DISEASES OF THE AORTA

Aneurysm of the ascending aorta

Artur Evangelista

Ascending thoracic aortic aneurysm (ATAA) is defined as a dilatation of the ascending aorta producing a cross-sectional diameter more than 1.5 times its normal value; values between 1.1 and 1.5 are considered dilated or ectatic ascending aorta. Normal values have been established by different imaging techniques: echocardiography, computed tomography (CT) and magnetic resonance imaging (MRI). Aneurysmal disease of the aorta is clinically important since, as the diameter of the aorta expands, linear wall stress increases, which in turn directly increases the risk of spontaneous aortic rupture—an event with extremely poor prognosis for the patient. Thoracic aortic aneurysms (TAAs) involve the ascending aorta most commonly (50%), followed by the descending aorta (40%), whereas arch aneurysms (10%) and thoraco-abdominal aneurysms (10%) occur less often. In 25% of patients with ATAA, concomitant abdominal aortic aneurysm is present. Anatomical distinction is important since the aetiology, natural history and treatment differ for each of these segments.

INCIDENCE

The incidence of thoracic aneurysms has been classically estimated to be 2–5 cases per 100 000/year; however, in recent series this figure has been reported to reach 10.4 cases per 100 000/year. This increase is probably due to improvements in diagnosis and case ascertainment. There are several significant differences between TAA and abdominal aneurysms. Age at onset for TAA is 10 years earlier than for abdominal aneurysms (65 vs 75 years); abdominal aneurysms are more predominant in men, with a 6:1 male-to-female ratio, whereas TAAs occur only slightly more frequently in men (1.7:1).

PATHOGENESIS

The ascending aorta has a greater concentration of elastic fibres and is more compliant than the descending aorta. The elastin-to-collagen ratio progressively decreases as the aorta traverses distally into the descending thoracic and abdominal aorta. The difference in anatomical and cellular composition between the ascending and descending aortas may explain why the aetiology of TAAs that develop in these areas differs. Elastic fibres and fibrillar collagens are the main determinants of the mechanical properties of the aorta, and loss of elastin is one of the most consistent histochemical findings in patients with aneurysms. In reference to aneurysm formation, one of the most important histological features of aneurysmal tissue is the fragmentation of elastic fibres.

The pathophysiology of aneurysm formation is complex involving, among other factors, inflammation, proteolysis and disturbed survival of smooth muscle cells. A pronounced elevation in proteolytic matrix metalloproteinase enzymes and a notable decrease in inhibitory enzymes have been described in the wall of the aorta as prime agents of deleterious change in aneurysm disease.

The events that play a role in the formation and expansion of ATAA are probably multifactorial and involve an interplay between genetic predisposition and haemodynamic factors such as systemic hypertension or aortic valvular disease. Aneurysms located in the ascending aorta occur secondary to connective tissue degeneration within the media, as opposed to arteriosclerosis which is seen more commonly in the descending aorta. Despite the diversity of genetic defects, aortic diseases develop through a common pathway represented by elastin destruction by proteolysis, cystic medial necrosis, and altered biomechanical properties.

AETIOLOGIES

Most ascending aortic aneurysms have unknown aetiology and are classified as idiopathic. Atherosclerosis is associated with aneurysms of the aortic arch and descending aorta, but spares the ascending aorta in which the aetiopathogenesis is more related to haemodynamic factors, bicuspid aortic valve, and genetic defects (table 2).

Degenerative aneurysms

Degenerative aneurysms comprise the majority of those seen in the ascending aorta and have a specific pathological profile. Elastin content in the ascending aorta is reduced and cystic media degeneration is accelerated with respect to the age of the patient. The term cystic medial degeneration is used to describe the accumulation of basophilic amorphous material seen within the media, which results in elastic fibre fragmentation and smooth muscle loss. This process occurs to some extent with ageing and is accelerated by hypertension. At younger ages, cystic medial degeneration is classically associated with Marfan syndrome and other genetic diseases.

