Catastrophes of Abdominal Aorta: Sonographic Evaluation

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Ultrasound has been used only rarely in the evaluation of the abdominal aorta, especially in the developed countries such as the United States, because of the ready availability of better and faster imaging modalities such as CT and MR imaging. The only limitation of these modalities is the high expense, which has encouraged the ultrasound use for nonemergent purposes such as screening for abdominal aortic aneurysm (AAA). Abdominal aorta also is evaluated as a part of general abdominal sonography, and often the sonographer and the radiologist encounter pertinent abnormalities of the abdominal aorta of which the patient or his/her physician is unaware and which may be the cause of patient’s symptoms. It therefore is essential that the sonographer or the radiologist be able to identify the important aortic catastrophes for appropriate further management. This article focuses on the ultrasound evaluation of some of the abdominal aortic catastrophes that one may encounter during routine ultrasound, such as AAA, AAA rupture, and aortic dissection.

ABDOMINAL AORTIC ANEURYSM

Aortic aneurysm is an abnormal dilatation of the aorta. It has significant morbidity and mortality and is found in up to 10% of male smokers older than 65 years of age. The major complication of AAA is rupture, and the goal of imaging is to identify the asymptomatic and indolent AAA, which has an increased incidence of rupture if it grows larger than 5.5 cm. According to the current recommendations, elective surgical repair is recommended for aneurysms that are larger than 5.5 cm to prevent rupture.

Predisposing Risk Factors

Atherosclerosis is the most common cause of AAA, and the atherosclerotic aorta is much more prone to aneurysmal dilatation. Men are more likely than women to have severe aortic atherosclerosis and peripheral vascular disease. Although AAA is more common in men than in women, the incidence of rupture is greater in women because growth rate of AAA is significantly greater in women than in men.

Peripheral artery disease also has a high association with AAA, particularly in men older than 75 years.

Other risk factors include risk factors that predispose to atherosclerosis, such as smoking, hypertension, advancing age, and hyperlipidemia. A family history of AAA and the presence of congenital disorders such as Marfan’s syndrome and Ehlers-Danlos syndrome are associated with an increased incidence of AAA.

Intracranial aneurysms are associated with AAA. Older males who have multiple or large intracranial aneurysms and who are current smokers should be examined for AAA using ultrasonography.

Screening

Schilling and colleagues were among the first to begin screening for AAA. In 2003 Lederle published data justifying regular screening.
Ultrasound is the preferred method of screening for AAA because of several advantages: accuracy (nearly 100% sensitivity and specificity for AAA), low cost, patient acceptance, lack of radiation exposure, the short length of examination time (a quick screening takes less than 5 minutes), and easy availability. CT scan may be used occasionally after ultrasound examination to obtain exact measurements, particularly in cases of tortuous aorta.

Three-dimensional ultrasonography using volume acquisition offers a new opportunity to acquire fast and reliable AAA measurements by ultrasound.\(^\text{10}\)

Screening for AAA is indicated in the population with increased risk factors, which includes men over 65 years age who have history of smoking. Although the United States Preventative Services Task Force recently recommended against primary screening for AAA in women, it has been observed that the incidence of AAA is increased among women age 65 years or older who have a history of smoking or heart disease. Women with these risk factors also should be considered for screening for AAA.\(^\text{11}\)

### Making the Diagnosis

The most common sonographic appearance of AAA is a dilated aorta with associated atherosclerotic changes, which include atherosclerotic plaque with or without calcifications (Fig. 1) and/or mural thrombus, either eccentric or concentric (Fig. 2). Diagnosis of AAA is made on the basis of cross-sectional measurements.

Criteria for diagnosis of AAA include (1) a focal dilatation of the abdominal aorta of more than 3.0 cm, (2) an increase in the aortic diameter to 1.5 times the normal expected diameter, and (3) a ratio of infrarenal to suprarenal aortic diameter of 1.2 or greater.\(^\text{12}\) The aneurysmal sac should be measured from outer wall to outer wall on a longitudinal image. The transverse diameter should be measured perpendicular to the long axis of the aorta. This measurement is particularly useful in a tortuous aorta (Fig. 3).

