# Chapter 21
# Aortic Aneurysms and Aortopathies

**Dustin Staloch and Joe X. Xie**

## Abbreviations

| | |
|---|---|
| AAA | Abdominal aortic aneurysm |
| AAS | Acute aortic syndrome |
| ACE-I | Angiotensin-converting enzyme inhibitor |
| ARB | Angiotensin receptor blocker |
| CTA | Computed tomography angiography |
| GCA | Giant cell arteritis |
| MRA | Magnetic resonance angiogram |
| MRI | Magnetic resonance imaging |
| TA | Takayasu arteritis |
| TAA | Thoracic aortic aneurysm |
| TEE | Transesophageal echocardiogram |
| TTE | Transthoracic echocardiogram |

## Overview

- Acute aortic syndromes are often a surgical emergency.

D. Staloch (✉) · J. X. Xie
Department of Medicine, Division of Cardiology, Emory University School of Medicine, Atlanta, GA, USA
e-mail: dustin.allen.staloch@emory.edu



A. A. Bhargava et al. (eds.), *Handbook of Outpatient Cardiology*, https://doi.org/10.1007/978-3-030-88953-1_21

- Feared complications of aortic disease include dissection/rupture, aortic regurgitation, or end-organ ischemia.
- Outpatient management of aneurysms and aortopathies center around surveillance to identify those at risk as well as medical therapies and risk factor modification to mitigate disease progression and complication.
- While more common risk factors such as hypertension or smoking are often implicated, aneurysms may present with or before recognition of genetic or systemic processes.

## Definitions

- Aortic dissection: a tearing of the intimal layer of the aorta with longitudinal propagation and formation of a blood-filled false lumen, classified by location
- Aortic intramural hematoma: a collection of blood within the medial layer of the aorta without an intimal tear or false lumen
- Penetrating aortic ulcer: localized perforation at the site of an atherosclerotic plaque through the intima without creation of a false lumen
- Aortic aneurysm: abnormal focal dilatation of the aorta beyond 1.5 times normal caliber
  - True aneurysm: an aneurysm of normal wall histology (involving all three layers)
  - Pseudoaneurysm (false aneurysm): a contained rupture of the aortic wall where the segment is a collection of blood bounded not by the aortic wall but by a fibrous peel of periarterial connective tissue
  - Ectasia: modest (<150% normal caliber) and generalized enlargement of the aorta

**Clinical Pearl**
Aortic rupture is the most common cause of death from aortic disease and dissection, following by acute, severe aortic regurgitation [1].

## Acute Aortic Syndromes

As aortic disease is identified incidentally on transthoracic echocardiogram (TTE), computed tomography (CT), or computed tomography angiogram (CTA) obtained for other reasons, it is important to exclude serendipitous recognition of acute processes at first identification to continue outpatient management.

### *Recognition*

- Acute aortic syndrome (AAS) is a general term which includes acute aortic dissections, intramural hematomas, and penetrating ulcers.
- Chief risk factors for AAS include long-standing hypertension (up to 72% of patients) and prior aortic aneurysm. Other risk factors include smoking, drug use, and hyperlipidemia [2].
- Presentation is overwhelmingly (>90%) with chest or back pain, often sudden and severe [2].
- AAS should otherwise be suspected in the presence of the diastolic murmur of acute aortic regurgitation, syncope, a blood pressure or pulse differential (weak or absent owing to a compromised true lumen flow by external compression or an intimal flap), or evidence of end-organ ischemia (disproportionate abdominal pain, weakness/paraplegia, or worsened renal function) [1].

**Clinical Pearl**
Listen closely! The murmur of acute aortic regurgitation may be short due to rapid equalization of aortic and ventricular pressures.

### *Management*

- Aortic dissections are classified based on the portion of the aorta involved (see Table 7.1).
- Emergent surgical intervention is warranted for dissections involving the ascending aorta (Stanford A or DeBakey I and II) or for high-risk features. If concerns for these exist, urgent surgical referral is indicated.
- In the absence of need for surgery, medical therapy aims to lower heart rate and blood pressure to minimize risk of propagation and complications. For these populations, surveillance imaging is warranted and future elective or urgent surgical intervention considered similar to chronic aneurysms [2].

