Optimal Imaging for Aortic Dissection

Choosing the best imaging modality to assess aortic dissection based on each patient's unique clinical factors.

BY YOUNG-WOOK KIM, MD; YANG-JIN PARK, MD; AND DUK-KYUNG KIM, MD

Aortic dissection (AD) is a dynamic pathology that changes rapidly over time and has a high rate of morbidity and mortality. For this reason, rapid and accurate diagnosis is critical in managing it. Furthermore, ascertaining ascending aorta involvement is crucial, as type A dissections usually require urgent open surgical repair.[1]

Successful management begins with clinical suspicion of AD and prompt, accurate assessment of the aortic anatomy and the presence of any complications of dissection, as well as determination of an underlying aortic pathology. Because evaluation of these factors must be completed in a limited amount of time, choice of the initial diagnostic imaging modality can be crucial.

In current practice, CT, echocardiography, and MRI are typically used to diagnose AD, and among these, CT is the most commonly used imaging modality. Each of the various imaging modalities have their individual advantages and disadvantages, and in order to make the best choice for the patient, several clinical factors must be taken into account. Such factors include the patient's hemodynamic status, urgency of the definitive treatment, anticipated distal extent of the AD, and purpose of the aortic imaging (ie, whether it is to be used for preoperative evaluation, postoperative examination, or serial measurement of the dissected aorta size).

CT ANGIOGRAPHY

CT angiography not only provides an accurate image of the aorta, but it can also reveal complications of AD or coexisting aortic or other organ pathology. In the report of the International Registry of Acute Aortic Dissection in 2002,[2] CT was the most frequently used (75%) primary imaging study in patients with acute AD. In current practice, it may be more frequently used than before.

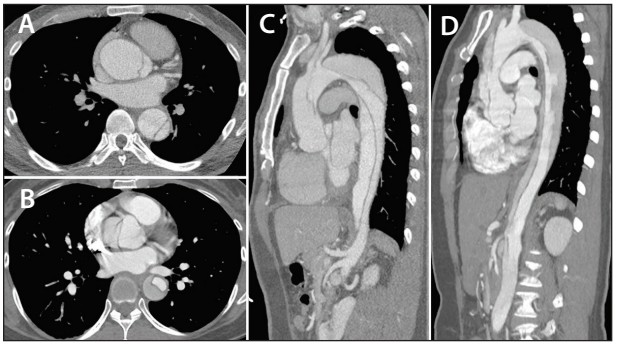

Figure 1. Comparison between ECG-gated (A, C) and non–ECG-gated (B, D) CT angiography in patients with type A AD. Axial (A) and multiplanar reconstructed (C) images of ECG-gated CT allow a precise depiction of AD. On the contrary, axial (B) and multiplanar reconstructed (D) images of non–ECG-gated CT demonstrate "step ladder" and blurring artifacts due to cardiac motion, which interfere with disease evaluation.

Current CT scanning technology can provide high-resolution images within a short time. Furthermore, the ability to perform three-dimensional (3D) volume rendering, maximum-intensity projection, as well as sagittal and coronal reconstructions facilitates pretreatment planning before endovascular or open surgical repair of AD. CT imaging should include the aorta from the level of the neck to the common femoral arteries at the groin (see the *Essential Imaging Information to Ascertain for Patients With AD* sidebar).

A recent multicenter clinical trial reported that thoracic endovascular aortic repair is the preferred

ESSENTIAL IMAGING INFORMATION TO ASCERTAIN FOR PATIENTS WITH AD

- Intimal flap and true/false lumen
- Extension of dissection (type of AD)
- Localization of entry and reentry sites
- Acute versus chronic dissection
- Involvement of tributary branches (branches of aortic arch and abdominal visceral arteries)
- Location of landmark arteries for endovascular treatment
  - -Left subclavian artery
  - -Vertebral artery
  - -Celiac artery
- Complications of AD
  - -Aortic dilatation
  - -Rupture
  - -Cardiac tamponade
  - -Aortic regurgitation
  - -Acute myocardial infarction
  - -Visceral malperfusion
  - -Ischemia of the spinal cord or lower extremity
- Pathology underlying AD
  - -Bicuspid aortic valve
  - -Evidence of hereditary connective tissue disease such as Marfan syndrome or Loeys-Dietz syndrome
  - -Adrenal tumor
  - -Renal artery stenosis
- Other aortic abnormalities
  - -Coarctation
  - -Penetrating atherosclerotic ulcer
  - -Intramural hematoma
  - -Right-sided arch
  - -Retroesophageal anomalous arch vessels
  - -Kommerell diverticulum

treatment for acute, complicated, type B AD, with improved late survival and positive aortic remodeling.[3] When preplanning for endovascular treatment of type B AD, precise measurement of the aortic diameter and segmental length of the aorta around the dissection, as well as the location and position of landmark arteries, are important. Erroneous diameter or length