Marfan syndrome

Marfan syndrome is an inherited connective tissue disorder which has an estimated incidence of 1/5000, and about 25–30% of cases represent new mutations. The syndrome involves many systems but the prominent manifestations are skeletal, cardiovascular, and ocular abnormalities. In 60–80% of adults with Marfan syndrome,
dilatation of the sinus of Valsalva is found. The Marfan gene mutation occurs in the portion of the genome coding for fibrillin-1, on chromosome 15q21, a key component of microfibrils forming the elastic scaffold. Genetic heterogeneity exists within this condition, as approximately 10% of cases have been linked to a separate mutation on chromosome 3p25. Recent advances provide insights into the mechanisms by which mutation in a single gene triggers a cascade of molecular, cellular and tissular alterations which lead to aortic dilatation. Fibrillin 1 mutation results in fragmentation of the elastic network by matrix metalloproteinases. A second mechanism by which fibrillin mutation causes aortic disease in Marfan syndrome involves the growth factor/cytokine transforming growth factor-β1 (TGF-β1). There is evidence that, upon mutation, abnormal fibrillin 1 has a low affinity for latent TGF-β and thus releases excessive amounts. Mutations in TGF-β receptors 1 and 2 cause Loyes–Dietz syndrome in which the ascending aorta dilates to aneurysmal size, with tortuosities, ruptures and dissections.

**Ehlers–Danlos syndrome**

Ehlers–Danlos syndrome is a heterogeneous group of generalised connective tissue disorders which affects type III collagen synthesis. This mutation can result in adequate collagen formation failure which leads to decreased arterial wall strength and predisposes to aneurysm formation or aortic rupture.

**Bicuspid aortic valve**

Bicuspid aortic valve is a common congenital cardiac anomaly, with an incidence of 1–2% of the general population. Some studies have shown that fusion of the right/non-coronary cusps is associated with greater mid ascending aortic dimensions. There has been controversy concerning whether aortic wall changes are caused by a congenital defect or whether they are due to the abnormal haemodynamic stress on the aortic wall secondary to valve malformation. Recent studies have demonstrated different expression patterns of matrix protein such as collagen, laminin and fibronectin from the dilated ascending aorta in bicuspid aortic valves, compared with either tricuspid aortic valves or Marfan syndrome patients. Accordingly, aortic valve replacement does not prevent progressive dilatation of the ascending aorta. These data provide additional support for the concept that aortic dilatation is mainly due to a congenital fragility of the aortic wall rather than haemodynamic factors. Fedak et al. hypothesised that patients with bicuspid aortic valve have an inherited defect in the genes that encode matrix elements, resulting in fibrillin-1 deficiency that might trigger matrix metalloproteinase production. The increased activity of matrix metalloproteinase-2 and -9 may partly explain the propensity to aneurysm formation in these patients.

The aortic valve and ascending aorta share a common embryonic origin. Therefore, the vascular smooth muscle cells (VSMCs) that undergo apoptosis in the media of the ascending aorta are of neural crest origin. Mutations in the NOTCH1 gene (chromosome 9q) have recently been identified which lead to signalling abnormalities that may be responsible for bileaflet aortic valve and accelerated calcium deposition.

**Familial predisposition**

Clinical studies have demonstrated that the development of aneurysmal disease can be linked to genetics in a non-syndromic way. Of the first degree relatives of patients with an aortic aneurysm, 15% were shown to have an aneurysm as well. Other studies showed that 21% of probands with TAA had first degree relatives with an arterial aneurysm. These data demonstrate that a predisposition to aneurysmal formation can in fact be established, and that adequate screening of family members of patients with a confirmed aneurysm may identify asymptomatic disease early enough for prophylactic intervention.

**Other aetiolologies**

Syphilis was once a common cause of ascending aortic aneurysm, but has now become rare as a result of aggressive antibiotic treatment in the early stages of the disease.

