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Review Article

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 dissection[1)] 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 rows[9)] 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-

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ral resolution of recent scanners have been increased to 0.275–0.35 s/rotation, which helps greatly reduce motion artifacts.[12]

Scanning with electrocardiography gating

Scanning techniques with ECG gating have enabled seeking an adequate cardiac phase, to reduce motion artifacts because of the heartbeat. In aortic diseases, the motion of the ascending aorta primarily depends on the heartbeat. Also, the dynamic motion of the thin intimal flap especially in patients with acute aortic dissection causes severe artifact. Thus, imaging with ECG gating could help detect precisely the intimal tear at the ascending aorta.[7,13]

Revised reconstruction techniques

Filtered back projection has been a standard for the reconstruction of CT images from raw acquisition data. The recently introduced iterative reconstruction (IR) technique is being widely used in clinical settings. Use of IR technique helps reduce noise of the images and dose of the scanning.[14]

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.[15] 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.[16] 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.[17] 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.[18] 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.

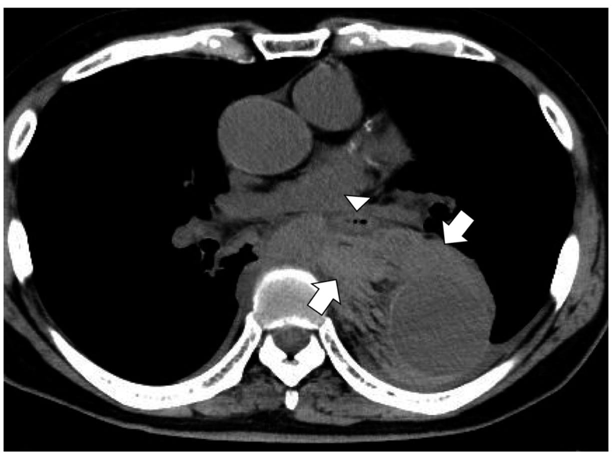

Fig. 1 Ruptured thoracic aortic aneurysm at the descending aorta.
Massive hematoma behind the left atrium is seen (arrows). Esophagus is also shifted forward due to compression by the hematoma (arrowhead), suggesting that the location of the ruptured point is at the descending aorta.

CT Imaging of Aortic Dissection

For acute aortic dissection, the use of ECG gating is recommended for reducing motion artifact due to heartbeat.[7,19] 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,

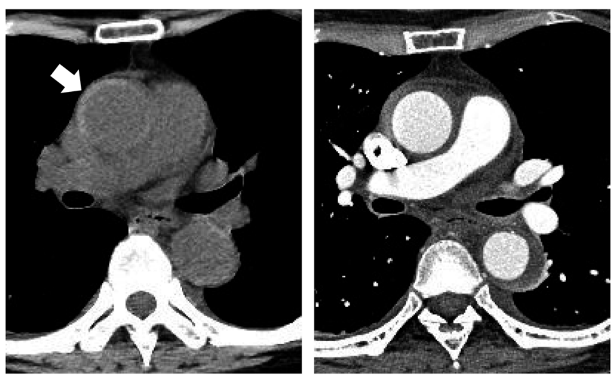

Fig. 2 Increased density of the acute thrombus in the false lumen.
Acute thrombus in the false lumen has marginally higher density than blood on the plain computed tomography (CT) (arrow) (**A**), whereas such high density is difficult to detect on the contrast-enhanced CT (**B**).

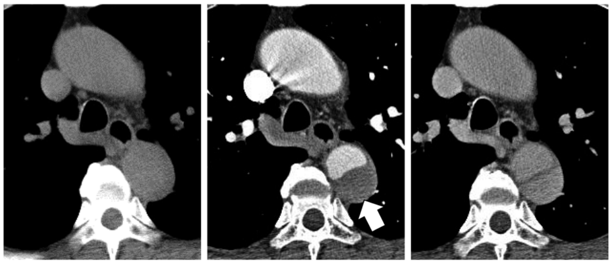

Fig. 3 Delayed enhancement of false lumen due to slow blood flow.
A: Plain computed tomography. **B**: Early phase of contrast enhancement. **C**: Delayed phase of contrast enhancement. Contrast enhancement of the false lumen depends on the flow speed of blood. On early phase of contrast enhancement, in the case of slow flow, the false lumen is often not enhanced (**B**: arrow). Delayed phase of contrast enhancement should be obtained for evaluating a thrombosed dissection or intra-mural hematoma.

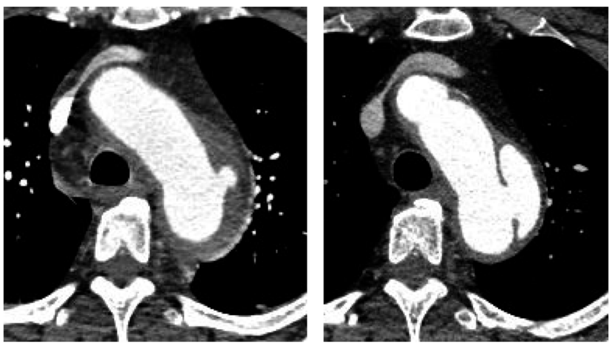

Fig. 4 Ulcer-like projection (ULP).
ULP is a term representative of the luminal morphology initially observed on angiography and indicates the disruption of intima due to aortic dissection. **A**: ULP is seen on the aortic arch in a case of acute aortic dissection. **B**: Two months later, the ULP has enlarged.