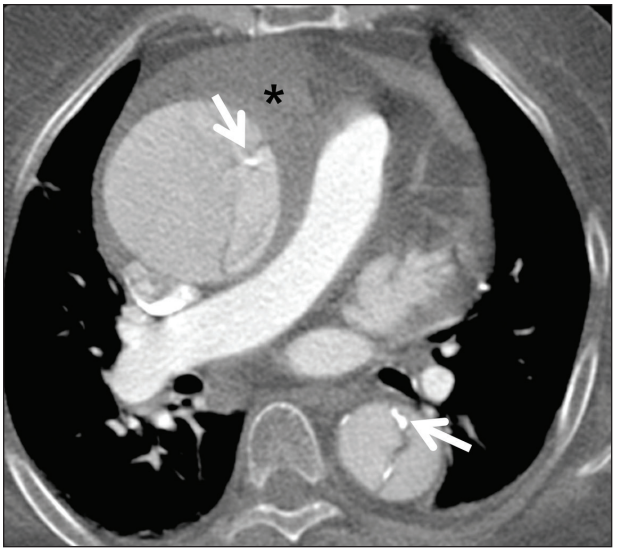

Figure 2. Axial CT image of a patient with a type A AD. The CT scan demonstrates an intimal flap with internal displacement of mural calcification (arrows) and associated hemopericardium (asterisk).

measurements can lead to unexpected procedural complications. The aortic diameter should be measured as an orthogonal diameter to the centerline of flow on reconstructed CT images.

Artifact due to cardiac motion presents a challenge for a static study such as CT. The diagnostic sensitivity decreases to < 80% when assessing the aortic root in patients with type A AD due to cardiac motion artifact. This gray zone of CT examination can be overcome by electrocardiography (ECG) gating or the addition of supplementary transesophageal echocardiography (TEE).

Currently, there are several techniques to improve CT imaging for the evaluation of type A AD. ECG gating allows for more precise depiction of the AD extent without motion artifact, particularly of the proximal segment in the area of the aortic valve (Figure 1).[4] Multidetector CT allows acquisition and multiplanar reconstruction of images in a very short time and is beneficial for hemodynamically labile patients. Proper vascular enhancement is also necessary when performing CT evaluation of AD. Slow injection rates or improper timing of image acquisition after contrast administration may result in incomplete vascular enhancement of the aortic lumen, which obscures visualization of the intimal flap. In addition, an unenhanced false lumen due to insufficient scan time may cause misinterpretation of a patent false lumen as thrombosis of the false lumen.[5]

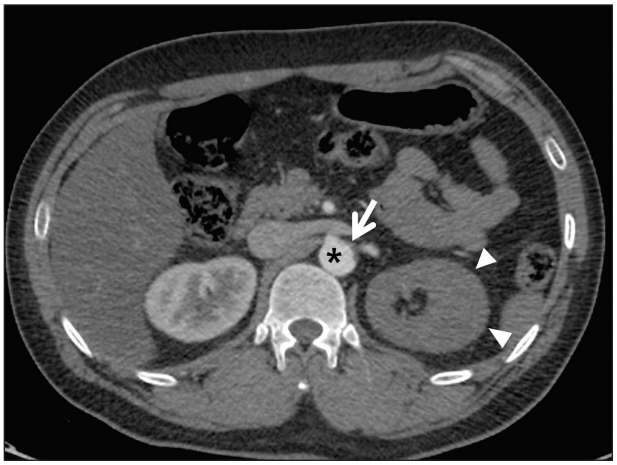

Figure 3. Axial CT image of a patient with an acute type B AD. The true lumen is severely collapsed (arrow), showing severely decreased left renal perfusion (arrowheads) while contrast fills the false lumen (asterisk).

TABLE 1. DIFFERING QUALITIES OF TRUE AND FALSE LUMENS IN AD

	True Lumen	False Lumen
Lumen size	Usually smaller	Usually larger than true lumen
During systole	Expansion	Compression
	Antegrade flow	Reduced antegrade flow or absent or retrograde flow
Localization within the arch	Inner curvature	Outer curvature
Sign of slow flow	Rare	Frequent, depending on degree of communication
Thrombus	Rare	Frequent, depending on degree of communication

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With recent advancements in CT technology and the development of optimally timed contrast injection protocols, "triple rule out" CT has become an established protocol for assessing patients complaining of chest pain who are at low risk for acute coronary syndrome.[6] This tailored ECG-gated CT enables evaluation of aorta and coronary and pulmonary arteries with a single scan, eliminating the need for multiple studies to individually rule out coronary artery disease, AD, and acute pulmonary embolism.

