Dual-Energy Computed Tomography

Physical Principles, Approaches to Scanning, Usage, and Implementation: Part 2

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KEYWORDS

• Dual-energy CT • Virtual monochromatic images • Weighted average images
• Basis material decomposition • Iodine maps • Virtual unenhanced images
• Spectral Hounsfield unit attenuation curves • Workflow

KEY POINTS

- Most clinically used dual-energy computed tomography (DECT) scanners can be used in single-energy or dual-energy mode, except for the layered detector scanners that always acquire data in dual-energy mode.
- DECT scans can be routinely obtained with acceptable doses similar to single-energy CT (SECT), with similar or even slightly better quality (or, conversely, lower dose for the same image quality) in some instances.
- Acquisition in DECT mode also enables generation of additional reconstructions or more sophisticated quantitative analysis not possible with conventional SECT acquisition.
- Commonly used DECT image reconstructions include virtual monochromatic images, weighted average or blended images, and material decomposition maps.
- Workflow friendly implementation is a key consideration and important for implementation of DECT into routine clinical practice.

DUAL-ENERGY COMPUTED TOMOGRAPHY IMPLEMENTATION AND USAGE IN CLINICAL PRACTICE: PRACTICAL CONSIDERATIONS

Different Modes of Acquisition with Current Dual-Energy Computed Tomography Scanners and Implications

Most dual-energy computed tomography (DECT) scanners currently in clinical use, such as dual-source scanners (Siemens AG, Forchheim, Germany) or rapid kilovolt peak (kVp) switching scanners (GE Healthcare, Waukesha, WI), can perform acquisitions in either single-energy computed tomography (SECT) or DECT mode. Indeed, in practice, when the additional information provided by the DECT mode is deemed to be superfluous for the clinical question at hand,

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these scanners are often operated in the SECT mode. DECT scanning has specific workflow requirements and implications, some of which are discussed later in this article or in an accompanying article in this issue on routine use of DECT scanning for neck imaging. It is therefore to be expected that a proportion of studies performed on such scanners will be performed in SECT mode, and the exact proportion would vary depending on the type of practice and patient population. However, using a DECT scanner *exclusively* in SECT mode does not take advantage of its full capabilities and defeats the purpose of having such a scanner. The only exception to this rule may be the case of a *dual-source* computed tomography (CT) that is primarily devoted to cardiac imaging where the 2 sources are used simultaneously to improve temporal resolution. As a reminder, with most DECT systems, a scan obtained in SECT mode will not be amenable to spectral characterization any more than one acquired using an SECT scanner.

The ability to switch modes of acquisition on these scanners also implies that DECT scanning must be planned and specified beforehand. A practical strategy for efficiently protocoling studies in a radiology department with DECT capability involves developing algorithms for determining which studies should be performed in DECT mode. The decision to acquire scans in DECT mode may be based on a specific referral pattern (eg, all neuro-oncology or head and neck oncology studies), specific highly specialized studies for very selective clinical questions (eg, all studies after intra-arterial interventions for ischemic stroke to distinguish hemorrhage from iodinated contrast), or it may be based on more broad criteria or even routinely based on the body area and/or certain indications (eg, all head CTs; all adult neck studies). These algorithms are likely to evolve as additional studies become available demonstrating applications and potential advantages of DECT technology. However, such algorithms will also likely be significantly impacted by the ease (or lack thereof) of integration into the clinical environment and workflow, in terms of processing effort, time at the CT console, and ability to analyze and reconstruct additional images at the time of clinical interpretation.

One exception to the need for preplanning a DECT scan is the layered or "sandwich" detector scanner (Philips Healthcare, Andover, MA) that is now commercially available. Because spectral separation is based on the detector structure and design, these systems always acquire scans in "DECT mode" and therefore enable retrospective spectral evaluation for all scan acquisitions. Because of this, with this type of scanner, preselection of scans for acquisition in DECT mode is unnecessary, although it may still be desirable to have preset protocols that determine automatic generation of additional reconstructions of interest for certain scan types and indications.

Radiation Dose and Image Quality

Before implementing DECT for routine clinical use, there are 2 basic requirements. First, images acquired in DECT mode should be at least equivalent to those obtained using standard SECT mode in terms of image quality. Second, the acquisition must be made with an acceptable (preferably, equivalent or lower) patient radiation dose. Once these 2 fundamental requirements are met, the additional postprocessing capabilities made possible by DECT mode are essentially for "free," without any dose or image quality penalty or the need for additional patient scanning (**Box 1**).

Image quality and dose are interrelated, and in effect, for practical purposes, any discussion of one should take the other into consideration. Therefore, strictly speaking, a valid evaluation and comparison of 2 different systems or acquisition modes should be based on a comparison of the dose required to achieve a similar image quality. One way in which image quality can be evaluated is based on image noise, with higher-quality images being less noisy. Image noise may be evaluated subjectively or quantitatively, the latter typically done by measuring the standard deviation (SD) within a region of interest (ROI) either placed on the image just outside a phantom or patient or alternatively within a tissue of interest.[1–4] Other measures of image quality include those related to contrast that can also be evaluated subjectively or quantitatively by different methods.[1–6] It is important to take these factors into account when

Box 1
Dual-energy computed tomography: essentials

- Basic DECT reconstructions generated for routine clinical interpretation have *at least* similar quality to conventional SECT images acquired with a similar dose.
- With current clinical scanners, DECT acquisition with an acceptable radiation dose similar to that of SECT is possible on a routine basis.
- Acquisition in DECT mode also enables generation of additional reconstructions or more sophisticated quantitative analysis not possible with conventional SECT acquisitions.