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.

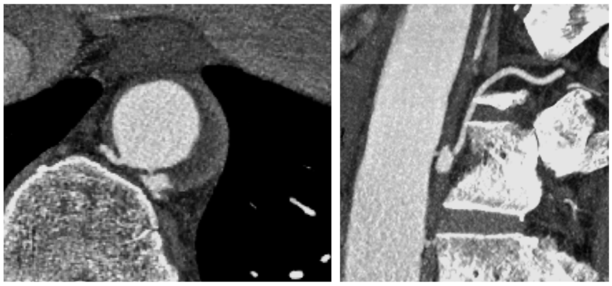

Fig. 5 Intra-mural blood pool (IBP).
IBP is a tiny blood pool in the false lumen caused by the disruption and transection of intima at orifice of branch vessels such as intercostal artery (**A**: axial image, **B**: parasagittal image). Therefore, IBP essentially has continuation to a branch artery, although it is difficult to differentiate ulcer-like projection from IBP when the branch artery is occluded.

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.

Disclosure Statement

All authors do not have any conflict of interest.

Author Contributions

Clinical investigation and data collection: all authors
Writing: RT
Critical review and revision: all authors
Final approval of the article: all authors
Accountability for all aspects of the work: all authors

References

1) [Guidelines for diagnosis and treatment of aortic aneurysm and aortic dissection (JCS 2006)]. J Cardiol 2007; **50**: 547-77.
2) Wada H, Sakata N, Tashiro T. Clinicopathological study on penetrating atherosclerotic ulcers and aortic dissection: distinct pattern of development of initial event. Heart Vessels 2016; **31**: 1855-61.
3) Akutsu K. Etiology of aortic dissection. Gen Thorac Cardiovasc Surg 2019; **67**: 271-6.
4) Humphrey JD, Schwartz MA, Tellides G, et al. Role of mechanotransduction in vascular biology: focus on thoracic aortic aneurysms and dissections. Circ Res 2015; **116**: 1448-

61.
5) Tamura K, Sugisaki Y, Kumazaki T, et al. [Atherosclerosis-related aortic dissection]. Kyobu Geka 2000; **53**: 194-201. (in Japanese)
6) Oderich GS, Kärkkäinen JM, Reed NR, et al. Penetrating aortic ulcer and intramural hematoma. Cardiovasc Intervent Radiol 2019; **42**: 321-34.
7) Johnson TR, Nikolaou K, Wintersperger BJ, et al. ECG-gated 64-MDCT angiography in the differential diagnosis of acute chest pain. AJR Am J Roentgenol 2007; **188**: 76-82.
8) Abbas A, Brown IW, Peebles CR, et al. The role of multi-detector-row CT in the diagnosis, classification and management of acute aortic syndrome. Br J Radiol 2014; **87**: 20140354.
9) Liu D, Liu J, Wen Z, et al. 320-row CT renal perfusion imaging in patients with aortic dissection: a preliminary study. PLoS One 2017; **12**: e0171235.
10) Prokop M. Multislice CT angiography. Eur J Radiol 2000; **36**: 86-96.
11) Motoyama S, Ito H, Sarai M, et al. Ultra-high-resolution computed tomography angiography for assessment of coronary artery stenosis. Circ J 2018; **82**: 1844-51.
12) Hara T, Urikura A, Ichikawa K, et al. Temporal resolution measurement of 128-slice dual source and 320-row area detector computed tomography scanners in helical acquisition mode using the impulse method. Phys Med 2016; **32**: 625-30.
13) Hiratzka LF, Bakris GL, Beckman JA, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation 2010; **121**: e266-369.
14) Singh S, Kalra MK, Do S, et al. Comparison of hybrid and pure iterative reconstruction techniques with conventional filtered back projection: dose reduction potential in the abdomen. J Comput Assist Tomogr 2012; **36**: 347-53.
15) So A, Hsieh J, Imai Y, et al. Prospectively ECG-triggered rapid kV-switching dual-energy CT for quantitative imaging of myocardial perfusion. JACC Cardiovasc Imaging 2012; **5**: 829-36.
16) Flohr TG, McCollough CH, Bruder H, et al. First performance evaluation of a dual-source CT (DSCT) system. Eur Radiol 2006; **16**: 256-68.
17) JCS Joint Working Group. Guidelines for diagnosis and treatment of aortic aneurysm and aortic dissection (JCS 2011): digest version. Circ J 2013; **77**: 789-828.
18) Siegel CL, Cohan RH, Korobkin M, et al. Abdominal aortic aneurysm morphology: CT features in patients with ruptured and nonruptured aneurysms. AJR Am J Roentgenol 1994; **163**: 1123-9.
19) Gruettner J, Henzler T, Sueselbeck T, et al. Clinical assessment of chest pain and guidelines for imaging. Eur J Radiol 2012; **81**: 3663-8.
20) Sueyoshi E, Matsuoka Y, Imada T, et al. New development of an ulcerlike projection in aortic intramural hematoma: CT evaluation. Radiology 2002; **224**: 536-41.
21) Bosma MS, Quint LE, Williams DM, et al. Ulcerlike projections developing in noncommunicating aortic dissections: CT findings and natural history. AJR Am J Roentgenol 2009; **193**: 895-905.
22) Wu MT, Wang YC, Huang YL, et al. Intramural blood pools accompanying aortic intramural hematoma: CT appearance and natural course. Radiology 2011; **258**: 705-13.