A typical CT finding of AD is the presence of an intimal flap, which separates the true and false lumen. An intimal flap varies in its presentation, including a circumferential and "windsock" appearance.[4,7] Secondary findings of AD include internal displacement of mural calcification, mediastinal widening, and pleural or pericardial hematoma (Figure 2).[4]

Differentiation of the true lumen from the false lumen is important for planning endovascular treatment (Figure 3). The true lumen can be determined by identifying its continuity with the undissected portion of the aorta on contrast-enhanced imaging. Although seemingly straightforward, in practice, it can be confusing. Signs indicative of the false lumen include the "cobweb sign" or the "beak sign," as has been proposed in the literature.[8,9] Table 1 summarizes the differing qualities of true and false lumens.[10]

CT scanning is particularly favorable in patients who have undergone previous aortic surgery or in those with ferromagnetic materials (eg, pacemaker guidewires or defibrillators) that preclude MR examination. Limitations of CT angiography are any conditions in which the use of contrast is contraindicated, such as renal insufficiency, iodine allergy, patients with severe untreated hyperthyroidism at risk of thyroid storm, or those at high risk for radiation exposure (eg, young patients and pregnant women). Contrast-induced nephropathy and allergy can be mitigated by pretreatment.

MRI

MRI is a highly accurate, noninvasive imaging modality for assessing AD with a sensitivity of 95% to 98% and a specificity of 94% to 98%.[11] MRI does not create ionizing radiation or require the use of intravenous iodinated contrast; however, for a more detailed assessment of AD, including aortic branch involvement, gadolinium-enhanced MR angiography (MRA) can improve accuracy.

As with CT, multiplanar imaging with 3D reconstruction is possible, and the addition of techniques, such as cine MRI, allows for differentiation of "slow-flow blood" from thrombus and detection of aortic regurgitation (Figure 4). Owing to its radiation-free noninvasiveness and reproducibility, MRA is the imaging modality of choice for serial evaluation of AD at follow-up.[1]

Despite the advantages of MRI, CT is still most commonly used as the initial imaging technique for patients with suspected acute AD.[2] The primary reason for this is the long scan time associated with MRI, which precludes its use in hemodynamically unstable patients and in emergency settings. In addition, the

presence of metallic implants (eg, cardiac pacemakers or defibrillators) is another limitation to MRA use. Despite its limitations, MRA should be considered in patients with renal insufficiency or a severe allergy to iodinated contrast when CT is contraindicated.

As with other imaging modalities, the characteristic MRI finding of AD is the presence of an intimal flap. Conventional unenhanced MRA techniques, such as two-dimensional and 3D time-of-flight sequences, require a long scan time and are prone to imaging artifacts.[12] Contrast-enhanced MRA is less prone to artifacts related to stent grafts or surgical grafts compared with conventional unenhanced MRA.[13] Breath-hold contrast-enhanced 3D MRA has a shorter imaging time with reduced motion artifact and improved spatial resolution compared with unenhanced MRA, and it has become the imaging modality of choice for patients with stable aortic disease at many institutions.[13] It is important to note that this technique requires an awake, cooperative patient who can hold his or her breath, which is crucial for obtaining optimal images.

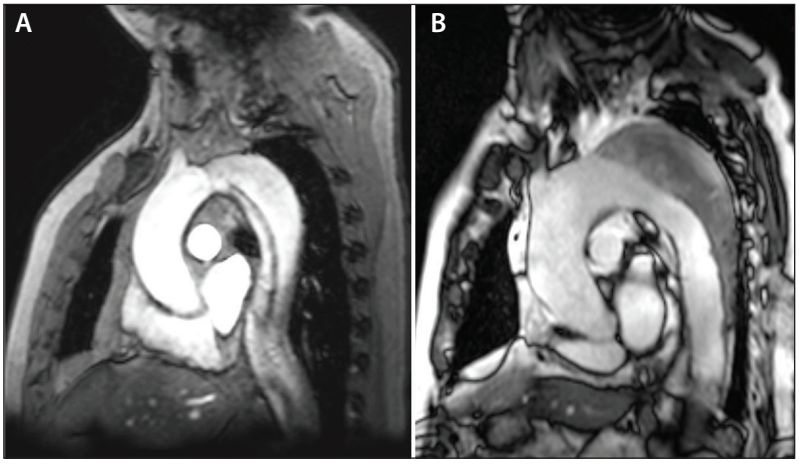

Figure 4. MRA of a type B AD. Oblique sagittal T2-weighted ultrafast spoiled gradient echo image shows the intimal flap extending from the aortic arch to the upper abdominal aorta (A). Oblique sagittal 3D cine image shows a thrombosed AD with the intimal flap extending from the aortic arch to the descending thoracic aorta (B).

