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Review

Multimodality Noninvasive Imaging of Thoracic Aortic Aneurysms: Time to Standardize?

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ABSTRACT

Aortic imaging is an essential part of a surveillance program for patients with a confirmed or suspected aortopathy because aortic size is crucial for predicting the risk of death, aortic rupture, or aortic dissection. Noninvasive aortic imaging relies on transthoracic and transesophageal echocardiography, cardiovascular magnetic resonance and computed tomography (CT) imaging. Echocardiography and cardiovascular magnetic resonance offer comprehensive anatomical and functional evaluation of the heart, aortic valve, and aorta, and CT is more limited to anatomical data. However, CT is fast, available, and less operator-dependent. There is general consensus that the aorta should be measured at reproducible anatomical landmarks on electrocardiogram-gated images, perpendicular to the blood flow and using multiplanar reconstruction if possible. The method of measurement must be included in the clinical report. Normal aortic size depends on age, sex, and body size. Serial measurements should use identical methods. There is controversy about the inclusion of the aortic wall in the vessel diameter and the trigger time in the cardiac

RÉSUMÉ

L'imagerie aortique constitue un élément essentiel d'un programme de surveillance des patients présentant une aortopathie soupçonnée ou confirmée puisque la taille de l'aorte est un facteur déterminant pour prédire le risque de décès, de rupture ou de dissection aortique. L'imagerie non invasive de l'aorte peut être obtenue par échocardiographie transthoracique et transœsophagienne, par résonance magnétique cardiovasculaire ou par tomodensitométrie. L'échocardiographie et la résonance magnétique cardiovasculaire permettent une évaluation anatomique et fonctionnelle détaillée du cœur, de la valve aortique et de l'aorte. La tomodensitométrie, pour sa part, se limite essentiellement aux données anatomiques, mais a l'avantage d'être plus facilement disponible, rapide à effectuer et moins dépendante de l'opérateur. Il est généralement admis que l'aorte doit être mesurée à des points de repère anatomiques reproductibles sur des images synchronisées à l'électrocardiogramme, perpendiculairement au flux sanguin et, si possible, au moyen d'une reconstruction multiplanaire. La méthode utilisée pour mesurer l'aorte

Thoracic aortic aneurysms often remain asymptomatic until aortic dissection, which occurs in approximately 6 per 100,000 patient-years.[1] The risk of death, aortic rupture, or aortic dissection doubles (8% vs 16%) when the thoracic aorta diameter increases from 35-39 mm to ≥60 mm.[2] In asymptomatic patients, surveillance of aortic size using noninvasive imaging is essential to time a prophylactic surgical intervention when dissection risk exceeds surgical risk. Accepted surgical thresholds vary depending on the clinical situation (Table 1). Open repair is the standard of care for patients with connective tissue disease.[8] Elective aortic root replacement might be performed with a 1.5% 30-day mortality in patients with Marfan syndrome compared with 11.7% for emergent repair.[9]

Echocardiography, cardiovascular magnetic resonance (CMR), computed tomography (CT), and CT angiography (CTA) can be used for surveillance and postoperative imaging of the thoracic aorta. Standardization of aortic imaging, although crucial for longitudinal follow-up, has proved challenging because of the variety of available techniques. In this review our aim was to summarize how to image, measure, and follow-up thoracic aortic aneurysms, and highlight concepts that reached consensus and areas of controversy. Comprehensive guidelines documents are also available.[3,4,8,10]

How to Image the Thoracic Aorta?

Aortic anatomy is complex and it is recommended to describe and measure the aorta at identifiable landmarks (Fig. 1). The proximal ascending aorta is usually measured at the level of the right pulmonary artery. Complete assessment of the thoracic aorta is achieved by combining the strengths of multiple imaging modalities (Table 2). Conventional angiography is not routinely used outside of the interventional setting and will not be discussed.

Chest radiograph

Although the yield of a chest radiograph is limited in thoracic aortic disease, subtle signs might be clues of an

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cycle for measurement, although diastole is more reproducible. The best method to measure the diameter of the sinuses of Valsalva remains unclear. Imagers and clinicians should pay close attention to the aorta measurement techniques and weigh the clinical implications of modification of their institutional protocols.

doit être indiquée dans le rapport clinique. La dimension normale de l'aorte dépend de l'âge, du sexe et de la taille du patient. Les mesures sériées doivent toujours être effectuées à l'aide de la même méthode. L'inclusion de la paroi aortique dans le diamètre du vaisseau est actuellement controversée. Il en va de même pour ce qui est de la phase du cycle cardiaque, mais la diastole est plus facilement reproductible. En outre, la meilleure méthode pour mesurer le diamètre des sinus de Valsalva demeure encore incertaine. Les spécialistes en imagerie et les cliniciens devraient accorder une attention particulière aux techniques utilisées pour mesurer l'aorte et bien peser le pour et le contre d'une modification des protocoles de leur établissement.

