ORIGINAL ARTICLE

Dual-Energy CT of the Abdomen and Pelvis: Radiation Dose Considerations

SA-CME

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Abstract

Dual-energy CT offers several new applications and opportunities for routine clinical practice. Increasing utilization in the context of both routine practice and clinical research raises questions about expected radiation dose when compared with conventional single-energy exams. Despite initial concerns, advanced iterative reconstruction techniques and creation of virtual unenhanced images in multiphase acquisitions offer methods for dose reduction. Although dose varies across patients and scanners, modern dual-energy exams allow for comparable and potentially decreased radiation dose when compared with single-energy CT. In this review, we examine dual-energy radiation dose considerations with discussion of accepted ACR diagnostic reference levels.

Key Words: Dual energy, CT, radiation dose, reference standard

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INTRODUCTION

Over the past 25 years, radiation doses to the general public related to medical imaging exposure have increased substantially. A major culprit for this trend has been the widespread proliferation of the use of CT imaging [1-3]. Among numerous indications, CT has become the standard of care in the radiologic evaluation of trauma, emergency medicine, and oncology imaging. As such, the demand for CT has increased exponentially. Along with increased demand for CT, the awareness of subsequent radiation dose has also been heightened, both in the radiology community and the medical field as a whole. Specifically, the ACR along with several societies has encouraged the judicious use of CT imaging through campaigns such as Image Wisely and Image Gently [4,5]. In an attempt to provide more concrete guidelines, the ACR also published diagnostic reference levels (DRLs) for CT radiation dose in 2008 for all examinations performed in the United States. A DRL of 25 mGy CT dose index in a volume (CTDIvol) was deemed acceptable for a standard CT of the abdomen in adults [6]. Revisions to the ACR-American Association of Physicists in Medicine Practice Guideline in 2013 introduced the concept of achievable dose with a value of 17 mGy for a CT of the adult abdomen and pelvis [7].

Although it is not yet ubiquitous across all settings, dual-energy CT (DECT) is quickly transforming from a novel imaging technique to prime-time clinical performer in many abdominal imaging practices [8-12]. With this trend, some have raised concern about further increase in radiation doses [13,14]. However, it is important to consider several factors when discussing radiation dose in DECT, including variations in CT radiation dose, utilization of multiphase protocols, and demographics of the target patient population.

DECT

The concept of performing CT scans at different photon energy levels was first introduced in the late 1970s [15-17]. However, the reality of implementing such a technique did not come to the forefront until recently, when a robust increase in CT performance and postprocessing software became available. Currently available methods of acquiring DECT examinations include single-source DECT with fast kilovolt switching

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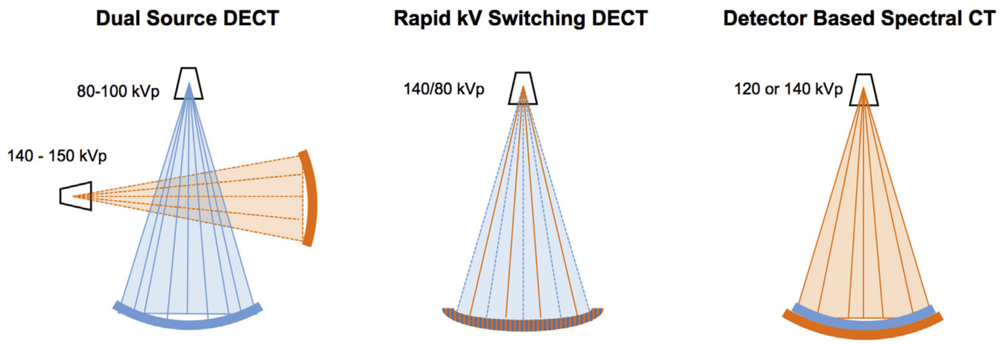

Fig 1. Illustration of the three major dual-energy CT (DECT) techniques. Dual-source DECT (Siemens Healthcare, Forchheim, Germany) utilizes two x-ray tubes and two detectors to generate low- and high-energy spectra. Single-source DECT (GE Healthcare, Milwaukee, Wisconsin) employs one x-ray tube and one detector with rapid switching between low- and high-energy levels. Detector-based spectral CT (Philips Healthcare, Andover, Massachusetts) uses a single x-ray tube with a "sandwich detector" to obtain low- and high-energy spectra.

(GE Healthcare, Milwaukee, Wisconsin), dual-source DECT with dual detector arrays (Siemens Healthcare, Forchheim, Germany), and single-source DECT with dual detector layers (Philips Healthcare, Andover, Massachusetts), with energies typically at 80 and 140 peak kilovoltage (kVp). An illustration of these techniques is provided in Figure 1.

Because acquisitions at two different energy levels are obtained in DECT, a common misconception may be that the radiation dose would double. However, this is not the case. There are techniques in place to mitigate the radiation incurred from the dual-energy acquisition. For example, relatively more time is spent imaging in the low kVp state (about 65%) in single-source fast-switching DECT, where simultaneous acquisitions of 80-kVp and 140-kVp images are generated in a rapid alternation between the energy levels at 0.5-microsecond intervals. In dual-source DECT, tube current modulation can be applied to reduce radiation dose, similar to conventional single-energy CT. Dual-source DECT can also apply a filter to the higher-energy tube, thereby not only improving spectral separation but also slightly lowering the dose. Dose can also be reduced in both single-source and dual-source DECT by applying iterative reconstruction techniques. However, detector-based single-source DECT platforms are likely to produce dose-neutral examinations due to the fact that they utilize single polychromatic energy spectra.

RADIATION DOSE

Comparing radiation doses between conventional CT and DECT is a difficult task. First, it is important to remember that doses reported by the scanner as dose length product or CTDIvol are estimations of radiation dose administered to a phantom, not an actual patient dose. Furthermore, radiation doses can vary significantly from patient to patient and scanner to scanner, even with the same exact protocol [18,19]. We have even seen radiation doses vary in the same patient on the same scanner at different times (Fig. 2). In fact, a recently published longitudinal study by Mileto et al, which followed 2,851 patients who underwent a total of 12,635 repeat identical CT scans, demonstrated a 10.26-mGy mean coefficient of variance for size-specific dose estimates for CTs of the abdomen and pelvis [20]. This potential variation in radiation dose must be considered when discussing CT, especially when comparing radiation doses between DECT and conventional CT acquisitions.

Over the past few years, radiation doses in DECT have decreased to the point that they are comparable or even lower than single-energy CT levels. Several studies between the years of 2012 and 2014 demonstrate radiation doses ranging between 12.7 and 21.8 mGy for DECT scans of the abdomen [21-26]. This range reflects levels that are all below the 25-mGy DRL published by the ACR, and almost all are at or below the achievable dose level of 17 mGy. In some studies, these levels are less than half of the reference standard (Table 1).

OPPORTUNITIES FOR DOSE REDUCTION

Beyond the radiation dose related to the acquisition of the CT, DECT offers additional opportunities for dose reduction. The most obvious dose-related benefit of