

Multidetector CT in the Evaluation of Thoracic Aortic Disease

The pre-eminent platform for the planning and surveillance of TEVAR patients.

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Computed tomography angiography (CTA) of the thoracic aorta has benefited greatly from the advent of multidetector computerized tomography (MDCT). Three-dimensional reconstruction of large datasets allows easy evaluation of pathological changes of the aorta. This improvement coincides with changes in treating thoracic aortic aneurysms (TAAs) because accurate preoperative assessment is critical to the early and late success in thoracic endovascular aortic repair (TEVAR). This article provides an overview of CTA of the thoracic aorta.

The choice of imaging modality is diverse when thoracic aortic pathology is suspected. Choosing the right study to image the affected area requires an understanding of the anatomy and the limitations of the modality, as well as the clinical scenario of presentation. Common indications for thoracic aortic CTA are shown in Table 1.

As carotid stenting has increased in popularity, the value of thoracic CTA has been shown. Arch evaluation with MDCT reduced the need for “unusual” maneuvers during stent placement in patients who underwent CTA of the thoracic aorta prior to carotid stenting. Recently, direct planimetric measurement of the aortic valve regurgitant orifice area in the diastole using 64-slice MDCT was shown to provide an accurate, noninvasive technique for detecting and quantifying aortic regurgitation.¹ MDCT has also been shown to provide aortic valve area in addition to ejection fraction and coronary artery anatomy.²

ACQUISITION

CT Thoracic Aorta Imaging Protocol

Before beginning the contrast-enhanced scanning, a thick-section (10 mm), unenhanced scan of the chest and the abdomen is performed to visualize the landmarks and to establish the field of view. An additional

benefit of the unenhanced scan is to define mural hematoma. Five-millimeter slices are used to eliminate volume averaging that occurs with thicker slices. Unenhanced scanning is also important to define calcification in the presence of a stent graft that may mimic endoleak after contrast administration.³ Injection pro-

TABLE 1. COMMON INDICATIONS FOR CTA OF THE THORACIC AORTA

- Posttraumatic vascular injury
- Diagnostic test for disease of the thoracic aorta, including aortic dissection, intramural hematoma, aneurysm, and atheromatous disease such as penetrating ulcers and aortitis
- Stent graft evaluation
- Postoperative or postinterventional vascular procedure for luminal patency versus restenosis, as well as complications such as pseudoaneurysms, leaks, and infection related to:
 - Surgical bypass grafts
 - Vascular stents and stent grafts
- As a diagnostic test for congenital abnormalities of the great vessels and thoracic vasculature, including aortic coarctation
- Vascular involvement from neoplasm
- Vasculitis
- Identification of the source for embolism or occlusion (when the suspected source is the thoracic aorta and/or proximal arch arteries)

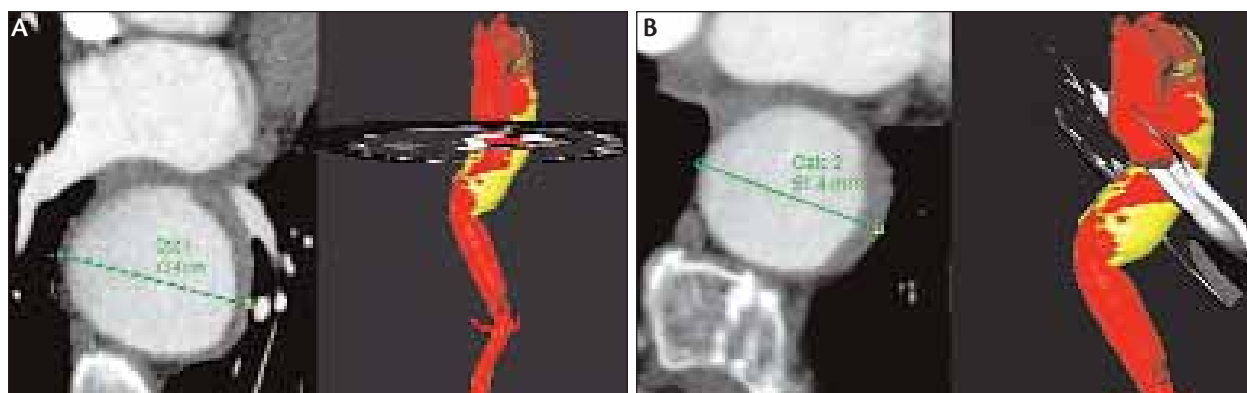


Figure 1. The difference of rotating the plane of the image into a true vascular axial plane for accurate determination of the TAA diameter. Axial plane (A) and MPR (B).

