Updates on Computed Tomography Imaging in Aortic Aneurysms and Dissection

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Computed tomography (CT) is a primary imaging modality for the diagnosis of aortic diseases, because of its minimal invasiveness and agility. Prompt and accurate diagnosis is crucial especially for acute aortic diseases, and the guidelines for acute aortic dissection recommend the use of CT for initial diagnosis. For the follow-up observation of longstanding aortic diseases, the strategy of imaging management by CT must be different from that for emergency and acute phases. In this review, we document the differences in characteristics and clinical course between aortic aneurysm and aortic dissection and explain the use of recent CT techniques in diagnosing short- and longstanding aortic diseases.

Keywords: computed tomography, aortic aneurysm, aortic dissection

Introduction

Computed tomography (CT) is the preferred mode of diagnostic imaging for acute aortic diseases, because of its least invasiveness and high agility. Recent advances in CT include increased number of rows, increased speed of gantry rotation, electrocardiography (ECG)-synchronization, and improved spatial resolution. However, radiation exposure and the use of an iodine contrast agent are the major limitations of CT, warranting caution.

Prompt and accurate diagnosis is important for acute aortic diseases, and guidelines for acute aortic dissection1) recommend the use of CT for initial diagnosis. However, the strategy of imaging management by CT for follow-up observation of longstanding aortic diseases must be different from that for emergency and acute phases.

The etiology and clinical course of aortic aneurysm and aortic dissection are extremely diverse. Although their pathologies are different, their pathogenesis is not independent and overlap to a certain degree.2)–6)

In this review, we discuss the differences in characteristics and clinical course of an aortic aneurysm from those of an aortic dissection and describe the use of recent CT strategies in diagnosing acute and chronic aortic diseases.

Technical Improvements on Recent CT Imaging

Multi-detector rows

Recent standard of multi-detector rows is 64-rows system.7,8) With helical scanning technique, such CT scanners have wide z-axis coverage in one scan with single breath-holding. High-end scanners with 128 or more rows9) also have the potential to shorten the scan duration, improve spatial resolution, and/or scan an organ in a single gantry rotation without moving the patient’s table.

Improvement of spatial resolution

The spatial resolution of recent scanners is up to 0.5 mm,10) with certain state-of-the-art scanners reaching a spatial resolution of up to 0.25 mm.11) High spatial resolution allows for the definitive evaluation of side branches and small tears of the intimal flap or ulcerations of the aortic wall.

Improvement of temporal resolution

Typically, patients with aortic diseases are older, and strict breath-holding during the scanning process is a challenge for this population. To overcome this challenge, tempo-
Dual energy imaging
For dual energy imaging, there are different concepts to obtain different energy spectrum data.

Scanning with switching tube voltage is the most popular concept. Rapid tube voltage switching is the typical method that brings different X-ray spectral data during one gantry rotation. The characteristics of this method are concurrent with phasic data, but the technique is associated with lower image quality due to the half amount of data obtained for each spectrum. Tube voltage switching on each gantry rotation is another method. Dual source CT is another concept for dual energy imaging. Orthogonal configuration of X-ray tube enables rapid scanning and/or acquisition of different spectral data sets in one gantry rotation.

Contrast Enhancement
Contrast enhancement is essential for a detailed evaluation of the image especially in patients with acute conditions. However, the contrast agent used for contrast enhancement could pose a risk of renal insufficiency especially in the elderly population. Therefore, the contrast media must be chosen considering the benefit of definitive imaging diagnosis versus the load and side effects of the contrast agent.

Typically, intravenous administration of the contrast agent has lower effect on renal function than transarterial administration. However, to reduce the adverse effects on renal function, optimal amount of the contrast media must be used.

Aortic Aneurysms versus Aortic Dissection
Aortic aneurysm is usually associated with atherosclerosis. Aortic aneurysm is a condition wherein the aortic diameter is >1.5 times larger than the reference range. Aneurysms occur either in fusiform or saccular shape, with saccular aneurysm being associated with higher rupture risk. In most cases, aneurysms are incidentally found on plain chest X-ray, ultrasound sonography, CT, or magnetic resonance imaging images, without typical symptoms but for the presence of a pulpable or pulsatile mass in the abdomen. When the patient complains of pain at the aneurysmal site, impending rupture should be differentiated from other non-emergent diseases that bring similar symptom. Typically, surgical indication for an aneurysm is based on its shape and diameter. Because the normal diameter of the aorta differs based on the position, the cutoff aortic diameter for the surgical indication of aortic repair is different between thoracic and abdominal aorta. The difference of diameter between the ascending aorta and descending aorta must be noted; the definition of aortic aneurysm is usually considered as “thoracic” aorta. The normal diameter or cutoff diameter of the thoracic aorta is the mean value of the diameters of the ascending aorta, aortic arch, and descending aorta.