**Table 1** Predicted size of aortic root and ascending aorta according to age and body surface area

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Diameter (cm)</th>
<th>Index (cm/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16–40</td>
<td>3.1 (0.3)</td>
<td>1.6 (0.1)</td>
</tr>
<tr>
<td>40–65</td>
<td>3.1 (0.3)</td>
<td>1.6 (0.1)</td>
</tr>
<tr>
<td>&gt;65</td>
<td>1.0 (0.2)</td>
<td>1.8 (0.2)</td>
</tr>
</tbody>
</table>

*Data from Lin et al.*

**Figure 1** Mechanism of thoracic aortic aneurysms (TAA) formation. The events that play a role in the formation and expansion of ascending TAA are multifactorial and involve an interplay between genetic predisposition and cellular imbalances as well as haemodynamic factors. EGf, extracellular matrix.

**Risk factors:** Systematic hypertension, aortic valvular disease, pregnancy, ↑ lipids, smoking
DIAGNOSIS

ATAA is usually raised by an abnormal contour of the superior mediastinum on chest x-ray. Trans-thoracic echocardiography (TTE) is very useful for the diagnosis and follow-up of aortic root aneurysms, which is important for patients with annuloaortic ectasia or Marfan syndrome. Since the predominant area of dilatation is in the proximal aorta, TTE often suffices for screening. This technique has had tremendous success in the serial measurement of maximum aortic root diameters (figure 2), evaluation of aortic regurgitation, and the timing of elective surgery. TTE has the advantage of permitting assessment of aortic valve disease and left ventricular function. In patients with a poor acoustic window, transoesophageal echocardiography (TOE) may play a role, but CT (figure 3) and MRI are more useful in the assessment of aortic aneurysm. The multiplanar capacity of multidetector CT (MDCT), together with its submillimetric spatial resolution, render it an excellent technique for the evolution and control of TAA. Measurements must adhere to a strict protocol that permits comparison between different imaging techniques as well as follow-up of the patient. MDCT enables the operator to choose an imaging plane in any arbitrary space orientation; thus, it is possible to easily find the maximum aortic diameter plane, which must be doubly orthogonal to the longitudinal plane of the aortic segment. A further common presentation of data is a parasagittal, oblique maximum intensity projection (MIP) plane. This plane is easily reproducible and comparable in follow-up studies.

MRI offers excellent visualisation of the whole aortic anatomy, and is very effective in the identification and characterisation of aneurysms. It is recommendable to combine MR angiography (MRA) images with spin echo in black blood images, which are very useful for detecting alterations in the wall and adjacent structures that could go unnoticed if only MRA images are acquired. The information provided by MRA in aortic aneurysm assessment is similar to that offered by current CT equipment with multidetectors. Both methods allow us to determine accurately aortic diameters in the sagittal plane, which permits the most reproducible measurements. It is recommended to conduct a functional study through the aortic valve using cine-MR sequences to rule out associated valvular disease that may be related to aortic dilatation. Recently, MRI has been established as an accurate non-invasive tool for the assessment of aortic distensibility and pulse wave velocity. These methods have been used to assess aortic elasticity in patients with Marfan syndrome, bicuspid aortic valve or aortic aneurysms. In patients with Marfan syndrome, aortic stiffness has proved to be an independent predictor of progressive aortic dilatation; evaluation of the elastic properties of the ascending aorta in patients with ATAA might therefore be used analogously to identify patients who are at risk of progressive dilatation of the aorta and other sequelae.

Since there is a high incidence of familial clustering in most ATAAs, first degree relative screening by echocardiography is advisable.

