurysms of the descending thoracic and thoracoabdominal segments of the aorta are more commonly associated with atherosclerosis of the aorta leading to degenerative changes and weakening if the wall. Abnormal proteolytic processes and deficiencies of collagen and elastin have also been implicated as causative factors[49].

For patients with chronic atherosclerotic or dissecting aneurysms of the descending thoracic aorta, elective resection is recommended if the aneurysm exceeds 6.0 to 6.5 cm in diameter or if symptoms are present[14]. The intervention size criteria for the descending thoracic aorta is set at a larger diameter than it is for the ascending aorta as perioperative complications are greater and the median size at the time of aneurysm-related complication (rupture or dissection) is larger for aneurysms of the descending aorta.

The major postoperative complication of extensive replacement of the descending thoracic and thoracoabdominal aorta include myocardial infarction, respiratory failure, renal failure, stroke, and spinal cord ischemic injury. As experience with these operations has increased, a clearer understanding of the risk factors and the pathophysiology involved has emerged, leading to the development of perfusion techniques and other adjuncts that substantially reduce the incidence of perioperative complications, particularly those related to stroke and paraparesis.

The use of distal perfusion and hypothermia has dramatically reduced the incidence of spinal cord ischemic injury and dialysis-requiring renal failure. Utilizing a technique that involves distal perfusion, hypothermic cardiopulmonary bypass, and intervals of hypothermic circulatory arrest, elective resection of thoracoabdominal aortic aneurysms and chronic dissections can be accomplished with an operative mortality of less than 8%, incidence of spinal cord ischemic injury of 3%, and incidence of renal failure of less than 3%[50-52]. Other techniques involving distal perfusion and cerebrospinal fluid drainage or sequential clamping and sensory evoked potential monitoring, usually combined with mild hypothermia, have also demonstrated favorable postoperative outcomes[53-57].

Endoluminal placement of covered stent grafts has developed as an alternative treatment modality that may be associated with decreased morbidity and mortality in a patient population that is frequently elderly and debilitated. In treatment of descending thoracic aortic aneurysms, satisfactory results have been obtained with a "first generation" stent graft device[58]. Medium-term results are acceptable, but continued aortic enlargement, with the late development of endoleaks, is a significant concern. These stent grafts are now available commercially. Continued clinical investigation appears to be justified in high-risk selected patients.

Aortic Dissection

Aortic dissection results when blood separates the layers of the aortic media through a tear in the intima. Usually this tear occurs in the ascending aorta adjacent to the aortic valve, but it may also occur in the arch and in the descending aorta. Hypertension if the most important risk factor for thoracic aortic dissection. Other risk factors include cystic medial degeneration of the aorta, Marfan's syndrome, a bicuspid aortic valve, aortic coarctation, blunt trauma, pregnancy, connective tissue disorders, and manipulations of and operations on the thoracic aorta[2].

Up to 90% of patients with acute dissection involving the ascending aorta that are not treated surgically die within three months. The majority of early deaths from all types of aortic dissection are due to rupture of the aorta into the pericardial or pleural cavity. Death may also occur from obstruction of the origins of the coronary, brachiocephalic, or visceral arteries. The early mortality rate is substantially lower for the subgroup of patients with aortic dissection not involving the ascending aorta.

Two classifications of aortic dissection are widely used:

1. The DeBakey Classification

Type I: The intimal tear usually originates in the proximal ascending aorta and the dissection involves the ascending aorta, the arch, and variable lengths of the descending and abdominal aorta.

TypeII: The dissection is confined to the ascending aorta

Type III: The dissection may be confined to the descending thoracic aorta (type IIIa) or may extend into the abdominal aorta and iliac arteries (IIIb). The dissection may extend proximal to involve the arch and the ascending aorta.

2. The Stanford Classification

Type A: Includes all cases in which the ascending aorta is involved by the dissection, with or without involvement of the arch or the descending aorta.

TypeB: Includes cases in which the descending thoracic aorta is involved.

A new classification proposed by the European Society of Cardiology is taking into consideration the fact that intramural hematomas and penetrating atherosclerotic ulcers may be signs of evolving dissections or dissection subtypes[66]:

Class 1: Classical aortic dissection with an intimal flap between true and false lumen.