## Thoracic Aortic Aneurysms

### *Background*

- Thoracic aortic aneurysm (TAA) is usually a degenerative disease of the media.
- Diagnosis is usually incidental as it is most often asymptomatic; less commonly, TAA may present with chest pain, an aortic regurgitation murmur, or compressive symptoms.
- The most common sites of involvement are the root (particularly in Marfan syndrome) and ascending aorta [2].

Table 7.1 Aortic dissection classification by dissection flap location

| **Stanford classification** | | **DeBakey classification** | |
|---|---|---|---|
| Type A: | Ascending ± descending aorta | Type I: | Ascending + descending aorta |
| | | Type II: | Ascending aorta |
| Type B: | Descending aorta | Type III: | Descending aorta |

- Lesser involved TAA sites include the transverse arch (10%), the descending thoracic aorta (distal to the left subclavian artery), and the thoracoabdominal aorta (involving both thoracic and abdominal components) [2].
- As with other degenerative disease, incidence increases with age with a mean age of 69 years at diagnosis and women being significantly older at presentation [3].

## *Associations and Risk Factors*

- The largest modifiable risks for development of TAA include hypertension and smoking.
- Mycotic aneurysm risk is greatly increased by IV drug use or congenital abnormalities such as coarctation of the aorta.
- Though rare in the modern area, the late manifestations of syphilis, such as syphilitic aortitis and possible resultant aneurysm, should not be forgotten.
- Genetic disorders associated with medial degeneration include [1]:
  - Marfan syndrome
  - Bicuspid aortic valve
  - Turner syndrome
  - Ehlers-Danlos syndrome
  - Loeys-Dietz syndrome
  - Familial aortic aneurysm
- As discussed later, inflammatory disorders such as Takayasu arteritis, giant cell arteritis, and ankylosing spondylitis may present with aortic aneurysm.

## *Diagnosis*

- Diagnosis requires focal enlargement >150% normal diameter, which varies based on gender, age, anatomic location, and imaging modality.

- With TTE, internal diameters are used by convention and judged against expected diameters based on age- and body size-adjusted nomograms.
- TTE has high specificity but low-moderate sensitivity for TAA. While it may be useful for diagnostic visualization of the aortic valve, root, and arch, TTE fails to consistently visualize and accurately measure the tubular portion of the ascending aorta [4].
- When diagnosis of TAA is made on TTE, full imaging of the aorta should be done with computed tomography angiography (CTA), magnetic resonance imaging (MRI), or magnetic resonance angiography (MRA) based on appropriateness of contrast agents.
- Unlike TTE, CT may struggle to define the aortic root unless properly protocolized. Also unlike TTE, there is no consensus on including or excluding the vessel wall when measuring aneurysm size with CTA or MRI/MRA [1].

## *Management*

- Decision for surgical versus medical management is based around rate of rupture.
- Surgery, in general, should be considered urgently for patients with symptoms of expansion (chest or back pain) and electively for asymptomatic patients with rapidly growing (>0.5 cm/year) ascending TAA or any TAA ≥5.5 cm.
- Medical management aims at atherosclerotic risk reduction, including smoking cessation and statin therapy to target low-density lipid cholesterol <70 mg/dL.
- With anti-impulse benefits via reduced heart rate and shear wall stress, beta-blockers are the preferred antihypertensive agent, with blood pressure goals of lowest pressure tolerated or as dictated by comorbid conditions. Angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs) are also reasonable selections [5].

- Pregnant patients or those desiring pregnancy deserve specialist input as prophylactic surgery may be considered for progressive aortic dilatation or aortic valve regurgitation [1].

**Clinical Pearl**
Dimensional criteria for surgical intervention apply *only* to asymptomatic aneurysms. Symptomatic aneurysms at any level should undergo surgery – regardless of size.

## *Surveillance*

- The goal of surveillance is to follow aneurysm enlargement, taking into account factors such as renal function, dissection location, and patient age.
- In general, serial imaging is best undertaken with the same modality and within the same institution to facilitate comparison.
- TTE's primary role is serial follow-up in patients with disease limited to the root. While CT may provide better anatomical detail, it comes at the expense of repeat radiation exposure – relevant in younger populations.
- The frequency of surveillance imaging is not entirely clear, due to lack of data to guide surveillance intervals. However, the mean rate of growth for all thoracic aortic aneurysms is approximately 1 mm/year [1, 6].
- It is prudent to obtain surveillance imaging on an annual basis provided the aneurysm size remains stable and every 2–3 years for stable, smaller aneurysms in older patients.

