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Comparison of radiation dose and image quality from single-energy and dual-energy CT examinations in the same patients screened for hepatocellular carcinoma

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AIM: To compare radiation dose surrogates [volume CT dose index ($CTDI_{vol}$), dose–length product (DLP), size-specific dose estimate (SSDE), and effective dose] and image noise in a cohort of patients undergoing hepatocellular carcinoma screening who underwent both single-energy CT (SECT) and dual-energy CT (DECT).

MATERIALS AND METHODS: In this institutional review board-approved, Health Insurance Portability and Accountability Act-compliant retrospective study, 74 adults (mean age 59.5 years) underwent 64 section SECT (120 kVp and weight-based reference mAs) and 128 section dual-source DECT (100/Sn 140 kVp and $CTDI_{vol}$, adjusted to match the $CDTI_{vol}$ of the SECT protocol) on different occasions. Noise levels were measured in the liver, inferior vena cava (IVC), retroperitoneal (RP) fat, and aorta. Generalized linear models were constructed to compare dose and noise, adjusting for effective diameter.

RESULTS: The total DLP (1371.11 mGy-cm, SD = 527.91) and effective dose (20.57 mSv, SD = 7.92) with SECT were significantly higher than the DLP (864.84 mGy-cm, SD = 322.10) and effective dose (12.97 mSv, SD = 4.83) with DECT ($p < 0.001$). The differences between SECT and DECT increased as the patient's effective diameter increased ($p < 0.001$). Noise levels in the liver (22.4 versus 21.9 HU), IVC (22.3 versus 23.4 HU), and RP fat (23.5 versus 23 HU) were similar for DECT and SECT ($p > 0.05$) but were significantly lower in the aorta for DECT (25.3 versus 26.4 HU; $p = 0.006$).

CONCLUSION: DECT imaging of the abdomen can achieve noise levels comparable to those seen with SECT imaging without a dose penalty to patients.

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Introduction

Dual-energy CT (DECT) utilizes CT data from two energy spectra to discriminate tissues and characterize tissue composition based on differences in the attenuation of photons with different energies by materials.[1] Over the last several years, DECT has become one of the most researched topics in the CT field, with approximately 500 papers published since the first paper on dual-source DECT was released online in December 2006.[2] This can be attributed to recent advances in DECT hardware and software that have further expanded the clinical applications of this imaging technique. Some of these advances have been shown to be useful in the evaluation of focal and diffuse liver disease.[3] For instance, iodine maps can improve liver lesion detection and characterization; virtual non-contrast (VNC) images may replace true non-contrast (TNC) images to decrease radiation exposure; and quantification of iron and fat deposition in the liver can be performed with DECT.[4–10]

The surge in interest to explore DECT applications coincides with growing awareness and concern regarding the potential long-term risks associated with exposure to ionizing radiation used in medical imaging, particularly in young patients and in those who require serial imaging, such as patients with chronic liver disease. Although some publications note that DECT provides comparable image quality at equivalent or reduced dose levels for various types of examinations,[11] careful studies comparing both radiation dose and image quality between DECT and single-energy CT (SECT) studies under similar conditions, particularly comparisons within the same patients, are lacking. A recent clinical study comparing radiation dose between abdominal DECT and 120 kVp SECT reported a minimal (~1 mSv) dose increase for DECT.[12] However, no corresponding analysis of image quality (e.g., noise level) was performed in that study.

The purpose of the present investigation was to compare radiation dose surrogates [volume CT dose index ($CTDI_{vol}$), dose–length product (DLP), size-specific dose estimate (SSDE), and effective dose] and image noise in a cohort of patients undergoing screening for hepatocellular carcinoma (HCC) who underwent both SECT and DECT examinations.

Materials and methods

The present study was compliant with the Health Insurance Portability and Accountability Act and was approved by the local institutional review board with a waiver of informed consent.

Patient population

Between January 2012 and February 2013, 146 adult patients (18 years and older) weighing up to 113.6 kg who had cirrhosis, chronic viral hepatitis, or a liver transplant and were being screened for HCC were examined using DECT on a 128 section dual-source CT system (Definition Flash; Siemens Healthcare, Forchheim, Germany). Among them, 75 patients had undergone a previous examination performed with SECT on a 64 section CT system at the Cleveland Clinic (Sensation 64; Siemens Healthcare). One patient was excluded due to an incorrect imaging protocol; therefore, 74 patients (59 men, 15 women) with a mean age of 60.1 years (range 25–77 years) were included in the study.

Patient morphometrics

Patients' heights and weights were obtained at the time of each examination, and the body mass indices (BMIs) were calculated. Sagittal and coronal reformatted images were used to measure the maximum anteroposterior and transverse diameters, respectively, at the level of the mid liver. The effective diameter (ED) was obtained by taking the square root of the product of these two dimensions.[13]

CT technique

The SECT examinations were performed using the following parameters: 64 × 0.6 mm detector configuration; 0.95 pitch; 120 kVp tube potential; and a weight-based reference tube current–time product (i.e., 1 ref mAs per 1 lb of the patient's weight). The DECT examinations were performed using the following parameters: 32 × 0.6 mm detector configuration; 0.6 pitch; 100 kVp tube potential for tube A, which has a full 50 cm diameter field of view (FOV), and 140 kVp tube potential with additional tin (Sn) filter for tube B (FOV, 33 cm); and reference tube current of tube A (and automatically tube B) adjusted at the scanner console to match the estimated (pre-scan) $CTDI_{vol}$ of the weight-based SECT protocol. The dose-modulation software CareDose4D (Siemens Healthcare) was used in both SECT and DECT examinations.

The imaging protocol consisted of unenhanced, arterial phase (45 s delay after contrast medium injection) and portal venous phase (70 s delay) images. An automatic double-head power injector was used to administer 2 ml/kg non-ionic iodinated contrast medium up to a maximum of 150 ml (iopromide, 300 mg iodine/ml; Ultravist, Bayer Schering Pharma, Berlin, Germany) at a flow rate of 3 ml/s, followed by a 20 ml saline flush. The unenhanced and arterial phase images were acquired from 2 cm above the diaphragm to the lower of the iliac crests or the bottom of the liver, and the portal venous phase images were acquired from 2 cm above the diaphragm to the pubic symphysis.

Image reconstruction

Both SECT and weighted-average (linear mixture of tube A and tube B) DECT images were reconstructed using a weighted filtered back projection (FBP) technique, with B31f kernel and 3 mm section thickness, in the axial, coronal, and sagittal planes. The weighted-average images from DECT examinations were reconstructed using the default mixing ratio of 0.5.