Class 2: Medial disruption with formation of intramural hematoma/hemorrhage.

Class 3: Discreet/subtle dissection without hematoma, eccentric bulge at tear site.

Class 4: Plaque rupture leading to aortic ulceration, penetrating aortic atherosclerotic ulcer with surrounding hematoma, usually subadventitial.

Class 5: Iatrogenic and traumatic dissection.

In this classification, all classes of dissection can be seen in their acute and chronic stages. Chronic dissections are considered to be present if more than 14 days have elapsed since the acute event or if they are found by chance.

All patients with acute dissection involving the ascending aorta (type A) should be considered candidates for surgery. Extensive, irreversible injury to the central nervous system may be the only major contraindication to surgery. The ascending aorta is replaced with a Dacron graft. A period of circulatory arrest is necessary to perform an open distal anastomosis, detect the possible presence of dissection in the arch, and perform an adequate approximation repair of separated layers[59,60]. Limited repairs involving replacement of a short segment of the ascending aorta have unacceptable long-term results, including chronic aneurysm formation in the ascending aorta and the arch. If the aortic valve is structurally normal but incompetent as a result of the altered geometry of the root of the aorta due to the dissection, it can be resuspended to the commissures with excellent long-term results[61]. If the aortic valve is not normal, it should be replaced. If the aortic sinuses are ectatic or extensively disrupted, or if the patient has Marfan's syndrome, a composite graft is used to replace the root of the aorta[62]. An important surgical advance in the treatment of acute aortic dissections has been the development of biological adhesives[63]. Although long-term data are lacking, the use of these adhesives may reduce the period of circulatory arrest required and may also reduce the incidence of hemorrhagic complications.

The approach to patients with intramural hematoma of the ascending aorta is similar to the approach of patients with acute aortic dissection[5].

In patients with acute aortic dissection, resection of the aortic arch is indicated when intimal tears are present within the arch. It is also indicated when the arch has ruptured, when the outer layer of the dissected aorta is thinned and hemorrhagic, and when the inner layer is fragmented[2].

Patients with aortic dissections not involving the ascending aorta (type B) are managed non-operatively, unless complications or symptoms develop. Medical therapy includes hemodynamic monitoring and aggressive blood pressure control with beta blockers and, if necessary, sodium nitroprusside. Surgery is indicated for patients with signs of impending rupture (persisting pain, hypotension, left-sided hemothorax) and those with ischemia of the legs of abdominal viscera, renal failure, paraparesis or paraplegia. Patients with impending rupture require graft replacement of the involved aortic segment while patients with malperfusion phenomena may be treated with fenestration procedures, if the involved segment is not aneurysmal[64].

Selected patients with acute type A aortic dissection who are referred or whose conditions are diagnosed several days after presentation, have survived the early dangerous period and can safely undergo surgery semielectively rather than emergently[65]. Still, immediate surgical therapy is recommended for acceptable operative candidates with acute type A aortic dissection who seek immediate treatment.

Patients with chronic dissection of the ascending or the descending aorta, are treated according to the principles outlined for management of chronic atherosclerotic aneurysms.

Conclusions

Important advances in the diagnosis and surgical treatment of thoracic aortic diseases have substantially improved the outcome. These advances include refined diagnostic modalities such as MRI and transesophageal echocardiography and refinements in surgical technique based on accumulated experience. Distal perfusion techniques in conjunction with systemic hypothermia have probably contributed the most in providing favorable postoperative outcomes. Studies of the natural history of thoracic aortic diseases indicate that current recommendations for surgery in asymptomatic patients are only guidelines subject to change as new information becomes available. In addition, in patients with coexisting medical conditions, the risk of operation may exceed the expected benefit from surgical treatment. Further research should focus on the development of more sensitive non-invasive techniques for the detection and serial evaluation of asymptomatic thoracic aortic disease and on refinements of surgical techniques that will further reduce the incidence of injury to various organs, particularly the brain and the spinal cord. Rapid advancements in the field of molecular genetics may help us understand better the nature of aortic diseases in patients with genetic predisposition, such as patients with Marfan's syndrome. Periodic postoperative evaluation of patients and statistical analysis of data is essential in order to gain the greatest possible knowledge that will help in further refinement of surgical techniques.

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