Strategies to Improve Image Quality on Dual-Energy Computed Tomography

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KEYWORDS

- Dual-energy CT • Image quality • Virtual monoenergetic images • Artifact • Metal

KEY POINTS

- Dual-energy computed tomography (DECT) is a promising modality that offers several advantages over conventional single-energy CT.
- Sources of potential image quality degradation may exist that are related to either the technical factors or the image reconstruction methods specific to DECT platform type.
- Familiarity with solutions to such potential sources of suboptimal image quality is crucial for routine clinical adoption of DECT.

INTRODUCTION

Dual-energy computed tomography (DECT) has gained much promise as a diagnostic modality. Through simultaneous (eg, dual-layer detector DECTs) and near-simultaneous (eg, single source, rapid kilovoltage-switching DECT [rsDECT] and dual-source DECT [dsDECT]) low- and high-energy acquisition, it offers several advantages and capabilities over conventional polychromatic images. These capabilities include material decomposition analysis (eg, iodine quantification), generation of material density images (**Fig. 1**), and reconstruction of virtual monoenergetic images (VMIs) across a wide x-ray energy range (ie, 40–190 keV).[1–3] VMIs have several advantages over conventional polychromatic images, including decreased susceptibility to beam hardening, improved image quality, and metal artifact reduction.[4–9] Moreover, VMIs at lower energy levels (eg, 50–60 keV) have increased iodine contrast as they approximate the K-edge of iodine, resulting in improved lesion conspicuity and vascular and parenchymal enhancement.[10] Such clinical value has led to widespread adoption of dual energy for several CT protocols across practices.[11] Although early momentum of rapid clinical adoption and use of DECT was plagued by image quality issues and noise, current DECT technology has allowed exceptional image quality and areas of improving it for certain niche applications (eg, metal artifact reduction). In this article, the authors review common sources of image-quality degradation that may exist because of the inherent dual-energy technology and acquisition and known strategies that overcome these limitations that have allowed routine usage of DECT in busy clinical practices. Based on the experience of the authors, this article focuses specifically on the rsDECT and dsDECT platforms.

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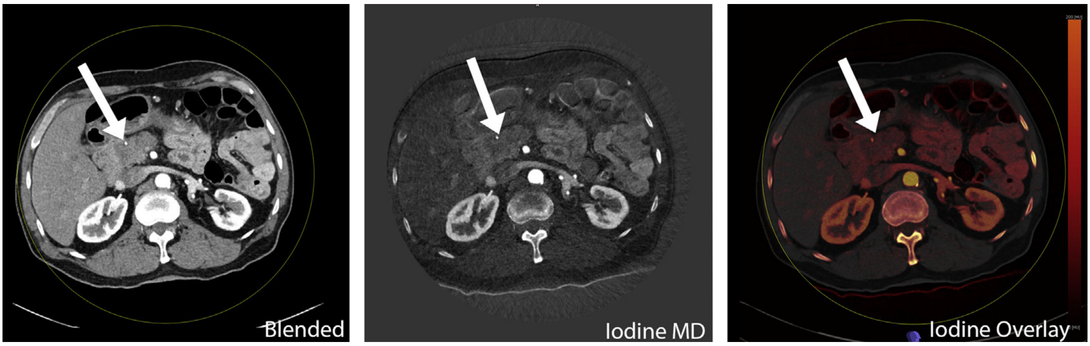

Fig. 1. Axial enhanced blended 120-kVp (50% tube A/50% tube B) equivalent image (*left*) shows a pancreatic head adenocarcinoma (*arrow*). Notice the increased lesion conspicuity on the iodine material density (MD) image (*middle*) and iodine color overlay image (*right*).

SPECTRAL SEPARATION

One of the major advantages of DECT is to allow quantitative compositional analysis of a given tissue, a task not possible with conventional attenuation measurements using single-energy polychromatic imaging. The CT number for a given voxel is related to the linear attenuation coefficient, which in turn is based on the atomic number of the elements, density, and the energy level.[12] For human tissue, 2 different elements with different densities may have similar attenuation at a given energy level. Consider, for example, tissues containing dense iodine or faint calcification, both of which may appear similar. However, with DECT, attenuation measurement at a second energy level would allow material differentiation.[1,2,12] The greater the degree of spectral separation of the low- and high-energy tube output used for dual-energy scanning, the greater the capability, reliability, and quality of material decomposition.[13] Traditionally, 80 kVp and 140 kVp commonly represented the low- and high-energy tube voltage settings, respectively, to achieve the spectral separation. This high and low energy selection affected image quality that necessitated a solution for both the rsDECT and dsDECT platforms.

Rapid-Kilovolt Switching Dual-Energy Computed Tomography

The second- and third-generation rsDECT scanners operate by using a single x-ray source that rapidly switches between 80 and 140 kVp during each rotation, with a fast switch time of 0.25 milliseconds. However, because of the significant tube ramp up and down between the high and low tube voltage, independent filtration and tube current modulation are not possible. Additionally, the rapid switching time between the high- and low-energy projections results in relatively decreased maximum x-ray flux.[2,12,14] Thus, without corrective strategies, each acquisition would result in images with poor quality attributed to photon starvation. In an effort to account for the aforementioned technical limitations, asymmetric sampling with 2 projections at the low tube voltage and one at the high tube voltage is acquired. This increase in sampling time allows the tube current-time product (milliampere) to be increased despite the lack of tube current modulation.[12] This increased sampling of the low tube voltage projection comes at a cost of associated increase in noise. To offset the noise, adaptive statistical iterative reconstruction techniques (ASIR and ASIR-V) are used.[2]

Dual-Source Dual-Energy Computed Tomography

Unlike the rsDECT, the dsDECT platforms are equipped with 2 x-ray sources and 2 x-ray detectors that have an angular offset. Because each tube is independent, tube current modulation and independent filtration is possible. The high-energy tube output can be filtered with a 0.4-mm tin (Sn) filter placed distal to the bowtie filter. This filtration results in a greater spectral separation between the low- and high-energy tube outputs.[13,15] This separation in turn translates to improved material decomposition. Using 80 kVp for the lower-energy tube output may potentially limit large patients from being scanned with DECT because of photon starvation. However, Sn filtration allows increasing the tube voltage for the larger tube A from 80 to 100 kVP for the second-generation dsDECT scanner or from 90 to 100 kVp for the third-generation scanner. Finally, the third-generation dsDECT scanner (ie, force) achieves a greater separation than the second-generation scanner by increasing the voltage setting of the larger tube A (ie, 150 Sn vs 140 Sn).

Another well-known potential technical source of image quality degradation of the dsDECT platform is the limited field of view (FOV) for scanning