# Abdominal Aortic Aneurysms

## *Background*

- Like TAA, abdominal aortic aneurysm (AAA) is usually a degenerative disease of aging but may occur with inflammatory disorders, infectious processes, or congenital conditions.
- Like TAA, diagnosis of AAA requires full-thickness dilation of the abdominal aorta exceeding normal caliber (varying by age, sex, and body size) by >50% (usually ≥3 cm).
- Abdominal aortic aneurysms are considered small if less than 5.5 cm; above this cut-off, they are considered large AAA.
- In more than 90% of cases, the proximal edge remains infrarenal [7].
- A minority of patients will have symptoms warranting early detection. However, AAA without rupture may be a source of hematuria, gastrointestinal bleeding, or chronic abdominal or low back pain. With rupture, AAA may present with sudden-onset pain, syncope, or a pulsatile abdominal mass.

## *Associations and Risk Factors*

- AAA is five times more common in smokers, in whom 89% of all aneurysm ruptures occur [1].
- Those most effected by AAA are men >65 years old. Other strong risk factors include family history of AAA, hypertension, and coronary artery disease.
- AAA is associated with most of the same congenital and inflammatory conditions TAA.

## *Diagnosis*

- Abdominal ultrasound is the gold standard for diagnosis and monitoring in asymptomatic patients. For cost-effective screening of the general population, the US Preventive Services Task Force (USPSTF) recommends a one-time screening by ultrasound in men 65–75 years who have smoked. Due to low yield, it is recommended against screening women. There is no recommendation for or against men who have not smoked [8].
- CTA is typically performed for asymptomatic but large AAA or for symptomatic/ruptured AAA, as it is better suited for preoperative assessment and determination of repair method.

**Clinical Pearl**
Find the sweet spot! One-time ultrasound screening for AAA is recommended for men aged 65–75 who have ever smoked. Screening the remainder of the general population is not recommended.

## *Management and Surveillance*

- Immediate surgical repair is indicated for aneurysms expanding >0.5 cm in 6 months or for any symptomatic aneurysms. Elective repair is usually considered for saccular aneurysms, AAA ≥5.5 cm for men, and ≥5.0 cm for women [9, 10].
- Smoking cessation is recommended for all patients to slow the growth of AAA.
- Evidence on medical management of AAA is mixed, as are society recommendations. While both statins and ACE inhibitors may be considered to reduce aortic complications in patients with small AAA, evidence is weak. These agents, along with ARBs and beta-blockers, are largely not

Table 7.2 Abdominal aortic aneurysm surveillance interval by aneurysm size

| Aneurysm size | Surveillance interval |
|---|---|
| 3.0–3.4 cm | Every 3 years |
| 3.5–4.4 cm | Every 1 year |
| 4.5–5.4 cm | Every 6 months |

indicated for use solely to reduce risk of AAA expansion or rupture [9, 10].
- AAA without indication for operative intervention should be monitored with abdominal ultrasound at intervals based on aneurysm size (see Table 7.2) [11].

## Inherited Aortopathies

### *Marfan Syndrome*

- Characterized by long, thin extremities, ectopia lentis, and ligamentous redundancy, Marfan syndrome usually stems from an autosomal dominant FBN1 gene encoding fibrillin-1.
- Characteristic cardiovascular issues include fusiform enlargement of the aortic root involving enlargement of the aortic annulus (leading to aortic regurgitation) through the proximal ascending aorta. This lends a "flask-like" shape to the root characteristic of Marfan syndrome and other disorders of cystic medial necrosis.
- Abnormalities may involve the entire length of the aorta, though dissection is seen most commonly in the thoracic aorta. Nearly half of patients have mitral insufficiency [12].
- Beta-blockers and ARBs are indicated to slow aneurysm and aortic root dilation progression, but are not proven to impact clinical outcomes [2].
- Surgical repair of aortic aneurysms is recommended for aortic aneurysms ≥5 cm, severe aortic regurgitation, or

≥4.5 cm with family history of dissection or growth rate >0.3 cm/year.
- Women should be counseled against pregnancy; repair of aneurysms 4.1–4.5 cm is recommended for women anticipating pregnancy and may be considered if >4 cm for those desiring pregnancy [2, 10].