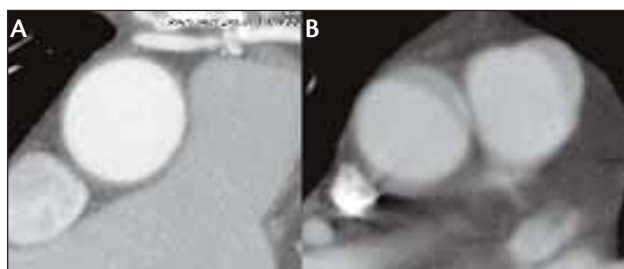


Figure 2. Note the distinct borders on the gated image (left), as opposed to the "double" borders on the nongated image. These occur due to cardiac motion and can be decreased by beta-blockade and gating the study. Gated axial view of ascending thoracic aorta (A), nongated axial view of ascending thoracic aorta (B).

protocols and rates can vary slightly, but we typically use an injection rate of 4 mL/s and 125 mL of contrast (gated thoracic CTA evaluation).

The acquisition of the image is usually started in the base of the neck extending to the point just below the diaphragm. This is performed because the disease processes affecting the aorta (commonly aortic dissection and aneurysm) frequently involve the supra-aortic great vessels and also to evaluate congenital malformations affecting these vessels. If the clinical symptoms warrant doing so, additional scanning to include the runoff vessels is performed. If needed, delayed scans are performed (usually in 2 minutes) to visualize late filling of the false lumen, endoleaks, or contrast extravasations from rupture.⁴ Patients being evaluated for TEVAR are usually scanned to the femoral head.

Postprocessing

Three-dimensional volume-rendering techniques permit real-time, interactive evaluation in any plane and



Figure 3. MIP (coronal plane) showing contrast in the left subclavian vein. The contrast column in the left subclavian vein results in attenuation artifact, making interpretation of the proximal left common carotid artery difficult (arrow). When proximal arch vessels need to be visualized, contrast administration by the left antecubital vein is desirable.

projection. This enhances the understanding of vessel dilatation, mural thrombus, branch vessel anatomy, and further allows visualization of vascular structures and adjacent viscera and airways.⁵ A ductal diverticulum and the presence of aortic dissection can also be frequently identified with this view. The following postprocessing image reconstruction techniques are commonly available:

Multiplanar reconstruction (MPR). Two-dimensional sections with a thickness of 1 voxel across different planes. This mode is very useful in evaluating thoracic aortic disease.

Maximum intensity projection (MIP). The highest attenuation voxel is projected in a ray through the scan volume. We find that along with the volume-rendered

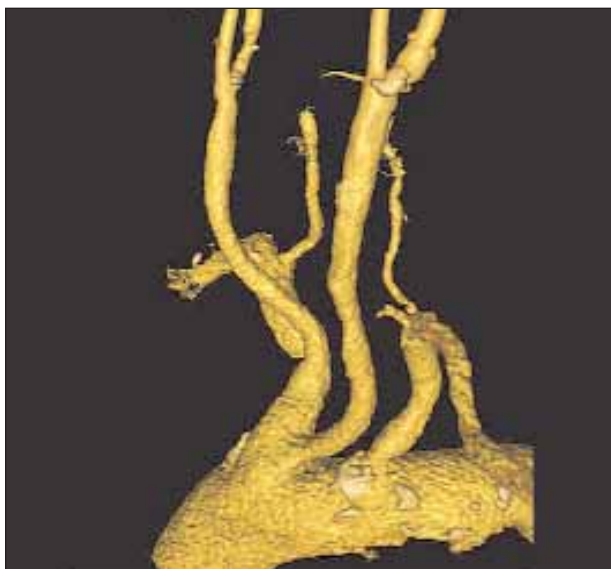


Figure 4. A bovine arch. The left common carotid artery arises from the base of the innominate trunk.

view, curved planar reformations and review of the axial data are most useful in assessing the thoracic aorta. Axial images are important in the review of source data to identify the presence of artifacts and to see the origins of the coronaries and the bypass grafts.