Three-dimensional ultrasound enables easier, quicker, and more accurate measurement of AAA.\(^\text{10}\)

Color Doppler evaluation of the aorta gives a better estimate of the patent lumen in the aneurysmal aorta. Sudden increase in the lumen size at the site of the aneurysm may give rise to turbulent flow within the sac known as the “pseudo yin-yang sign” (Fig. 4) because of its similarity in appearance to the pseudoaneurysm finding of “yin-yang sign”.\(^\text{12}\)

### Classification of Abdominal Aortic Aneurysm

AAAs can be classified according to location, morphologic shape, and etiology (Box 1).

### RUPTURE OF ABDOMINAL AORTIC ANEURYSM

Rupture of AAA is the most common complication of AAA and is associated with a high mortality rate of almost 90%. In a clinical presentation of acute AAA rupture, CT, which is considered

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**Fig. 1.** Atherosclerotic plaque. (A) Longitudinal gray-scale sonogram of the abdominal aorta demonstrates a calcified atherosclerotic plaque (arrow). Also seen is a dissection flap (arrowhead). (B) Corresponding sagittal reconstructed image of the contrast-enhanced CT of the abdominal aorta better demonstrates the calcified atherosclerotic plaques (arrows) and also the intraluminal dissection flap (arrowhead). (C) Transverse color Doppler image of the abdominal aorta demonstrates an aneurismal aorta with a small noncalcified echogenic plaque anteriorly (arrow) that shows a twinkle artifact (arrowhead) suggesting presence of cholesterol in the plaque.
much more accurate and definitive than ultrasound, is the modality of choice. The most important role of ultrasound is identify the risk of rupture in these patients by assessing the size of the aneurysm and its rate of enlargement, the two most important factors in predicting the likelihood of rupture.

Occasionally, acute AAA rupture may be detected on ultrasound because of clinical misdiagnosis or because of unknown AAA presenting with abdominal pain thought to be caused by renal colic or appendicitis.

Fig. 2. Mural thrombus in aortic aneurysm. (A) Transverse and (B) longitudinal gray-scale sonographic images of the abdominal aorta demonstrate an aortic aneurysm with a nearly concentric thrombus (T), occupying almost 50% of the aortic lumen.

Fig. 3. Aneurysm sac measurement. Diagrammatic representation of the correct (green check) and incorrect (red cross) methods of measuring the aneurysm sac in a tortuous aorta.

Fig. 4. Pseudo yin-yang sign. Longitudinal color Doppler image of the abdominal aortic aneurysm shows an appearance resembling the yin-yang sign.
Several factors have been or are being studied as reliable predictors of AAA rupture (Box 2).

Role of Sonography

Ultrasound is not the imaging modality of choice in patients presenting with the clinical picture of aortic rupture. Contrast-enhanced CT is the preferred modality for assessment and detection of aortic aneurysmal rupture.

AAA rupture sometimes may be identified on ultrasound during screening and monitoring of AAA. The identification of aortic rupture, if present, is essential for appropriate triage of patients.

If rupture is identified correctly on ultrasound, particularly in a hypotensive patient, the patient should be taken directly to the operating theater for repair instead of wasting more time in obtaining further imaging such as CT.