NATURAL HISTORY

Although an indolent process, ATTA is a virulent disease. Symptoms typically occur in the setting of either a complication of the disease (ie, rupture or dissection) or when these complications are imminent. The thoracic aorta grows very slowly—approximately 1 mm per year. The rate of growth is significantly greater for aneurysms of the descending aorta (1.9 mm/year) than those of the ascending aorta (0.7 mm/year). In addition, dissected thoracic aneurysms grow significantly more rapidly (1.4 mm/year) than non-dissected aneurysms (0.9 mm/year). Analysis revealed sharp ‘hinge points’ in the aortic size at which rupture or dissection occur. These hinge points occur at 6 cm in the ascending aorta and 7 cm in the descending aorta. It is important to recommend surgery before the aorta reaches these hinge point dimensions.

The natural history of special aetiological subtypes of ATAA has also been studied recently. The known association of bicuspid aortic valve and ascending aortic aneurysm carries a higher risk for aortic growth (1.9 vs 1.5 mm/year in non-bicuspid valve). In patients with aortic stenosis and bicuspid aortic valve disease, the risk for aortic

Table 2  Aetiology of thoracic aortic aneurysms

<table>
<thead>
<tr>
<th>Subtype</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degenerative</td>
<td>Marfan syndrome, Marfan-like syndrome</td>
</tr>
<tr>
<td>Ehlers–Danlos syndromes</td>
<td></td>
</tr>
<tr>
<td>Familial</td>
<td></td>
</tr>
<tr>
<td>Bicuspid aortic valve</td>
<td></td>
</tr>
<tr>
<td>Aortic valve disease</td>
<td></td>
</tr>
<tr>
<td>Syphilis</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2  Two dimensional echocardiogram. Parasternal long axis view showing measurement of the dimensions of the aorta at Valsalva sinuses (1), sinotubular junction (2), and proximal ascending aorta (3). AA, ascending aorta; LV, left ventricle.
overestimates the maximum aortic diameter due to obliquity with respect to the aortic wall.

Figure 3 The true maximum diameter of the aortic lumen is measured in a double oblique multiplanar reformatted image through a plane orthogonal to the direction of blood flow as defined in both coronal (a) and sagittal (b) multiplanar images. Axial image (c) overestimates the maximum aortic diameter due to obliquity with respect to the aortic wall.

 complications was higher than in those without aortic stenosis. The rate of aneurysmal expansion is not constant, however, as growth rates accelerate as the ATAA enlarges. A faster rate of growth relates to increased risk of rupture, as patients who proceed to rupture show an increase in size of 7 mm/year.

RISK FACTORS
Risk factors for increased growth of TAA have included increasing age, female sex, chronic obstructive pulmonary disease, hypertension, and a positive family history. However, aorta size is the principal predictor of aortic rupture or dissection. Aortic diameter is a significant predictor of dissection and rupture, particularly when the ascending aorta reaches 6 cm. From a database of 1600 thoracic aneurysms and dissection, those >6 cm had annual rates of rupture, dissection, and aorta related death of 5.6%, 5.7% and 10.8%, respectively; the cumulative rate of any of those events was 14.1%, more than double the rate of adverse events for aneurysms between 5–6 cm (6.5%). The mean and median ascending aortic diameter at the time of dissection or rupture were 5.9 cm and 6.0 cm, respectively. In a large retrospective study of TAA of different aetiologies, the risk of rupture or dissection was 6.9% per year and, including death, was 15.6% per year for a size >60 mm. The odds ratio for rupture increased 27-fold compared with lower values. Female sex and increasing age have been associated with an increase in the event rate. In a more recent study, the Yale group suggested the use of an aortic size index, where the maximum aortic diameter was referenced to body surface area. In that study, an indexed aortic size >4.25 cm/m² correlated with an event rate at 25%. Importantly, even patients presenting with aortic sizes <2.75 cm/m² displayed an event rate of 4%, while those presenting sizes between 2.75–4.25 cm/m² had event rates approaching 8%. The authors recommended elective operative repair before the patient enters the zone of moderate risk with an aortic size index >2.75 cm/m². One limitation of this study was that no separate analysis between ascending and descending thoracic aneurysm evolution was performed.

