Pearls, Pitfalls, and Problems in Dual-Energy Computed Tomography Imaging of the Body

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KEYWORDS

• Dual-energy CT • Computed tomography • Abdominal imaging • Iodine-selective imaging

KEY POINTS

- Dual-energy computed tomography (DECT) is a disruptive technology that has the potential to change the way that CT is performed and interpreted.
- As the use of DECT grows, it is essential for radiologists to be aware of the fundamental principles of DECT acquisition, postprocessing, and clinical use.
- DECT introduces several unique challenges, imaging artifacts, and potential diagnostic pitfalls that the interpreting radiologist should understand.

INTRODUCTION

Dual-energy computed tomography (DECT) refers to CT acquisition using 2 different x-ray energy spectra, which has the potential to characterize tissues based on their material composition. Although the theoretic possibility of material characterization with DECT has been known since 1976, DECT was not technically feasible with early-generation CT scanners; it was not until the introduction of the first dual-source scanner in 2006 that vendors began to develop DECT technology in earnest. The introduction of DECT has been accompanied by research on a variety of clinical applications in body imaging,[1–8] as well as many technological advancements aimed to increase the use of DECT in routine clinical practice.

As the clinical use of DECT continues to grow, it is important for radiologists to be aware of potential challenges and problems related to performing DECT scans, postprocessing, and displaying images, and incorporating DECT into routine clinical practice. In addition, DECT introduces several unique artifacts and interpretive pitfalls, which may be unfamiliar to radiologists who are new to using this technology.

In this article, we provide a practical overview of DECT in body imaging, focused on problems and diagnostic pitfalls associated with DECT and steps that can be taken to avoid them. Following a review of technical principles and postprocessing techniques available with DECT, we describe several challenges and pitfalls of DECT related to image acquisition, postprocessing and display, and interpretation.

BASIC PRINCIPLES OF DUAL-ENERGY COMPUTED TOMOGRAPHY

With conventional single-energy CT (SECT), imaging is obtained with a single polychromatic energy spectrum, ranging from 80 kVp to

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140 kVp depending on the anatomic region and scan indication. DECT instead acquires data with 2 different energy spectra, typically low energy at 80 or 100 kVp and high energy at 140 or 150 kVp. Different vendors have different approaches to DECT data acquisition, including dual-source DECT, which uses 2 different x-ray tubes operating at different kVp, each with a matching detector array; single-source DECT, which rapidly switches between low energy (80 kVp) and high energy (140 kVp) using a single x-ray tube and detector; and dual-layer detector-based DECT, which uses a single 120-kVp x-ray tube, with a layered detector that preferentially absorbs the low-energy or high-energy photons in the superficial and deep detector layers, respectively.

Tissue Differentiation with Dual-Energy Computed Tomography

For materials to be differentiated with DECT, they must have sufficiently different x-ray absorption behaviors as a function of kVp. This is often characterized by the *CT number ratio* of materials, which is defined as the ratio of the CT number (in Hounsfield units [HU]) of the material at low energy to the CT number of the same material at high energy.[9] For example, iodine and calcium both exhibit higher HU values at low kVp compared with high kVp, with iodine having a higher CT number ratio than calcium (**Fig. 1**) due to its greater atomic number and its k-edge near the mean of the low-kVp energy spectrum. Conversely, fat and uric acid demonstrate lower HU values as kVp increases. Most other soft tissues behave similarly at high and low kVp, and thus have CT number ratios close to 1.

The difference between CT number ratios of materials is determined not only by the atomic number of the materials, but also by the *spectral separation* between the low-energy and high-energy spectra. The greater the separation between the 2 energy spectra, the easier it is to distinguish between materials with DECT. Unfortunately, there is a large degree of spectral overlap between the typical high-energy and low-energy spectra, and methods to increase spectral separation are thus crucial to tissue differentiation with DECT. A variety of techniques have been used to increase spectral separation: adding a tin (Sn) filter in front of the high-energy x-ray tube on dual-source systems to preferentially attenuate the low-energy photons in the spectrum, or using the highest possible difference between kVp values, including use of 80 kVp for the low-energy spectrum, or still lower kVp values when available on the scanner.[9,10]

Dual-Energy Computed Tomography Postprocessing

For each dual-energy acquisition, an image series is typically sent to the Picture Archive and Communication System (PACS) for routine interpretation that is a weighted average of the high and low-energy data. This is commonly referred

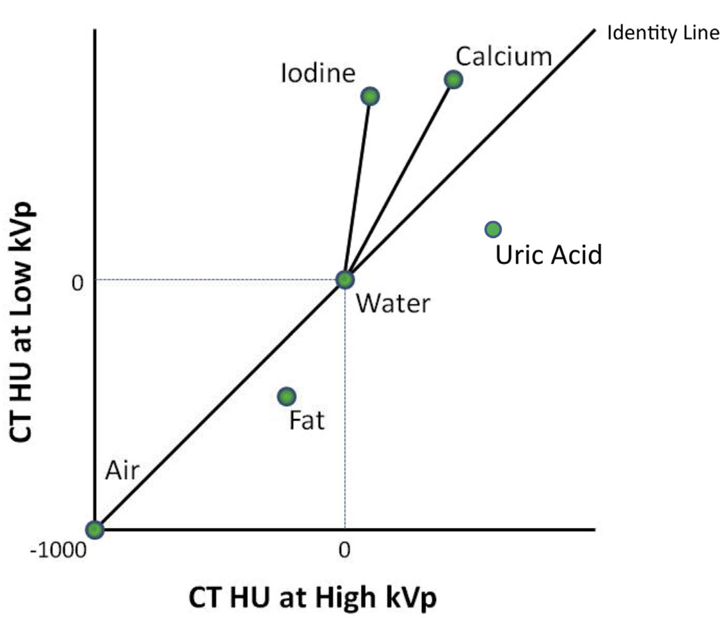

Fig. 1. Material-dependent x-ray absorption with DECT. HU values of different materials exposed to low kVp (y axis) and high kVp (x axis) x-ray spectra. Water and air are calibrated to 0 and −1000 HU, respectively. Iodine and calcium show progressively higher x-ray absorption at low energy, with characteristic slopes as concentration increases. Fat and uric acid demonstrate lower x-ray absorption as x-ray energy is decreased. Most other soft tissues lie very close to the identity line.