Imaging Techniques in Improving Image Quality of CT Angiography: What are the Latest?

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Learning objectives

The aim of this exhibit is to review various latest imaging techniques that can improve the image quality and diagnostic utility of CTA.

Background

CT angiography (CTA) has been established as the first line imaging modality for evaluation of vascular anatomy and pathology. It plays a vital role in diagnosing and monitoring conditions such as stenosis, occlusion, thrombo-embolism, aneurysm, dissection, bleed and endoleak of a stent graft. Its advantages in comparison to digital subtraction angiography (DSA) are shorter acquisition time, non-invasive nature, less procedural complications and the ability to study soft tissue structures around the blood vessels. These are especially useful in the emergency setting.

CT angiographic image quality is described in terms of contrast, spatial resolution, image noise and artifacts. The vessel assessment on CTA can be limited by a) motion, such as from cardiac and aortic pulsations and breathing (Figure 1), b) beam-hardening artifacts from vessel wall calcifications and adjacent metallic clips and coils that can obscure the vessel lumen, and c) poor contrast opacification of vessel lumen due to inadequate contrast dose, cardiac dysfunction, arterial or venous steosis, contrast column interruption related to breath-hold or wrong timing of CT acquisition.

Images for this section:
**Fig. 1:** Axial image of a contrast enhanced CT pulmonary angiogram showed cardiac and aortic pulsation artefacts (arrow) in pulmonary artery and ascending aorta.
Imaging findings OR Procedure details

A number of techniques are available for improving image quality of CTA include:

1. **Temporal resolution**

   Increased number of multi-detector rows up to 320, dual tube configuration and faster rotation time in modern CT scanners produce superior temporal resolution which can be down to 66 msec.

   Latest development of soft-ware motion correction technique, eg. Snapshot freeze (GE Healthcare, Milwaukee, USA), may further lower the temporal resolution down to 28 msec (1)(Figure 2).

   All these can produce superior temporal resolution and help correcting motion artifact from cardiac and aortic pulsations, breathing and body motion With these techniques, the vessel definitions can be defined down to small vessel caliber of 1mm.

2. **Lowering KVP**

   The K-edge of iodine is 33.2 keV. Obviously, the maximum contrast in CTA using iodinated contrast could be obtained by using a monochromatic beam of radiation of energy just above 33.2 keV. This is, however, not practicable in the body scanning (2). With the aid of iterative reconstruction, CT acquisition can now be lowered to 80KVP from the standard 100-120KVP that result in contrast optimization within the vessel lumen and facilitates the detection of luminal and vessel wall pathology and contrast leak (Figures 3 & 4).

3. **ECG-gating**

   Most modern CT scanners have ECG-gating facility that limits the pulsation artifact from heart and aorta leading to superior vessel wall and luminal clarity (3,4) (Figure 5). Vessel clarity is of high importance in the examination, such as CTPA, as motion artifact degrades vessel borders and may lead to erroneous diagnosis of pulmonary embolism (5). This ECG gating in particular enhances the clarity of the subsegmental branches of the pulmonary arteries in the medio-basal segments of both lower lobes adjacent to the heart border (Figure 6).

4. **Model-based iterative reconstruction (MBIR) and knowledge-based iterative reconstruction (KBIR)**
The latest MBIR and KBIR not only reduce the radiation dose in CT scanning, but are able to reduce image noise, improve low subject contrast detectability and minimize some of the blooming artifact from dense calcified plaques in vessel walls (6-10). These better delineate the vessel luminal and adjacent soft tissue details (Figures 7 & 8).

5. **Fine-focal spot CT scanning**

Two (standard and fine) focal spots are found in x-ray tube of CT scanners. The advancement in tube technology and better cooling system allow the employment of fine focal spot for CTA scanning. The fine-focal spot in x-ray tube minimizes the penumbra effect of x-ray (11,12,13,14) (Figure 9) and, therefore, improves vessel wall clarity and reduces calcium blooming artifact (Figure 10 & 11).

6. **Dual energy scanning**

In dual-energy CT, two CT datasets are acquired with different x-ray spectra, which are generated using different tube potentials. Several technical approaches, such as sequential acquisition, rapid voltage switching, dual-source CT, layer detector, quantum-counting detector, can offer different spectral contrast and therefore dual energy acquisition (15). Spectral information is then obtained. Dual energy can optimize contrast opacification in vessel lumen by lowering KeV (Figure 12), and remove calcium and metal artefacts (Figure 13). It can also provide an added benefit of an iodine/perfusion map that may aid the diagnosis.

7. **Single photon metal artifact reduction technique**

Metal within the computed tomography (CT) field of view causes streak artifact that degrades the diagnostic quality of the processed images. This is related to the high Z-number of most metals and is physically due to a combination of beam hardening, scatter, edge effects and photon starvation. The recently developed single photon metal artifact reduction software technique removes metal artifact from coils, clips and adjacent prosthesis to allow improved view of adjacent vessels, soft tissue and bone details (16-18) (Figure 14). This software technique also helps to remove blooming artefacts from calcified plaques in vessel walls.