Another limitation of MRI is gadolinium-based contrast and its potential hazard for nephrogenic systemic fibrosis in patients with markedly impaired renal function, although the reported incidence is extremely rare.[14,15] Nonetheless, the potential for nephrogenic systemic fibrosis has led to the development of new sequences for nonenhanced MRA.[16] Among these, free-breathing cardiac- and respiratory-gated 3D steady-state free precession MRA using nonselective radiofrequency excitation has been reported as a promising imaging technique for evaluating thoracic vasculature with increased intravascular signal-to-noise ratio in recent studies.[17,18] As the name suggests, this technique does not require patients to hold their breath during image acquisition. It has been reported that unenhanced steady-state free precession MRA is comparable to conventional contrast-enhanced MRA for assessing thoracic aortic pathology, including thoracic AD.[19]

More conventional MR imaging protocols for evaluating the thoracic aorta are the combination of multiple nonenhanced gradient echo (Figure 4A) and spin echo sequences and a contrast-enhanced 3D gradient echo sequence.[20] The total scanning time ranges from 10 to 45 minutes and is therefore applicable for evaluation of hemodynamically stable patients.[19,20] Despite the longer scan time, there are several advantages of MRA over CT, including its noninvasiveness, lower risk for nephrotoxicity, and lack of radiation risk. It is therefore favored for serial follow-up evaluations of AD patients when nephrotoxicity or the cumulative radiation dose can be a concern. Furthermore, cine MRA (Figure 4B) can provide dynamic evaluation of blood flow direction and velocity.[21] This enables surveillance of valvular and cardiac function, which allows for improved detection of complications such as left ventricular dysfunction or valve regurgitation.

TRANSTHORACIC AND TRANSESOPHAGEAL ECHOCARDIOGRAPHY

Transthoracic echocardiography (TTE) has been used to evaluate aortic valve function, cardiac wall motion, and pericardial tamponade. In the evaluation of AD, it is particularly useful to screen AD involving the proximal ascending aorta to just above the sinotubular junction.

For type A AD, TTE has a sensitivity of 78% to 100%, but decreases to only 31% to 55% for type B dissection; TEE has a sensitivity of 99%, with a specificity of 89%.[22-24] In contrast to TTE, TEE is more accurate in detecting AD given the proximity of the esophagus to the ascending and descending segments of the aorta. TEE also allows for visualization in real time. Artifactual echoes may be confused with a dissection flap when evaluating the

ascending aorta, but color flow imaging or M-mode echocardiography will help distinguish an intimal flap from an artifact.

Both TTE and TEE demonstrate AD by identifying an intimal flap separating the true and false lumens.[25] If the false lumen is completely obliterated with echogenic thrombus, central displacement of intimal calcifications can be considered to be diagnostic of AD.[24,26] Also, the entry site can be ascertained by identifying a disruption in the dissected membrane on grayscale images or a communication between the two lumens using color flow Doppler imaging.[27] The primary disadvantage of TEE compared to TTE is the need for esophageal intubation, which can be an issue in patients with esophageal disease (eg, stricture, varix, cancer, diverticulum) or cervical spine stiffness. Furthermore, the examination depends more on operator experience compared to other imaging modalities. The distal ascending aorta and arch branches may be inadequately evaluated in TEE due to a poor sonic window caused by adjacent anatomic structures.[10,28] Nonetheless, considering its ability to be used in hemodynamically unstable patients at the bedside, immediate interpretation, excellent ability to differentiate the true from false lumens, and ability to identify entry/reentry sites, TEE plays a unique role in the assessment of AD. In current practice, TEE is commonly utilized in emergent assessment of AD and intraoperatively.[29]

CONCLUSION

When choosing the proper imaging modality for AD assessment, various clinical and anatomical factors should be considered, and the advantages must be weighed against the disadvantages for each imaging tool. By carefully considering these options, we can provide optimal care for our patients. ■

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