MANAGEMENT
Serial imaging
Careful follow-up of maximum aortic diameter is paramount for correct therapeutic management. Aneurysms affecting the aortic root can be correctly followed by TTE if the echocardiographic window is adequate. The excellent reproducibility of measurements at this level and information from other parameters such as aortic regurgitation severity, ventricular function, etc, facilitates appropriate follow-up. However, adequate TTE views of the mid and distal ascending aorta and arch can be difficult to obtain, especially in patients with large body habitus. If TTE cannot provide measurements from the ascending aorta, CT or MRI should be performed. TOE will only be warranted when the acoustic window is poor and the type of surgical treatment (repair or valve replacement) is considered. Both TTE and TOE have limitations for adequate measurement of distal ascending aorta diameters and aortic arch. However, contrast enhanced CT scanning and MRI determine the size of TAA very accurately. Serial follow-up evaluation of aortic diameters should be performed every 6–12 months, depending on aortic dimensions, rate of expansion and aortic valve dysfunction, by echocardiography, CT or MRI, depending on aneurysm location and quality of the studies. Finally, when surgical treatment is indicated, MDCT permits assessment of coronary abnormalities, which reduces the need for invasive coronaryography.

MEDICAL TREATMENT
Medical management should entail aggressive control of hypertension; β-blockers and angiotensin II receptor blockers should be considered as first line agents. Practice guidelines suggest that β-blockers reduce aortic wall stress and are indicated for non-operative candidates with dilated aortas (>4 cm) in the absence of aortic regurgitation (AR), but this recommendation is based on consensus opinion rather than clinical trials. In patients with Marfan syndrome, β-blockers have been the mainstay of pharmacotherapy based on a theoretical decrease in aortic wall stress. However, there are conflicting data regarding the effects of β-blockers on elastic properties in Marfan patients. A recent meta-analysis of six
studies (one of which was a prospective randomised trial with >800 participants) showed no clinical benefit of β-blockers in Marfan syndrome. In a study comparing the ACE inhibitor enalapril versus propanolol or atenolol, the ACE inhibitor treated group had a significantly lower aortic stiffness index and a significantly lower rate of aortic root growth. The angiotensin II receptor blockers losartan or perindopril have also been shown to reduce the rate of aortic dilatation in patients with Marfan syndrome.17 There is no evidence as to whether β-blockers or ACE inhibitors, alone or in combination, are preferable in the treatment of bicuspid aortic valve or other AAT aetiologies.

**ELECTIVE SURGICAL TREATMENT**

The mortality rate for elective surgical repair of ATAA at large centres has improved considerably in recent years, and is now 3–7%. The risk of perioperative stroke is 1.7%, mainly when aortic arch surgery is included. Although aortic diameter is currently the major criterion for timing elective surgical repair of ATAA aneurysms, it is an imperfect predictor of aortic dissection or rupture since 60% of type A dissections of the International Registry of Acute Aortic Dissections (IRAD) series had aortic diameters <5.5 cm. Additional methods of risk stratification are needed. To identify patients at risk for thoracic aneurysmal disease or those at risk for rapid expansion of a known aneurysm, analysis of biophysical properties using MRI or serum markers such as matrix metalloproteinases and endogenous inhibitors could permit both monitoring of the natural history of ATAA disease and surgical staging.

Deciding whether or not to repair an ATAA involves assessment of both the likelihood of rupture and the operative risk in each individual (Table 3). Symptomatic aneurysms are generally resected regardless of size. The general size criterion for surgical intervention of aneurysms located in the ascending aorta is >5.5 cm, and for the descending aorta >6.5 cm. For genetic conditions that increase the risk, an earlier intervention (5.0 cm) is recommended by the American College of Cardiology/American Heart Association18 and European guidelines. Patients without Marfan syndrome, but with a family pattern of aortic disease, may be as vulnerable as Marfan patients, and thus these lower criteria should be used. Similarly, the 5.0 cm criterion for indicating surgical treatment in patients with bicuspid aortic valve is accepted, although the evidence is not so clear and enlargement rate or other biophysical variables from imaging techniques may be taken into account in the future. Finally, if patients require aortic valve replacement for a dysfunctional valve and ascending aorta is recommended if its diameter is >4.5 cm; some authors have suggested 4.0 cm, given that these patients are now recognised to be at high risk for postoperative aortic dissection. In patients with Marfan syndrome, surgical treatment is also indicated if maximum aortic root diameter is between 4.5–5.0 cm and an aortic valve sparing operation is planned. When pregnancy is desired, surgery would be recommended for aneurysms >4.0 cm. Of course, the aggressiveness with which surgical repair is undertaken should be appropriately influenced by the general condition of the individual patient.