Aortic dissection is a longitudinal tear in the aorta and is associated with disruption of the aortic wall media. Classical aortic dissection is the disruption of the aortic wall with intimal tear. Original lumen of the aorta is the true lumen, whereas the new lumen that is formed following the disruption of the aortic wall is the false lumen. A proximal intimal tear usually acts as an entry point for blood flow into the false lumen. Of the multiple intimal tears that usually exist, the distal intimal tear most probably acts as the re-entry point. In the case of small or lack of the distal intimal tear, thrombosis or enlargement of the false lumen occurs. The inner layer of dissected aortic wall is the intimal flap. Although dissection usually exists on the aortic wall, it often extends to the branch arteries. The extension of the dissection and the anatomical relationships between the intimal flap and branch arteries result in a complex dissection pathology. Dynamic or static obstruction of branch arteries causes organ ischemia, a severe complication of aortic dissection. Ascending aortic dissection is frequently associated with severe cardiac or neurological complications. Therefore, diagnosing the presence of dissection and intimal tear at the ascending aorta is crucial.

CT Imaging of Aortic Aneurysms
The emergent status of an aortic aneurysm is either immediate rupture or impending rupture. Although contrast...
enhancement is indispensable to evaluate the lumen and the aortic wall, the use of non-contrast (plain) CT must also be considered for a definitive diagnosis. Notably, acute hematoma or thrombus shows marginally higher density than the blood or chronic mural thrombus. A high crescent attenuation is often observed in patients with an impending rupture of the aortic aneurysm. In case of local pain at the site with high crescent attenuation, impending rupture is highly suspected. In the case of aneurysm rupture, it is crucial to identify the point of rupture. The amount or extension of hematoma is the important clue for its identification. Rupture at the ascending aorta can frequently cause cardiac tamponade. At the descending aorta, mediastinal hematoma at the posterior mediastinum is observed. Typically, a hematoma surrounds the esophagus behind the left atrium (Fig. 1).

In the case of non-ruptured aortic aneurysms, it is important to evaluate the diameter and shape of the aneurysm. For the measurement of aneurysmal diameter, the maximum short axis diameter is used for most fusiform aneurysms. However, because measurement of the maximum short axis diameter is inadequate for saccular aneurysms, evaluation on reformatted images, such as multiplanar reformation, must be considered. The absolute diameter and expansion speed are important factors to determine the indication of surgical or interventional (endovascular) aortic repair.

In preoperative cases, characteristics of the aortic wall are important. Also, the amount and location of calcification and aortic plaque, as well as the tortuosity and diameter of aorta and major branch arteries must be noted.

CT Imaging of Aortic Dissection

For acute aortic dissection, the use of ECG gating is recommended for reducing motion artifact due to heartbeat. Detection of aortic dissection and intimal tear at the ascending aorta is important for planning the operative procedure, especially for determining the surgical approach site.

The basic imaging procedure must contain both plain and contrast enhancement CT. On the contrast-enhanced CT, images on both arterial phase and equivalent phase need to be obtained.

Plain CT is important for detecting a fresh thrombus at the false lumen in an acute aortic dissection. Fresh thrombus shows slightly higher density than blood, chronic organized thrombus, and atheromatous plaque on plain CT (Fig. 2), although the detection of the slight high density of the acute thrombus becomes difficult if contrast enhanced. Therefore, the acute and chronic aortic dissections can be differentiated based on the density of the thrombus on a plain CT.

The entire anatomical extent of the dissection is well detected on the arterial phase images. Concurrently, the images of the arterial phase are useful for detecting the delay of arterial blood flow due to arterial stenosis or occlusion by dissection. Importantly, the detection of an intimal tear must also be done on the arterial phase images.

The images of equivalent phase are beneficial for detecting the extent of the mural thrombus, especially in the false lumen. In the arterial phase, the false lumen is not enhanced if the blood flow in the false lumen is considerably slow, making it highly difficult to distinguish whether or not the false lumen is thrombosed (Fig. 3). In addition,
organ ischemia is well detected on the images of equivalent phase because the contrast between damaged and non-damaged area of the solid organ is obvious.

Ulcer-like projections (ULPs)\(^{20,21}\) and intra-mural blood pools (IBPs)\(^{22}\) are often associated with worsening of the aortic dissection, warranting a careful review. The radiological findings of ULPs and IBPs are highly similar, but ULPs focus only on the consequences of intimal lacerations (Fig. 4), whereas IBPs are essentially defined as the result of branch vessel destruction due to aortic dissection (Fig. 5). Therefore, ULPs are also detected in the ascending aorta, whereas IBPs are only observed in the descending and abdominal aorta. Generally, IBPs are thought to be less dangerous than ULPs.

The Role of CT Imaging for Aortic Disease

As discussed, CT is an indispensable and useful diagnostic imaging method for aortic diseases. CT plays an important role especially in the initial diagnosis. However, the radiation dose and the contrast agent toxicity must always be considered before ordering a CT. Indications and strategies for using CT should be carefully considered based on the chronic or acute state of the aortic dissection.

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