The most frequent site of aortic rupture is in the left retroperitoneum, where it occurs more frequently in the posteri or wall (67%) and in the inferior portion (61%). The most common ultrasound findings of AAA rupture include retroperitoneal hematoma, which appears as an echogenic retroperitoneal fluid collection, particularly in the peri aortic location, and hemoperitoneum. Other uncommon sonographic findings that can be seen in AAA rupture include morphologic deformation of the abdominal aorta, hypoechoic or anechoic areas within the thrombus, or abrupt interruption of the thrombus, floating thrombus within the aortic lumen and a break in the continuity of the abdominal wall with or without the para-aortic hypoechoic area. Rarely, active leak can be demonstrated on ultrasound as a focal discontinuity in the aortic wall, with blood leaking through the break in the aortic wall on color Doppler imaging (Fig. 5).
Contrast-enhanced sonography is potentially useful for the assessment of aortic aneurysmal rupture, with efficacy comparable to that of CT and with the added advantages of easy bedside availability and relatively lower expense than with CT. Because of the urgent nature of aortic rupture, however, contrast-enhanced sonography may not be the preferred modality for imaging.

**ENDOGRAFT EVALUATION**

Ultrasound is used to evaluate the effectiveness of endograft by monitoring the aneurysm size and the presence or absence of an endoleak. Endoleaks are defined as the persistence of blood flow outside the lumen of the endoluminal graft but within the aneurysm sac and are suggested by the increasing size of aneurysm sac after endograft placement. (Endotension is the continued expansion in size of the aneurysm sac without evidence of endoleak. It is thought to be associated with high pressure inside the aneurysm sac and may potentially rupture if left untreated.)

Endoleaks are classified into four types according to the White classification, as given in Box 3 and shown in Fig. 6.

It is important to identify these endoleaks to prevent a possible rupture of the aorta secondary to continued expansion of the aneurysm. Contrast-enhanced CT is the preferred imaging modality to assess the anatomy and migration of the graft as well as to assess for endoleaks.

**Box 3**

**White classification of endoleaks**

- **Type I**: Direct communication between the graft and aneurysm sac via an ineffective seal at the graft ends or attachment sites
- **Type II**: Retrograde flow through lumbar arteries, the inferior mesenteric artery, or accessory renal arteries feeds into the aneurysm sac
- **Type III**: Seen in modular, multisegmental grafts; leak occurs through deficiency in graft fabric and may be a result of altered hemodynamics secondary to aneurysm sac shrinkage
- **Type IV**: On contrast CT appears as a blush of contrast outside the graft from contrast diffusion through the naturally porous graft fabric or through small defects in the fabric at the site of sutures or struts; may require angiography to distinguish from Type III graft

Contrast-enhanced ultrasound, however, is an alternative in patients who have poor renal function. Type 1 leaks demonstrate high-velocity flow at the site of the proximal attachment. Leaks at the distal limb attachment site demonstrate flow in the sac opposite the direction of flow in the lumen. Inferior mesenteric artery flow is antegrade in Type 1 leaks. Type 2 leaks are characterized by slower flow within the aneurysm sac and retrograde flow in the inferior mesenteric artery.

Color Doppler ultrasound is not very accurate (66.7%) in distinguishing the type of endoleak but can detect its presence. It is considered even better than CT for detecting Type 2 endoleaks because of its real-time capability. Contrast-enhanced ultrasound also allows true endoleaks.
to be distinguished from false endoleaks (secondary to clotted blood). Demonstration of an arterial waveform confirms the continuity of the true endoleak with the vessel lumen and differentiates it from pulsating clotted blood. Contrast-enhanced sonography has been reported to have a sensitivity of 80%, specificity of 100%, and a positive predictive value 100% in detecting endoleaks.

**PSEUDOANEURYSM**

A pseudoaneurysm is a focal outpouching from the aorta resulting from the disruption of one or more layers of the aortic wall. Pseudoaneurysms of the abdominal aorta are rare and account for only 1% of all abdominal aneurysms. Their most common cause is trauma, which may be caused by blunt or penetrating injuries or may be iatrogenic secondary to vascular procedures. Pseudoaneurysms may present as late as 27 years after initial injury. They also may develop from large penetrating atherosclerotic ulcers. Rarely, they can be mycotic in origin (e.g., such as tubercular). Most reported cases of pseudoaneurysms have been seen in males, associated with penetrating injuries and involving the suprarenal aorta. They can be identified by the saccular shape with a narrow neck. Doppler ultrasound demonstrates a to-and-fro pattern of blood flow in the neck of the pseudoaneurysm and a yin-yang pattern within the sac.

