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The Importance of Imaging Assessment Before Endovascular Repair of Thoracic Aorta

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Abstract Indications for and experience with placement of endovascular stent grafts in the thoracic aorta are still evolving. Recent advances in imaging technologies have drastically boosted the role of pre-procedural imaging. The accepted diagnostic gold standard, digital subtraction angiography, is now being challenged by the state-of-the-art computed tomography angiography (CTA), magnetic resonance angiography (MRA) and trans-oesophageal echocardiography (TEE). Among these, technological advancements of multidetector computed tomography (MDCT) have propelled it to being the default modality used, optimising the balance between spatial and temporal resolutions and invasiveness. MDCT angiography allows the comprehensive evaluation of thoracic lesions in terms of morphological features and extent, presence of thrombus, relationship with adjacent structures and branches as well as signs of impending or acute rupture, and is routinely used in these settings.

In this article, we review the current state-of-the-art radiological imaging for thoracic endovascular aneurysm repair (TEVAR), especially focusing on the role of MDCT angiography. After analysing the technical aspects for optimised imaging protocols for thoracic aortic diseases, we discuss pre-procedural determinants of candidacy, and how to formulate interventional plans based on cross-sectional imaging.

Since the first thoracic endovascular aortic repair (TEVAR), using homemade devices, published by the Stanford University in July 1992, significant improvements were made in the following generations, which are widely manufactured commercially. However, delivery systems remain large (22F to 24F), relatively rigid and difficult to deploy smoothly and accurately, owing to extensive frictional resistance.[1] Furthermore, hybrid procedures, which combine surgical and endovascular techniques, have expanded the potential applications of stent-grafting to

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more complex situations, such as stent-graft placement anchored to an elephant trunk or TEVAR of the arch. For these reasons, imaging is crucial for patient enrollment, device selection in correlation with the anatomy of the lesion, as well as formulation of a plan for the intervention.

Recent advances in imaging technologies, in part inspired by advancements in stent-graft technology, have drastically changed the character and role of pre-procedural imaging. The accepted diagnostic gold standard, digital subtraction angiography, is now being challenged by the state-of-the-art computed tomography angiography (CTA), magnetic resonance angiography (MRA) and trans-oesophageal echocardiography (TEE). These techniques provide information not only on the aortic lumen but also on the wall and surrounding mediastinal structures. Of these, technological advancements of multidetector computed tomography (MDCT) have propelled it to being the default modality used, optimising the balance between spatial and temporal resolution and invasiveness. In this article, we review the current state-of-the-art radiological imaging for TEVAR, especially focusing on the role of MDCT angiography.

Imaging Techniques Chapter 1

CT angiography

Computed tomography (CT) currently is the most widely used modality in the evaluation of the thoracic aorta due to its high diagnostic accuracy for detection of aortic pathology. MDCT can simultaneously acquire up to sub-millimetric sections with gantry rotation time of approximately 0.5—0.33 s. Respiratory motion artefacts are no longer a problem, since high-resolution imaging of the entire aorta can be obtained in a single breath hold. Imaging of all phases of contrast enhancement has also become possible using a single-contrast agent bolus. Thinner section allows isotropic voxels, essential to obtain high-resolution three-dimensional (3-D) reconstructions in any selected plane. Despite ionising radiation hazards and the nephrotoxicity of contrast agents, the technique is widely available, fast, cost-effective and efficient.

Optimising CT parameters

MDCT scanning requires an understanding of the basic principles for optimum results. Pitch and collimation are two important parameters of image acquisition. The slice thickness is dependent on the detector collimation. The smaller the collimation, the thinner is the available slice thickness. The quality of the 3-D reconstructions is directly related to the thickness of the obtained axial slices. A CT arteriogram should be acquired with the thinnest available collimation (0.625—0.75 mm). Pre-contrast or delayed images can be acquired with thicker collimations (1.5 mm or greater) to reduce irradiation, as they are not used in post-processing. Currently, the standard tube voltage for CTA is 120 kV. The tube current should be approximately 120 mAs, and automated dose modulation should be used. A tube voltage of 100 kV increases the contrast-to-noise ratio because of a more effective X-ray absorption by iodine at lower tube voltages, which improves image quality and reduces patient radiation exposure by 35% in comparison with 120 kV at a constant tube current.[2] Consequently, lowering the voltage during CTA can reduce the volume of required iodinated contrast medium.

Electrocardiographic gating

Although less-frequent with MDCT, the motion caused by transmitted cardiac pulsation to the major arteries may create problems. These pulsation artefacts are particularly pronounced in the proximal ascending aorta and may frequently mimic an intimal flap resulting in a false-positive diagnosis of aortic dissection. Electrocardiogram (ECG) gating can avoid this problem; it is available in new CT scanners and may be applied prospectively or retrospectively. A decision should be made as to the need for ECG gating. As a general rule, if the heart, coronary arteries, aortic root or ascending aorta are to be evaluated, ECG leads should be placed for gating to minimise cardiac pulsation artefacts. Moreover, it has been shown that diameters of the thoracic aorta can change by up to 17.8% through the cardiac cycle.[3] Considering that most clinicians oversize endografts by only 10%, inadequate estimation of the fluctuations in aortic diameters may lead to serious errors of undersizing, hence contributing to the various means of graft failure. For these reasons, the use of ECG gating has been proposed when endograft choice is to be made so that the optimal sizing can be ascertained.

On the other hand, in emergency imaging for chest pain, some authors push the benefits of exploiting a single CT acquisition with the so-called triple rule-out technique to simultaneously explore pulmonary arteries, coronaries as well as thoracic aorta. ({Johnson, 2008 #155,{Urbania, 2009 #156)}.[4–6] We are reticent to embrace this approach as we believe that scans should be tailored for individual clinical questions, given that contrast timing and scanning parameters are much different if only one clinical question needs to be answered, that is, a pulmonary embolism CT is much different from a coronary CTA, where artefacts may limit the study for certain structures while other structures may be better visualised. Moreover, in acute aortic syndromes, we need to have a complete exploration of the aorta at an arterial phase, from the thoracic inlet down to the bifurcation of the femoral arteries for complete assessment, which is not achievable with ECG gating. The coverage suffices to both detect disease extension and assess the delivery route for endovascular devices that might be the preferred therapeutic modality to treat the abnormality.

Contrast-enhancement methods

CT angiography requires intravenous injection of iodinated contrast agents to display the vessel lumen. The use of additional iodinated contrast media in TEVAR candidates can be a problematic clinical issue, especially in patients presenting with multiple co-morbidities where the risk of contrast-induced nephropathy is greatly accentuated. Faster scanners have resulted in shorter scan duration and contrast bolus duration, allowing the use of less contrast agent. This advantage can be used to inject the same amount of contrast at a higher flow rate to achieve a greater luminal enhancement. Right ante-cubital veins are the preferred injection sites because dense contrast in