Learning objectives

- To review and illustrate normal CT appearances of abdominal aortic aneurysms;
- To describe the spectrum of complications associated with abdominal aortic aneurysms and illustrate its key imaging findings.
Abdominal aortic aneurysms (AAA) are cumbersome pathologies, with catastrophic consequences when not properly diagnosed and treated. They are defined as permanent focal dilatations of the aorta, superior to 3 cm in maximum diameter or 50% greater than the normal proximal aortic segment.

Its estimated prevalence amongst men over the age of 50 is 5%, with an increasing rate, reaching 12.5% in men over 74 years. Several risk factors for AAA development are known, and include age (> 60 years), male gender, smoking, hypertension, hypercholesterolemia and family history.

Atherosclerosis is the most common causative factor, but other causes are known, and include connective tissue disorders (such as Ehlers-Danlos or Marfan syndrome), vasculitis (such as Takayasu arteritis) as well as inflammatory, infectious and traumatic etiologies.

In most cases, AAA's are asymptomatic until impending rupture ensues and they are commonly diagnosed incidentally on abdominal radiologic examinations. However, in some situations, unruptured AAA's may cause abdominal or back pain, and are frequently observable on physical examination as palpable pulsatile abdominal masses.

The majority of AAA's only become symptomatic when complications develop, with rupture being the most common. The classical clinical triad of aneurysm rupture is present in up to 50% of patients and includes intense abdominal pain, pulsatile abdominal mass and shock. A maximum diameter superior to 6 cm, expansion rate over 0.6 cm/year, severe smoking, poorly controlled hypertension, family incidence, eccentric shape, high wall stress and female gender are some of the factors associated with a higher risk of rupture. When ruptured, overall mortality rates exceeds 80%, making it essential to early recognize and closely monitor those patients.
Findings and procedure details

Imaging studies are essential not only for the diagnosis of AAA but also to monitor its growth rate, to detect complications and plan surgical interventions.

Abdominal radiographs may show curvilinear calcifications in the paravertebral regions but are neither specific nor sensitive in the detection of AAA. Ultrasonography (US) is a simple, safe and inexpensive method with a sensitivity of 95% and specificity of nearly 100% in the detection of AAA. Since it is not associated with radiation exposure, it may be the preferred imaging modality in some individuals (Fig. 1). However, Computed Tomography Angiography (CTA) remains the gold-standard for AAA diagnosis, characterization, treatment planning and follow-up. CTA allows an accurate evaluation of both the aneurysm size and configuration, as well as extension and visceral vessel involvement. It also allows the detection of signs of impeding rupture and other complications, such as thrombosis or rupture.

Classification

Abdominal aortic aneurysms can be differently classified depending on both their location and morphology.

Location

According to their location, AAA’s can be divided in:

- Supra-renal aneurysms: affect the renal arteries origin and extending proximally to the celiac trunk and mesenteric artery origin (Fig. 2);
- Juxta-renal aneurysms: located just distal to the origin of the renal arteries (Fig. 3);
- Infra-renal aneurysms: originating > 1 cm distal to the origin of the renal arteries (Fig. 4).

Among these, infra-renal aneurysms are the most frequent of all, accounting for approximately 90% of all cases. This occurs because this aortic segment is exposed to the highest pressure load from the reflected pressure waves from the aortic bifurcation. The decreased distribution in vasa vasorum in the distal aorta may increase the risk of ischemic injury and contribute to this distribution.

Morphology

Regarding their morphology, AAA’s can be classified as:
• Fusiform aneurysms: concentric dilations that involve the full circumference of the vessel wall. They are by far the most common morphology encountered (Fig. 5);
• Saccular aneurysms: eccentric dilations, involving only a portion of the circumference of the vessel wall (Fig. 6). They are commonly associated with rarer causes of aneurysm formation, such as inflammatory and infectious etiologies, and are associated with greater growth rates and a higher risk of rupture.

Aneurysm size, growth rate and indication to treat

Currently aneurysm size and growth rate are considered the main determinants for intervention vs surveillance in AAA’s, because there is strong evidence that increased size and rapid growth rates indicate a higher risk of rupture. Although, there are certain limitations in the prognostic value of these variables, current guidelines for AAA management consider aneurysm size (defined as its maximum diameter) and growth rate as the only variables in which the elective decision to treat is based. Therefore, the European Society of Vascular Surgery (SVS) defined cut-off points for intervention which are: 1) maximum diameter of > 55 mm and/or 2) a growth rate of > 10 mm/year. It must be highlighted that an accurate measurement of the greatest aortic diameter should always be pursued. Axial CT images can potentially overestimate aortic diameter because they do not account for vessel tortuosity or may represent oblique cross-sections (Fig. 7). With the advent of thin-slice CT and digital imaging, 3D-reconstructions of AAA became possible and have allowed more accurate measurements of AAA size parameters. Recent guidelines recommend that the maximum diameter should be measured in a plan perpendicular to the vessel centerline of flow (Fig. 8).

