Helical CT evaluation of aortic aneurysms and dissection
A pictorial essay

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Abstract

The relative noninvasive nature, easy accessibility, convenience and accuracy of helical CT in the rapid evaluation of not only the aorta and its branches, but the entire thorax/abdomen, makes it the best suited imaging modality for use in evaluation of aortic aneurysms and dissection. Excellent vascular opacification, the advantage of reconstructing overlapping scans without respiratory misregistration, multiplanar reconstruction and 3D rendering of the vessels highlight the benefits of helical CT. Helical CT evaluation combines the advantages of conventional CT, giving true information about the exact transverse and longitudinal extent of the aneurysm, the vessel wall, luminal thrombus and structures around the aorta, and those of aortography in the form 3D volumetric information display. The purpose of this essay is to present a spectrum of aortic aneurysms and dissection to highlight the role of helical CT in their evaluation.

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1. Introduction

Aortic aneurysm is a frequently encountered disorder in cardiovascular practice [1]. Its incidence has increased multifold, likely due to increased life span and improved detection. Most common cause of aortic aneurysm formation is atherosclerosis. Male gender, smoking, advanced age and family history are risk factors for atherosclerotic aneurysms [2]. Other causes include cystic medial necrosis (primary, Marfan’s syndrome, Ehler-Danlos syndrome), vasculitis (Takayasu’s arteritis, giant cell arteritis, rheumatoid arteritis), infection (syphilis, mycotic, tuberculosis), trauma or the result of dissection [3].

Dissection is the most common acute catastrophe involving the aorta, which occurs by spontaneous longitudinal separation of media. Hypertension is the main predisposing cause. Whether secondary to hypertension or connective tissue disease, the mechanism of dissection is likely related to aortic dilatation and shear stress. Commonly dissections propagate in the antegrade direction. Intimal dissections involving the abdominal aorta almost always extend from the thoracic aorta [3]. Various systems based on anatomic characteristics have been proposed to classify aortic dissection.
DeBakey describes the three types of aortic dissection [4]. In type I, the intimal tear originates near the root of the aorta and extends distal to the left subclavian artery. In type II, it originates near the aortic root and extends up to the origin of innominate artery. In type III, it develops immediately distal to the left subclavian artery and may extend into the abdomen. In the widely used Stanford classification, type A dissection involves the ascending aorta and type B dissection refers to that which is distal to the left subclavian artery [5].

2. CTA technique

CTA combines a rapid bolus intravenous injection using a pressure injector with a timed breath hold and spiral CT acquisition during peak arterial opacification. Curved planar reformations and 3D reformations using maximum intensity projection (MIP), and shaded surface display (SSD) following segmentation and editing of bony and other unwanted structures, give excellent visualization of the aorto-iliac circulation and the major branch vessels [6–13].

It is important that the patient receives no oral contrast before CTA because it would hamper 3D editing. Hyperventilation just before the scan acquisition should be performed routinely to enable a good uninterrupted breath hold without discomfort to the patient. Preliminary scans without intravenous contrast are obtained to localize the dilated segment as well as to demonstrate the aortic wall calcification. A noncontrast CT would also identify any acute thrombosis in aneurysm lumen or in the false lumen of a dissection and would appear hyperdense. This is followed by the CTA, taking care to include normal aorta above and below the lesion. If thoracic aorta is involved, ascending aorta and arch should always be included. If the patient has dissection, entire aorta should be scanned.

We routinely inject between 120 and 150 ml of contrast at a rate of 3–4 ml/s for our patients. The scan delay time is adjusted between 12 and 16 s from the onset of contrast injection. Helical CT is performed during a single breath hold at 3–5 mm (mostly 5 mm) collimation and 7.5 mm/s table speed with a pitch of 1.5–2, depending upon the volume of scan and breath holding capacity of the patient. Scanning is done in craniocaudal direction. Scan reconstruction is done at 2 mm (overlapping thin section) for making 3D images. The data set is then utilized for generating curved planar reformations and 3D rendering where MIP, SSD are reconstructed.

3. Aortic aneurysm

The strict definition of an aneurysm is a localized, irreversible dilatation of the aorta. In the elderly, the radiographic definition is typically reserved for focal dilatation greater than 3 cm [14]. Because of its decreased scan time, CTA is the imaging study of choice in suspected leaking aneurysm and rapid evaluation is imperative in such circumstances [15–17]. The evaluation of the location of the aneurysm and its extent is important for its management and CTA exactly delineates the site and extent of the lesion (Figs. 1–4). The longitudinal extent can be particularly well seen on 3D images. The extension of aneurysm into common, external or internal iliac arteries is also accurately demonstrated. This helps determine the type and length of prosthetic graft. CTA clearly displays the different shapes of aneurysm, whether saccular or fusiform (Figs. 1 and 2).

The line of management largely depends on the size of the aneurysm as the risk of rupture rises with the size. CT scan accurately defines the size of aneurysm. CTA (axial images) have the advantage of demonstrating the aortic wall thickening, calcification and luminal thrombus, thus, displaying the true axial extent of the aneurysm, as the aortography or 3D MIP and SSD images display only the

Fig. 1. Aortic aneurysm: (A) axial image shows large fusiform aneurysm of descending thoracic aorta with wall calcification and eccentric thrombus. The left atrium and pulmonary vein are displaced anteriorly. Partial collapse of left lower lobe is also seen. (B) SSD image of the same patient shows aneurysm of entire descending thoracic aorta. A “curvilinear shell,” which represents calcification, is seen around the aneurysm, which cannot be interpreted without the help of axial images. The surface of ascending aorta is irregular due to linear, horizontal cardiac pulsation artifacts.
enhancing lumen of the vessel (Fig. 5). The wall calcification can also be well seen on MIP images, but is impossible to identify or difficult to interpret on SSD images (Figs. 1B and 2B,C). These wall parameters are also important features in establishing the etiology of aneurysm and in decision making for further management. It should however be noted that measurement based purely on the basis of axial images can be potentially misleading. Tortuosity of the aorta can lead to false estimation of aneurysm size or extent (Fig. 3). Tortuosity can be easily assessed on 3D SSD images. MIP images on the other hand can be confusing in this regard, which do not give a sense of depth or perspective to the image.