**AORTIC DISSECTION**

Aortic dissection of the abdominal aorta usually is associated with thoracic aortic dissection and can propagate in either the anterograde or retrograde direction. It classically presents as sudden, severe chest, back, or abdominal pain that is characterized as ripping or tearing in nature and is often likened to renal colic. Atypical presentations often may puzzle the emergency physicians and can lead to delayed management, thus increasing the mortality rate. Therefore a high index of suspicion is necessary for its diagnosis. Hypertension is the major risk factor of aortic dissection. Other etiologies include cystic medial necrosis as seen in Marfan’s syndrome, which is a common cause of dissection in younger population. Focal aortic dissections are seen commonly as extensions of penetrating atherosclerotic ulcers. About 5% of dissections are iatrogenic in nature, caused by the introduction of intravascular catheters.

Predisposing conditions for aortic dissection are listed in **Box 4**.

Ultrasound is not the imaging modality of choice, and if aortic dissection is detected incidentally sonographically, further imaging with contrast-enhanced CT is required to evaluate the exact extent of the dissection. Sonographically, aortic dissection is diagnosed by the identification of an undulating intimal flap, which is very specific for aortic dissection. It is seen as a linear, mobile, hyperechoic structure within the aortic lumen (Fig. 7). The lumen is divided by the flap into a true and false lumen. This flap may be calcified in a few cases (Fig. 8). In acute dissection, the true and false lumens can be identified on color flow Doppler ultrasound as two parallel lumens with or without an entry point from the true lumen into the false lumen. In chronic aortic dissections, there may be thrombosis of the false lumen with nonvisualization of the intimal flap. Such an appearance may mimic an AAA if the aorta is dilated and can be distinguished on ultrasound by the presence of intimal calcification in the inner wall of the thrombus.

Aortic dissection can be mimicked by the presence of layers of mural thrombi of varying echogenicities, which may give a false appearance of two lumens within the aorta. Color Doppler helps to differentiate these entities.

**SUMMARY**

Although ultrasound has a limited role in the emergent evaluation of the aorta, it still has a significant role in screening for AAA and for monitoring after endovascular repair. Awareness of sonographic features of AAA, AAA rupture, and aortic dissection helps identify the problem and enables timely follow-up and management in these emergent cases. Contrast-enhanced ultrasound potentially

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**Box 4**

Predisposing conditions for aortic dissection

- Hypertension
- Marfan’s syndrome
- Ehlers-Danlos syndrome
- Chromosomal aberrations (Turner’s and Noonan syndromes)
- Aortic coarctation
- Pregnancy
- Cocaine use
- Trauma, blunt or penetrating
- Iatrogenic responses
- Atherosclerosis
Fig. 7. Aortic dissection in a patient who has Marfan's syndrome. (A) Longitudinal and (B) gray-scale sonographic images of the abdominal aorta demonstrate a linear, echogenic dissection flap (arrow) within the aortic lumen. (C) Corresponding transverse color Doppler image shows two intra-aortic lumens. (D) Color Doppler image of the aorta more inferiorly demonstrates the entry point (arrow). (E) Corresponding contrast-enhanced axial CT image further confirms the aortic dissection (arrowhead).
has a significant role in assessment of these emergent conditions of the abdominal aorta, but because of the urgency involved, CT often is preferred over ultrasound.

REFERENCES


Fig. 8. Aortic dissection. (A) Transverse gray-scale and (B) power Doppler image of the aorta shows the echogenic dissection flap (arrow), dividing the aortic lumen into two lumens. (C) Corresponding nonenhanced axial CT image further confirms the presence of a calcified dissection flap (black arrow).