Signs of aneurysm instability

Besides size and growth rate there are several other imaging signs of aneurysm instability that should be promptly recognized by radiologists.

1. High-density crescent sign

The hyperattenuating crescent is one of the most specific CT signs of acute or impeding rupture of AAA’s. It represents blood dissecting into the mural thrombus or the aneurysmal wall and it is better evaluated on nonenhanced CT images. The sign consists in a periluminal crescentic area of hyperattenuation along the mural thrombus or the aortic wall (Figs. 9; 11).

2. Tangential calcium sign and fracture of the calcium ring
Many aneurysms are lined with circumferential wall calcifications, reflecting their atherosclerotic etiology. The tangential calcium sign consists in a discontinuity of the intimal calcification of an AAA that is seen to the tangentially point away from the aneurysmal lumen. It occurs at the point of breach of the calcium ring (Figs. 10; 11). More commonly, only a focal discontinuity in the circumferential wall calcification is found. This is better appreciated when a previous CT study is available for comparison and more frequently occurs at the posterolateral aneurysm wall. It also represents aortic wall instability.

3. Draped aorta sign

The draped aorta is a sign of contained rupture of AAA that is highly indicative of aortic wall insufficiency and aneurysm instability. It consists of an area of discontinuity of the posterior aortic wall associated with obliteration of the fat planes between the aorta and vertebral bodies and molding/ draping of the adjacent vertebrae (Fig. 12). Chronic contained ruptures may lead to vertebral erosions in up to 30% of cases (Fig. 13).

4. Thrombus fissuration

Thrombus fissuration is another sign of impending rupture of AAA. It reflects blood dissecting into the mural thrombus and therefore is better appreciated on enhanced CT scans. It appears as a linear area of contrast infiltration from the aneurysmal lumen into the intramural thrombus (Fig. 14).

Complications of AAA

1. Retroperitoneal hematoma

The most dreadful complication of AAA is undoubtedly rupture, because it is associated with mortality rates higher than 80%. Retroperitoneal hematomas are the most common imaging finding of AAA rupture. Acute hemorrhages are usually seen as high-attenuation (>30 HU) fluid collections located in the retroperitoneum (Fig. 15; 16). Periaortic blood may extend into the perirenal, anterior and posterior pararenal spaces and along the psoas muscles. Large hematomas may displace the adjacent viscera.

Intraperitoneal extension into the pouch of Douglas, perihepatic space or mesenteric folds, may occasionally occur either as an immediate or delayed finding (Fig. 17).

Active extravasation of contrast medium into the peritoneal cavity can sometimes be seen with ruptured AAA's and is a specific sign of rupture (Fig. 18).
2. Infected / mycotic aneurysms

Infected aortic aneurysms are uncommon, accounting only for 1% of all surgically treated aneurysms. In contrast to the more common atherosclerotic aneurysms, they are most often pseudoaneurysms with saccular morphology and supra-renal location. Typical CT findings of mycotic aneurysms include lobulated contours, periaortic inflammation/ fat stranding and abscesses (Fig. 19). Periaortic gas is an uncommon and threatening feature. They can also lead to adjacent vertebral anomalies due to local spread of infection.

Infected aneurysms are associated with a poor prognosis, having a faster expansion rate and a higher risk of rupture (irrespective of their size) than atherosclerotic aneurysms. Rapid changes in aneurysm size or shape should increase awareness about this diagnosis.

3. Aortoenteric fistula

Aortoenteric fistulae can occur in patients with atherosclerotic disease without previous surgery, but are much more frequently encountered after surgical reparation of AAA. Most fistulae involve third and fourth portions of the duodenum and present as lower-GI bleeding. Endoscopic studies may show an active point of bleeding but CT scans are also useful for the diagnosis. Imaging findings include loss of the normal fat planes between the aneurysm and the involved bowel segment and the presence of intra and extraluminal gas within the aneurysmal sac (Fig. 20). When patients present with GI bleeding, active extravasation of contrast into the bowel can occasionally be seen on CTA.

4. Aortocaval fistula

Aortocaval fistulae are rare entities that occur in less than 4% of all ruptured aneurysms. Common clinical manifestations include symptoms of heart failure and venous congestion. On unenhanced CT, normal fat planes between the AAA and the inferior vena cava (IVC) are lost. Following contrast administration there is simultaneous opacification of the aorta and IVC associated with a later than common enhancement of the renal cortices.
Fig. 1: Abdominal US of a 65-year-old male demonstrating an abdominal aortic aneurysm, measuring 4 cm of maximum transverse diameter (A) and 3.7 cm of extension in the longitudinal plane (B).