INTERPRETATION OF TAAs BY CTA

The three-dimensional volumetric datasets allow the clinician to rotate the aorta into a number of views to best visualize the aortic pathology. As seen in Figure 1, the axial slice of a TAA may overestimate the degree of dilatation of a TAA, whereas the rotation of the image into a “true vascular axial plane” gives a better representation of the true diameter. Rotating the images in the MPR views can typically achieve this.

Gating by ECG has been proposed by some investigators to be a mandatory addition for ascending aorta CT angiograms.⁶ In our lab, we routinely use ECG gating for thoracic aortic studies, as well as beta blockade to decrease the heart rate. In our experience, this results in a more accurate study by limiting the amount of motion artifact. There is no doubt that gating the CTA will increase the radiation dosage depending on several different factors, including the length of the scan, but this can be modified by modulating the CT dose as it is done in coronary CTA. The exact phase of the cardiac cycle may be less important in thoracic CTA as compared to the coronaries when measuring the diameter; however, one should be aware that the end-systole phase and the end-diastole phase may give slightly different volumes and lengths. This difference becomes



Figure 5. Three-dimensional volume-rendered view of the aortic arch. The right subclavian artery (dotted arrow) arises distal to the left subclavian artery and courses posterior to the trachea and esophagus to cross the midline (see also Figure 6).

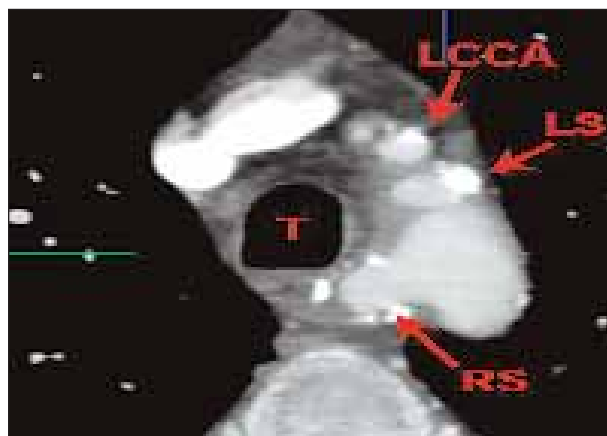


Figure 6. Axial view of the great vessels. The origin of the right subclavian artery in relation to other arterial branches and midline structures in dysphagia lusoria. Note the posterior origin of the right subclavian artery and calcification of the origins of the left subclavian and left common carotid artery. RS = right subclavian artery, LS = left subclavian artery, LCCA = left common carotid artery, T = trachea.

very important for the evaluation of TEVAR in which volumetric changes may predict potential complications after implantation.⁷ Most common artifacts seen during the MDCT of the thoracic aorta are due to cardiac motion (Figure 2). Motion artifacts from aortic wall motion have been shown to simulate the appearance of a dissection flap, particularly in the aortic root

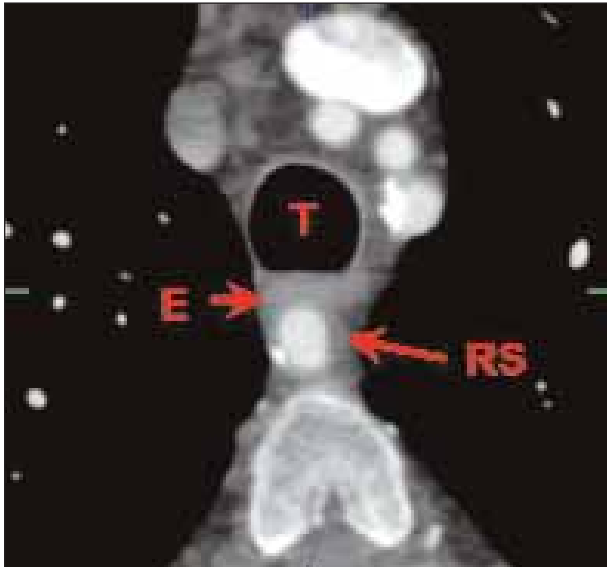


Figure 7. Axial view of the esophagus “constricted” between the right subclavian artery and trachea—dysphagia lusoria.

and the ascending thoracic aorta, leading to an erroneous diagnosis of ascending aortic dissection.⁸⁻¹⁰

Artifacts due to surgical clips and venous contamination and attenuation from adjacent venous structures (Figure 3) are also observed.