underlying aortopathy.[11] Mediastinal widening on the posteroanterior film might suggest ascending aortic dilatation. The left para-aortic interface might show an increased convexity possibly related to tortuosity of the thoracic descending aorta, aneurysm, or dissection. In case of suspected aortic dissection, chest radiograph findings might include mediastinal widening, a double density at the lateral aspect of the aortic arch, displacement of intimal calcification, mass effect on adjacent trachea, esophagus, or left main bronchus, or an apical cap and pleural effusion (more often left-sided). The lateral chest film might show a narrow posteroanterior diameter and a pectus excavatum deformation, raising the possibility of a connective tissue disease, such as Marfan or Loeys-Dietz syndrome. Because the chest radiograph is not sensitive (64%) or very specific (87%) for aortic disease, further diagnostic evaluation is recommended if subtle abnormalities of the aorta are noted.[12]

Echocardiography

Echocardiography is recommended as a baseline imaging modality in most aortopathies (Table 3). We will discuss transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) but not intracardiac echocardiography, which is covered in other reviews.[10]

TTE. Assessment of the thoracic aorta using TTE begins in the left parasternal long-axis view (Supplemental Fig. S1), which shows the aortic root, including the aortic annulus, sinuses of Valsalva, sinotubular junction, and proximal tubular aorta along with the left ventricle (LV) outflow tract (LVOT).[14,15] Sliding the probe cephalad reveals more views of the ascending aorta to show supravalvular stenosis (Supplemental Fig. S1D). Normally, the aortic root and left atrium (LA) are of equal dimension in the parasternal long-axis view. Asymmetric aortic leaflets that appear to prolapse during closure and dome in systole suggest a bicuspid aortic valve and restricted thickened leaflets suggest aortic stenosis. Colour flow imaging might reveal aortic regurgitation, turbulent systolic flow suggestive of stenosis, or loss of sinus integrity in the rare case of sinus of Valsalva rupture.[16] Clockwise rotation of the probe reveals the parasternal short-axis view displaying the cross-sectional view of the normally tricuspid aortic valve (Supplemental Fig. S2A). The presence of a bicuspid, unicuspid, or quadricuspid aortic valve can readily be confirmed in this view (Supplemental Fig. S2, C, E, and G).

The examination proceeds to the apical windows, which reveals the 4-chamber view in which a transverse cut of the descending aorta can be obtained posterolaterally to the LA. Upward tilting from the 4-chamber view reveals the 5-chamber view that shows the LVOT, aortic valve, and aortic root (Supplemental Fig. S3). Continuity equation and proximal isovelocity surface area methods might be used to quantify aortic regurgitation.[16] Clockwise probe rotation from the 4-chamber view reveals the 2-chamber view. A slight lateral tilt from this view might reveal a longitudinal view of the distal descending thoracic aorta and upper abdominal aorta behind the LA. Further clockwise rotation reveals the 3-chamber view, and shows the same structures as the parasternal long-axis view from the apical perspective. LV volumes and function measurements using the apical views with 3-dimensional (3-D) or multiplane Simpson method of discs is a more reliable method than parasternal LV dimensions but both techniques underestimate LV volumes compared with CMR.[14,17] The examination then proceeds to the subxyphoid views, which show the subcostal 4-chamber view. Clockwise probe rotation reveals the short-axis of the aortic valve leaflets and a longitudinal view of the abdominal aorta (Supplemental Fig. S4). A limited abdominal ultrasound examination focused on the aorta might be added to the TTE examination to rule out abdominal aortic aneurysm.[18]

The examination next moves to the suprasternal views, where pointing the probe marker toward the left scapula reveals the usual (left) aortic arch and brachiocephalic vessels and identifying aortic coarctation or patent ductus arteriosus (Supplemental Fig. S5) and occasionally atheromatous plaques (Supplemental Fig. S6). Rightward anterior tilting of the probe might reveal the distal ascending aorta. A circular aortic arch with a left brachiocephalic vessel should raise the possibility of a right aortic arch. Counter clockwise probe rotation toward the right scapula might then confirm its presence. In the presence of good acoustic suprasternal windows, the descending and ascending aorta can be assessed in the coronal plane. Finally, the TTE examination is concluded by turning the patient in the right lateral decubitus to assess the ascending aorta in a longitudinal view, with the marker positioned cephalad. This view probably provides the closest probe position to the ascending aorta, even enabling Doppler assessment of ascending aortic flow acceleration using a nonimaging (Pedoff) probe. Although challenging, a diagnosis of type A dissection of the ascending aorta can be occasionally made using a combination of left and right parasternal long-axis views (Supplemental Fig. S1, E and F).