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT

Fig. 2: Sagittal CTA (A) and 3D-reconstruction (B) of a supra-renal AAA. The aneurysm involves the the aorta proximally to the emergency of the renal arteries.
**Fig. 3:** Juxta-renal abdominal aortic aneurysm. Coronal CTA depicts a juxta-renal AAA, extending up to the emergency of the renal arteries.
Fig. 4: Coronal enhanced CT depicts an infra-renal AAA, originating approximately 2 cm distal from the renal arteries. Infra-renal AAA’s account for more than 90% of all cases.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 5: Fusiform AAA. Coronal CTA depicts an infra-renal fusiform AAA. Circumferential dilation of the aortic walls can be noted.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 6: Coronal CTA (A) and 3D reconstruction (B) of an infra-renal saccular AAA. An excentric bulging of the aortic wall (asterisk; arrow) proximal to the aortic bifurcation can be observed.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT

Fig. 7: Axial (A) and coronal (B) CTA imagens of a tortuous AAA. The maximum diameter on the axial plane was inferior to the maximum diameter on the coronal plane, revealing the importance of accurate measurement for procedure planning.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 8: Centerline reconstruction of an infra-renal aortic aneurysm. Centerline reconstructions grant precise measurements for the planning of aortic endovascular repairs.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT

Fig. 9: Hyperattenuating crescent sign. Axial unenhanced CT scans of two different patients with AAA (A; B) depict a periluminal crescentic area of hyperattenuation along the mural thrombus / aortic wall. It is one of the most specific CT signs of acute or impeding AAA rupture.
Fig. 10: Tangential calcium sign. Axial CTA shows a focal discontinuity of the intimal calcification which is seen to point away from the aortic lumen. This sign also represents aortic wall instability and is seen with impending ruptures or contained leakages.
Fig. 11: Axial enhanced CT depicting a large AAA with a tangential calcium sign (arrows) associated with a hyperattenuating crescent (asterisks). Retroperitoneal hematoma can also be observed, confirming aneurysm rupture.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 12: Draped aorta sign. Axial CTA demonstrates an area of indefiniton of the posterior aortic wall with loss of the normal fat planes between the aorta and the vertebrae (arrows). The posterior contour of the aorta follows the contour of the vertebra, consistent with contained rupture and aneurysm instability.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 13: Axial CTA on soft tissue (A) and bone (B) windows show a focal erosion of the vertebral body in the area of contiguity with the AAA (circle). Chronic contained ruptures can lead to bone erosions in up to 30% of cases.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 14: Thrombus fissuration. Axial CTA shows a linear area of contrast infiltration extending from the lumen of the aorta into the mural thrombus (arrows). This is another sign of impending AAA rupture.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Fig. 15: Axial enhanced CT depicts a large ruptured AAA associated with a massive retroperitoneal hematoma (arrows).

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT

Fig. 16: Retroperitoneal hematoma. Axial non-enhanced (A) and enhanced CTA demonstrate a voluminous retroperitoneal hematoma dissecting into the anterior and
posterior pararenal spaces and along the psoas muscle. Retroperitoneal hematomas are the most common imaging findings of ruptured AAA.

Fig. 17: Intraperitoneal hematoma - free rupture. Axial arterial (A) and venous (B) phase CT depict a ruptured AAA with active extravasation of contrast material and associated retroperitoneal and intra-peritoneal hematomas.

Fig. 18: Coronal (A) and axial (B) CTA depicts a ruptured AAA with associated retroperitoneal hematoma. There is active extravasation of contrast material into the abdominal cavity (asterisk; arrow).
**Fig. 19:** Mycotic aneurysm with associated abscess. Axial (A) and Coronal (B) CTA depicts a saccular AAA with signs of impending rupture, including fracture of the ring of calcium and tangential calcium sign. There was an adjacent soft-tissue collection with gas bubbles, compatible with a peri-aortic abscess (arrows).
**Fig. 20**: Aorto-enteric fistula. Axial CTA shows a loss of the normal fat planes between the aorta and the third and fourth portions of the duodenum, consistent with an aorto-enteric fistula. Subsequent endoscopy confirmed the diagnosis.

© Department of Radiology, Centro Hospitalar São João, Faculdade de Medicina da Universidade do Porto - Porto/PT
Conclusion

Radiologists should become familiar with the vast spectrum of imaging findings that can be encountered in patients with abdominal aortic aneurysms. CT reports should always include information regarding aneurysm size and configuration, as well as extension and visceral vessel involvement, since the risk of rupture and treatment strategies vary accordingly. Early detection of signs of impending rupture or aneurysm related complications is also crucial so that rapid treatment and better final outcomes can be achieved.
References