NORMAL ANATOMY

The ascending aorta includes the aortic root, as well as the ascending portion of the thoracic aorta. The normal diameter of the aortic root is <4 cm. The ascending aorta usually measures <3.5 cm at the level of the pulmonary artery. The ascending aorta terminates at the level of the innominate trunk. The right and left main coronary arteries arise from their respective sinuses from the aortic root. The aortic arch extends from the innominate trunk to the aortic isthmus. The normal diameter of the aortic arch is 3 cm. The descending thoracic aorta starts at the isthmus and extends to the diaphragmatic crura. A normal descending thoracic aorta measures ≤2.5 mm in diameter.

In approximately 70%¹¹ of the population, there are three vessels arising from the aortic arch. From right to left, they are the innominate trunk, the left common carotid artery, and the subclavian artery. The most common variant is the left common carotid artery sharing an origin with the innominate trunk, which is seen in 13% of the general population. This pattern, along with the left common carotid artery arising from the innominate trunk, has been erroneously named the *bovine arch* (Figure 4).¹² Both of these patterns are seen more frequently in African Americans. A true bovine arch is seen



Figure 8. MIP view. Note the dilated aortic root in a patient with Marfan's syndrome with evidence of a DeBakey type 1 (Stanford classification A) aortic dissection.

in cattle, where a single trunk arises from the thoracic aorta to give rise to the right and left subclavian arteries and a bicarotid trunk. The bicarotid trunk then divides into the left and right carotid arteries.¹³ An aberrant right subclavian artery is the most common vascular ring anomaly in the aortic arch, with a reported incidence of 0.5% to 2% (Figure 5).¹⁴ Although the majority of these patients are asymptomatic, approximately 10% of these patients experience dysphagia due to extrinsic compression on the posterior aspect of the thoracic esophagus—a condition called *dysphagia lusoria* (Figures 5 through 7). An anomalous origin of the left vertebral artery arising from the aortic arch is relatively

common, with a reported prevalence of 2.4% to 5.8%.¹⁵ An anomalous origin of the right vertebral artery is rare. Anomalous origins of vertebral arteries are usually asymptomatic. CTA is an established technique in assessment of the TAA and aortic dissection because it rapidly and precisely evaluates the thoracic aorta to determine the location and extent of the aneurysm and the relationship of the aneurysm to major branch vessels and surrounding structures. CTA can classify the dissection according to DeBakey or Stanford classification. Easy accessibility and speed of the test, especially in an unstable patient, makes MDCT the ideal test in this situation. CTA is valuable in identifying the intimal flap (Figure 8); visualizing branch vessel involvement, pericardial fluid (due to intrapericardial rupture), and periaortic hematoma (aortic rupture); identifying the extent of dissection; and evaluating the size of the hematoma, the patency of the false lumen, and the degree of the true lumen compression. Intramural hematoma is a clinical entity distinct from aortic dissection and is characterized by a high attenuation area within the aortic wall on a noncontrast CT without a visible intimal flap. Conventional angiography usually does not reveal the presence of an intramural hematoma.¹⁶

MDCT of the thoracic aorta is the study of choice to evaluate the thoracic aorta in planning for endograft repair of the TAA. Usually, fine 3-mm slices are performed from the neck to the femoral heads. MDCT aids in evaluating the great vessels to determine the proximal landing zone, establish the patency of the vertebral vessels (stent graft covering the subclavian artery), and determine the common femoral artery access. Traumatic rupture of the proximal great vessels most commonly occurs after blunt chest trauma in high-speed motor vehicle accidents.¹⁷ Aortography has been the traditional investigational method for these patients. With the advent of MDCT, the entire chest can be scanned during a single bolus; this has led to the widespread use of this modality in patients with blunt chest trauma.¹⁸ Multiple studies have documented 100% negative predictive value for MDCT.¹⁹⁻²¹ Compared to angiography, contrast-enhanced spiral CT has not only been shown to be less invasive, less time consuming, and less expensive, but also reveals other injuries requiring rapid intervention.²²

CONCLUSION

CTA is instrumental in diagnosing the pathology of the thoracic aorta and can readily identify dissections, aneurysms, intramural hematoma, and ulcers. CTA of the aortic arch may decrease complications and help

with planning of carotid interventions. CTA is the pre-eminent platform for the planning and surveillance of TEVAR patients. ■

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