## *Ehlers-Danlos Syndrome*

- Comprising a group of rare disorders of collagen synthesis, Ehlers-Danlos syndrome (EDS) occurs in 1 in 5000 persons worldwide with widely varying presentations from mild skin hyperextensibility to life-threatening cardiovascular complications.
- In the vascular EDS form, an autosomal dominant COL3A1 mutation leads to defective production of type III collagen and medial degeneration.
- Management strategies tend to parallel Marfan syndrome. Due to resultant challenges in healing, bleeding, and other complications, surgical intervention is avoided whenever possible.

## *Loeys-Dietz Syndrome*

- With five subtypes, Loeys-Dietz syndrome (LDS) types 1 and 2 are classified as connective tissue diseases. While these patients were previously characterized as having Marfan syndrome of EDS, it is now recognized that LDS 1 and 2 are due to mutations of TGFBR1 and TGFBR2.
- With significant phenotypic overlap with the vascular EDS type, individuals are prone to pregnancy-related complications and rapidly enlarging aneurysms that are predisposed to rupture, with a mean age of death of 26 years.
- LDS 1 may be recognized by the triad of vascular aneurysms, cleft palate and/or bifid uvula, and hypertelorism; LDS 2 is notable for cutaneous manifestations akin to

vascular EDS such as easy bruising, atrophic scars, and velvety translucent skin [13].

## *Bicuspid Aortic Valve*

- Structural abnormalities of the ascending aorta predispose those born with bicuspid aortic valves to aneurysm and dissection. In many, aneurysmal changes precede and are recognized prior to diagnosis of valvular dysfunction.
- These patients frequently undergo both aortic valve and aorta replacement owing to more rapid aneurysm growth compared to aneurysms of trileaflet patients, possibly due to excess matrix metalloproteinase activity [1].
- Repair or replacement of the ascending aorta or aortic root is recommended for:
  - Diameter ≥5.5 cm (class 1 indication)
  - Diameter >5 cm + family history of dissection or growth rate ≥0.5 cm/year (class 2a)
  - Diameter >5 cm + low surgical risk + experienced surgical team and center (class 2a)
  - Diameter >4.5 cm if aortic valve surgery is planned (class 2a) Aortic root repair/replacement or ascending aorta repair

## *Turner Syndrome*

- In phenotypic females, Turner syndrome results from the absence of an X chromosome and resultant 45 XO genotype.
- Cardiovascular disease is common, including bicuspid aortic valve (up to 25%), coarctation of the aorta (up to 10%), and ascending aorta ectasia and aneurysm.
- Surveillance at routine intervals (typically annually) are recommended when abnormalities are identified or every 5–10 years in the absence of known cardiovascular complication [14].

## Other Aortopathies

### *Takayasu Arteritis and Giant Cell Arteritis*

- Takayasu arteritis (TA) and giant cell arteritis (GCA) are idiopathic vasculitides of the aorta and its branches with considerable phenotypic overlap.
- Both present predominately in women with indolent progression of systemic symptoms of fatigue, weight loss, fevers, and nonspecific elevations in inflammatory markers.
- A major distinction between the two is age, as TA diagnosed in younger patients (<40 years) and GCA in older patients (>50 years).
- Both may result in aneurysm of the aorta, but TA may also affect vascular beds from the coronary arteries through to arteries of the head, neck, and abdominal viscera.
- Treatment in general is with immunosuppression, and surgical intervention is avoided when possible (especially without disease quiescence) [15].

### *HLA-B27-Associated Spondyloarthropathies*

- In patients with Reiter syndrome and ankylosing spondylitis, aortitis is common and is of highest prevalence in those with long-standing spondylitis, iritis, or peripheral arthritis.
- Driven by medial necrosis, aortic dissection has been reported as well as aortic regurgitation and cardiac conduction disease owing to local inflammation.

### *Infectious Aortopathies*

- Primary infection of the aortic wall is uncommon but may be seen with *Staphylococcus*, *Salmonella*, and *Pseudomonas* species, giving rise to aortic aneurysms which are more

often saccular. "Mycotic" or infectious aneurysms may be due otherwise to secondary infection of pre-existing aneurysms. Infection may lead to weakness of the aortic wall with high propensity for rupture.