**SURGICAL TECHNIQUES**

Surgical technique depends on location of the aneurysm, distal extent of aortic involvement, and aortic regurgitation severity. An ascending aortic aneurysm distal to the sinotubular junction is treated by a simple supracoronary tube graft, whereas an aortic root aneurysm which involves the coronary ostia as well as the aortic valve needs to be spared or replaced. Composite replacement of the aortic valve and ascending aorta is the standard treatment for patients with aortic regurgitation and aortic root aneurysm. Replacement of the aortic valve and root is performed using a composite graft including a prosthetic valve. The coronary arteries are reimplanted into the tube. This operation, described by Bono and Bentall, has shown excellent results; the operative risk for mortality is about 5%, although the need for lifelong oral anticoagulation is probable. In selected cases without dilatation of the sinuses, the valve and ascending aorta may be replaced separately.

Aortic root aneurysms frequently lead to secondary aortic regurgitation, despite the presence of morphologically normal valve leaflets. Valve insufficiency occurs because dilatation of the root and/or sinotubular junction will displace the valve commissures outwards so that the leaflet edges cannot coapt in diastole. Echocardiography can offer dynamic evaluation of the aortic regurgitation mechanisms.17 The diastolic tenting of aortic leaflets is strongly related to functional aortic regurgitation. The mismatch of the sinotubular junction and aortic annulus is significantly associated with diastolic leaflet tenting. The tethering indexes may have potential to guide the planning of aortic valve sparing ATAA surgery. Patients who have aortic root pathology and normal aortic valve leaflets are suitable for a remodelling procedure.20 It is imperative

**Table 3 Indications for elective surgical treatment of ascending aorta**

<table>
<thead>
<tr>
<th>Aortic diameter &gt;5.5 cm</th>
<th>Aortic diameter &gt;5.0 cm associated with any of the following:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marfan syndrome and other genetic disorders</td>
<td>Bicuspid aortic valve</td>
</tr>
<tr>
<td>Tricuspid aortic valve with more than mild aortic regurgitation</td>
<td>Expansion rate &gt;5 mm/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aortic diameter &gt;4.5 cm in Marfan syndrome or bicuspid valve associated with any of the following:</th>
<th>First degree relative with ascending aortic dissection or rupture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of aortic diameter to body surface area &gt;2.75 cm/m²</td>
<td>Expansion rate &gt;5 mm/year</td>
</tr>
</tbody>
</table>

Concomitant indication for aortic valve replacement

Pregnancy is desired*  

*In this case, when aortic diameter >4.0 cm, if aortic valve replacement is not required.
Aneurysm of the ascending aorta: key points

- Ascending thoracic aorta aneurysm (ATAA) is defined as a dilatation of over 1.5 times its normal size. In general, it is considered to be present when maximum diameter is over 45 mm or 2.5 mm/m².
- The most common cause of ascending aortic aneurysms is degenerative, a condition known as idiopathic cystic medial degeneration. Other causes are genetic disorders such as Marfan syndrome, bicuspid aortic valve, Ehlers–Danlos syndrome, or family predisposition.
- Transthoracic echocardiography is the technique of choice for the diagnosis and follow-up of aortic root aneurysms. CT and MRI offer better visualisation of the upper half of the ascending aorta and accurate measurement of diameters in the sagittal plan.
- The general size criterion for surgical intervention of ATAA is 5.5 cm. For genetic conditions, such as Marfan syndrome or bicuspid aortic valve, it is 5.0 cm, and in the presence of a first degree relative with aortic dissection/rupture it is 4.5 cm. When pregnancy is desired an aortic valve sparing operation is planned, and surgery may be advisable in cases where the aneurysm is >4.0 cm.
- Composite replacement of the aortic valve and ascending aorta is the standard treatment for patients with aortic regurgitation and ATAA. However, in the presence of a normal aortic valve leaflet, a remodelling procedure is suitable.