8. **Colour image display according to attenuation value**

The arteries may be obscured by the adjacent veins, or vice versa, in CTA due to un-intended early or late contrast enhancement. By applying different colour display according to the attenuation values of contrast in vessel lumen help distinguishing the vessel of interests from other non-interested vessels (Figure 15).
9. **CT-Digital Subtraction Angiography (CT-DSA)**

When advanced subtraction technique is applied on dynamic CTA on wide area detector scanner, it produces CT DSA and renders dynamic information of vascular pathology including the direction of flow (Figure 16), and arterial supply and venous drainage of a lesion (14). It also allows better assessment of vessel lumen, in particular, those vessel segments that courses through bones or obscured by calcified plaques (Figure 17).

**Images for this section:**

![Image](image_url)

**Fig. 2:** Axial images of aortic root showed degradation of aortic root and aortic valvular details due to cardiac pulsation artefacts (a), which was markedly improved by the motion correction software (Snapshot freeze) (b).
Fig. 3: Coronal image from a contrast enhanced CTPA scanned at 80KVp demonstrated good contrast opacification in pulmonary arteries to the periphery. Pulmonary emboli (arrow) are noted.
**Fig. 4:** Coronal image with volume rendering technique from a contrast enhanced CT AV fistulogram scanned at 80KVP showed good contrast enhancement of the AVF where there was a tight stenosis in the draining cephalic vein in the forearm (arrow).
Fig. 5: Coronal image from an ECG-gated CT thoracic aortogram revealed aortic root dilatation. There was no motion artefact in the aorta. Aortic valves could also be visualized (arrow).
**Fig. 6:** Axial image of the left lower zone from contrast enhanced CTPA showed motion-free heart border and adjacent pulmonary vessels when ECG gating was applied (a) compared to non-ECG tagged image (b).

**Fig. 7:** Axial image from contrast CTA of abdominal aorta displayed an endoluminal aortic stent graft with the metal struts. The aortic stent graft and aortic contour were better depicted on images with model based iterative reconstruction (b) than that with statistical iterative reconstruction (a) due to reduction of image noise.
**Fig. 8:** Contrast renal CTA showed bilateral renal artery stenoses of >50% due to both calcified and non-calcified plaques, which were better defined on model based iterative reconstruction images (b) than the statistical iterative reconstruction image (a). These were due to reduction of image noise and less blooming artefact from the larger calcified plaques (b).
**Fig. 9:** This diagram demonstrated that the area of blurriness expanded as the focal spot size increased. Therefore, use of fine focal spot in CT scanning could produce image sharpness.

**Fig. 10:** Axial images of CTAA demonstrated common iliac stents bilaterally. The fine focal spot CT scan produced less streak artifact from the iliac stents (b) compared to the standard focus CT scan (a). The vessel, soft tissue and bone details were of better clarity in fine focal spot CT images (b).
**Fig. 11:** Sagittal images of CT chest and abdominal angiography demonstrated an aortic dissection extending from the aortic arch to the abdominal aorta. The intimal flap was more clearly depicted on the fine focal spot CT scan (b) with much sharper contour. The superior mesenteric arterial wall was also noted to have a better vessel definition on the fine focal spot CT scan (b).

**Fig. 12:** Routine dual energy contrast CTPA performed at 100KVP showed suboptimal contrast opacification of pulmonary arteries (a), and the contrast appearances in pulmonary artery improved when 70 KeV was selected from spectral imaging (b).
Fig. 13: Dual energy contrast CT cerebral angiogram demonstrated strong aliasing artifacts from a GDC coil in a cerebral aneurysm partly obscuring the adjacent cerebral arteries (a). Manipulation of different energy levels minimized the degree of aliasing artifacts (b).

Fig. 14: Coronal reformat from contrast CT cerebral angiogram showed an aneurysmal clip that produced aliasing artifacts obscuring adjacent right middle cerebral artery (a). The artifacts were markedly reduced after the application of single photon energy metal reduction software, and as such, the right middle cerebral artery was better displayed (b).
**Fig. 15:** Coronal CT cerebral arteriogram reformatted by MIPS showed degraded cerebral artery details due to partial obscuration by adjacent contrast contaminated cerebral veins (a). By displaying the images in colour display according to attenuation values of contrast improved visualization of cerebral arteries (b).
Fig. 16: Representative images (a to d) from CT-DSA in lateral projection showed an arteriovenous malformation (AVM) (arrow) in frontal lobe which had an arterial supply from anterior cerebral artery and a venous drainage into adjacent superior sagittal sinus. The CT-DSA provided the dynamic information of the AVM.
Conclusion

CTA has become first line imaging method for many vascular conditions. The image quality can, however, be limited by motion and blooming artefacts and poor contrast in vessel lumen.

CT technology is rapidly advancing. CTA is a prime example of utilizing some of these latest techniques that lead to superior diagnostic image quality with no compromise of radiation dose.

Radiologists are no longer just imaging diagnosticians, but are also forefront technological experts who are able to guide the development and applications of new imaging techniques for appropriate clinical settings, and keep transforming radiology into future. These will result in better patients' care, and at the same time, gaining stronger confidence from clinicians.

Personal information

References