- Though rare in the modern antibiotic era, syphilitic aortitis should not be forgotten. This form of tertiary syphilis occurs years after initial infection and may lead to aortic aneurysms.
- Tuberculous aneurysms may arise following infection extension from hilar lymph nodes leading to loss of aortic wall integrity from granulomatous medial destruction. Usually identified as saccular aneurysms arising from the posterior or posterolateral aortic wall, progression may give rise to perforation, aortoenteric fistulae, or pseudoaneurysm.

**Key Learning Points**

1. Outpatient management of aneurysms and aortopathies seek center on appropriate selection of imaging modality and intervals to identify surgical need.
2. While specific antihypertensive agents such as beta-blockers and ARBs are reasonable, evidence is not overwhelming. Blood pressure control, smoking cessation, and statin therapy are recommended for most.
3. Aortic aneurysms may not be a primary disorder, but instead a feature of congenital, systemic, or infectious conditions.

## References

1. Elefteriades JA, Olin JW, Halperin JL. Diseases of the aorta. In: Fuster V, et al., editors. Hurst's the heart. 14th ed. New York, NY: McGraw-Hill. p. 2261–89.
2. Hiratzka LF, Bakris GL, Becman JA, et al. 2010 ACCF/ AHA/ AATS/ ACR/ ASA/ SCA/ SCAI/ SIR/ STS/ SVM guidelines for

the diagnosis and management of patients with thoracic aortic disease. JACC. 2010;55(14):e27–129.
3. Ramanath VS, Oh JK, Sundt JM, et al. Acute aortic syndromes and thoracic aortic aneurysm. Mayo Clin Proc. 2009;84(5):465–81.
4. Cheitlin MD, Armstrong WF, Aurigemma GP, et al. ACC/AHA/ASE 2003 guideline update for the clinical application of echocardiography—summary article: a report of the American College of Cardiology/ American Heart Association Task Force on Practice Guidelines. JACC. 2003;42(5):954–70.
5. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/ AHA/ AAPA/ ABC/ ACPM/ AGS/ APhA/ ASH/ ASPC/ NMA/ PCNA guidelines for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. JACC. 2018;71(19):e127–248.
6. Davies RR, Goldstein LJ, Coady MA, et al. Yearly rupture or dissection rates for thoracic aortic aneurysms: a simple prediction based on size. Ann Thorac Surg. 2002;73:17–27.
7. Sakalihasan N, Michel JB, Katsargyris A, et al. Abdominal aortic aneurysms. Nat Rev Dis Primers. 2018;4(1):34.
8. Carnevale ML, Koleilat I, Lipsitz EC, et al. Extended screening guidelines for the diagnosis of abdominal aortic aneurysm. J Vasc Surg. 2020;72(6):1917–26.
9. Hirsch AT, Haskal ZJ, Hertzer NR, et al; ACC/AHA 2005 Practice Gui delines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines. Circulation. 2006;113(11):e463–654
10. Erbel R, Aboyans V, Boileau C, et al. ESC Committee for Practice Guidelines. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). Eur Heart J. 2014;35(41):2873–926.
11. Chaikof EL, Dalman RL, Eskandari MK, et al. The Society for Vascular Surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. J Vasc Surg. 2018;67(1):2–77.

12. Finkbohner R, Johnston D, Crawford ES, et al. Marfan syndrome: along-term survival and complications after aortic aneurysm repair. Circulation. 1995;91:728–33.
13. Loeys BL, Chen J, Neptune ER, et al. A syndrome of altered cardiovascular, craniofacial, neurocognitive and skeletal development caused by mutations in TGFBR1 or TGFBR2. Nat Genet. 2005;37:275–81.
14. Gravholt CH, Andersen NH, Conway GS, et al. Clinical practice guidelines for the care of girls and women with Turner syndrome: proceedings from the 2016 Cincinnati International Turner Syndrome Meeting. Eur J Endocrinol. 2017;177(3):g1–70.
15. Helmich B, Agueda, Monti S, et al. 2018 Update of the EULAR recommendations for the management of large vessel vasculitis. Ann Rheum Dis. 2020;79(1):19–30.