You can get CPD/CME credits for Education in Heart

Education in Heart articles are accredited by both the UK Royal College of Physicians (London) and the European Board for Accreditation in Cardiology—you need to answer the accompanying multiple choice questions (MCQs). To access the questions, click on BMJ Learning: Take this module on BMJ Learning from the content box at the top right and bottom left of the online article. For more information please go to: http://heart.bmj.com/misc/education.dtl

RCP credits: Log your activity in your CPD diary online (http://www.rcplondon.ac.uk/members/CPDiary/index.asp)—pass mark is 80%

EBAC credits: Print out and retain the BMJ Learning certificate once you have completed the MCQs—pass mark is 60%. EBAC/EACCME Credits can now be converted to AMA PRA Category 1 CME Credits and are recognised by all National Accreditation Authorities in Europe (http://www.ebac-cme.org/news/). Please note: The MCQs are hosted on BMJ Learning—the best available learning website for medical professionals from the BMJ Group. If prompted, subscribers must sign into Heart with their journal’s username and password. All users must also complete a one-time registration on BMJ Learning and subsequently log in (with a BMJ Learning username and password) on every visit.

that perioperative TOE be used in these patients. This will provide the surgeon with important information regarding the morphology of the aortic root and also the dimensions of the aortic annulus and severity of any aortic regurgitation. TOE must also be used following the procedure to ensure there is no residual aortic regurgitation.

Competing interests In compliance with EBAC/EACCME guidelines, all authors participating in Education in Heart have disclosed potential conflicts of interest that might cause a bias in the article. The author has no competing interests.

REFERENCES

3. This study established age and sex specific MDCT reference values for thoracic aortic diameters in 103 healthy adults.
5. This study assesses the normal reference values of aortic root size in 120 healthy volunteers, 10 of each sex in each decile between 20 and 80 years, from steady state free procession cine acquisitions, including dimensions at annulus and sinotubular junction levels and cross sectional area at sinuses level.
7. The incidence of TAAAs has increased more than threefold in the past four decades. Elderly women represent an increasing number of patients whose aneurysm ruptures. Overall survival has improved significantly in the past 15 years.
9. An excellent revision of the structure of aneurysmal thoracic aorta placing the new findings regarding extracellular matrix proteinolysis in perspective with regard to TAA formation and progression.
14. Exhaustive review of the recent evidence highlighting the dysregulation of transforming TGF as a pathway of AAT.
18. Updating the most recent advances in pathophysiology, molecular biology, and clinical implications of TAA.
23. Risk stratification of 410 patients with TAA. Three intervals of aortic size index defined the risk of complications as an indexed aortic size >4.25 cm/m² correlated with an event rate of 25% per year. Importantly, even patients presenting with aortic sizes <2.75 cm²/m² displayed an event rate of

Provenance and peer review Commissioned; not externally peer reviewed.
4%; those presenting with sizes between 2.75–4.25 cm/m² had event rates approaching 8%.


In a small cohort study, the use of angiotensin II blockade in patients with Marfan syndrome significantly slowed the rate of progressive aortic root dilatation.


This study showed the usefulness of TOE in the diagnosis of functional aortic regurgitation secondary to ascending aorta aneurysm.


This study showed the excellent long term evolution of patients with aortic insufficiency whose valve was repaired by reducing the diameter of sinotubular junction.