The site of origin of aortic branches and their relation to the aneurysm (Fig. 6) and presence of branch stenosis (Figs. 7 and 8) is crucial from management point of view. CTA is able to display clearly the branch vessels in relation to the aneurysm. The axial (Figs. 6–8A) and SSD (Figs. 4B and 5B) images are particularly useful while MIP can be confusing in this regard (Figs. 4A and 8B). The involvement of renal arteries and the effect on the kidneys can also be evaluated at the same time (Figs. 5A, 7 and 8A). Additionally, presence of anatomical variants such as accessory renal arteries can also be evaluated.

CTA also has the advantage of demonstrating the adjacent structures and can provide information about coexistent nonvascular abdominal disease that may be of relevance to the surgeon [18]. Pleural effusion, ascitis, associated lung collapse and displacement of adjacent blood vessels (Fig. 1A), bowel loops, etc. can be confidently detected.
The radiographic findings of a ruptured aneurysm include periaortic hemorrhage, break in the intimal calcification, an intramural high attenuation opacity, and extravasation of intraluminal contrast media.

4. Aortic dissection

The hallmark of imaging in dissection is the identification of the intimal flap which partitions the aorta into the true and false lumina. Such a partitioning formed by the intimal flap is found in approximately 70% of cases [5]. The true and false channels may be distinguished by differential enhancement brought about by variations in flow (Fig. 9).

The two most important steps in the evaluation of suspected aortic dissection are to confirm or rule out dissection and to identify the type of dissection. The risk
of acute aortic insufficiency, occlusion of the coronary vessels, or rupture of the dissection into the pericardium is extremely high (approximately 90%) in type A dissection and necessitates immediate replacement of aorta [5]. The risk is lower in type B dissection, which can be controlled medically unless there is aortic rupture or renal or visceral vascular compromise. CTA affords excellent evaluation of the entire aorta to evaluate the proximal as well as distal extent of the disease and detects ischemic branch involvement that can increase the morbidity and mortality [5]. Both axial as well as 3D images are complementary in conceptualization of the dissection and to communicate the relationship of true and false lumen viz a viz the major arterial branches taking off from the aorta (Figs. 9 and 10).

The status and site of origin of aortic branches is very important from the surgical point of view. Aortic branch involvement in the form of osteal narrowing or dissection can be reliably shown on CTA. Dissections that extend to the abdomen most commonly spiral on the left posterolateral side of the aorta. This most often spares the origins of the celiac, superior mesenteric artery and right renal arteries, which arise from the true lumen, although exceptions do exist [3]. The left renal artery can arise from the false lumen. Spiraling is a typical appearance of dissection and is clearly demonstrated in both axial and 3D image.

MIP is able to show the mural thrombus which may be seen usually in the false lumen because of the slow flow. Aortic intimal calcification, if present, is displaced towards the true lumen, and can be easily seen (Fig. 10). The extent of aneurysm can be delineated, although multiple views maybe required to show the tortuous course of aorta and the origin/involvement of aortic branches. In addition, differential contrast density in true and false lumina are well demonstrated (Fig. 9). The limitation of MIP, however, is that it does not provide the idea of depth of a structure and hence, visceral branches overlapping with the lumen of the aorta cannot be seen separately. Consequently, there is
difficulty in determining the site of origin (true or false lumen) of these branches.

SSD has the advantage to demonstrate the irregularity of aortic wall and extent of the lesion. Tortuosity is also better seen in SSD. SSD images are more easily understood by the vascular surgeon. Caution is, however, required in selecting the range of threshold attenuation values. Calcification and differentiation of the true and false lumina cannot be identified.

Both CT and MRI accurately demonstrate intimal dissections, with CT having the advantage of shorter scan times (especially with multislice scanners) and easy availability. Unlike MRI, CTA is, however, unable to demonstrate aortic regurgitation precisely. Spiral CT provides excellent evaluation of intimal flaps within the aortic branches, restriction of flow into the branches from compression by the false lumen, and intimal flap fenestration.

Fig. 8. Thoraco-abdominal aneurysm: (A) MIP image shows extensive irregularity and calcification of a dilated thoraco-abdominal aorta in a patient of aorto-arteritis. Meandering collateral formation from the inferior mesenteric artery is seen supplying the blocked superior mesenteric artery. (B) Axial section shows renal artery stenosis soon after its origin with a smaller right kidney.

Fig. 9. Dissection type 1: (A) MIP and (B) MPR show type 1 aortic dissection. Differential density of contrast is seen in true (better enhancing) and false lumina. Arch vessels, celiac and superior mesenteric arteries are arising from the true lumen. (C) Axial CTA image at aortic root shows the intimal flap to good advantage. The true lumen shows better enhancement. Left coronary artery is seen to arise from the true lumen.
Compared to this, DSA has the disadvantage of limited-view angle, single lumen opacification [3] and can be quite confusing to interpret especially in the situation of complex dissections (Fig. 10).

5. Conclusion

CTA is an excellent imaging modality for comprehensive evaluation of aortic aneurysm and dissection, combining the
The marked reduction in examination time, increased contrast resolution, its minimally invasive technique, fewer potential complications and reduction in cost makes CTA the single best investigation for evaluation of aortic aneurysm and dissection.

References