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Evaluation of image quality, radiation dose and diagnostic performance of dual-energy CT datasets in patients with hepatocellular carcinoma

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AIM: To evaluate image quality and diagnostic accuracy of different dual-energy computed tomography (DECT) datasets for identification of hepatocellular carcinoma (HCC), assess the reliability of virtual unenhanced (VU) images in replacing standard unenhanced (SU) images, and quantify effective dose (ED) at different tube voltages.

MATERIAL AND METHODS: Thirty cirrhotic patients underwent liver contrast-enhanced DECT. Two blinded observers retrospectively evaluated conventional unenhanced and VU images, 140 kVp/80 kVp/mixed tube potential arterial datasets and conventional portal-venous/late phases in consensus. Final diagnosis was based on pathological proof or imaging criteria. Image quality, ED, sensitivity, and specificity of arterial datasets were calculated.

RESULTS: Thirty-eight HCC and 18 benign lesions were detected at 80 kVp, 33 HCC and 22 benign lesions were detected at 140 kVp, and 36 HCC and 20 benign lesions were detected at mixed tube potentials. Final diagnosis confirmed 37 HCC and 20 benign lesions. There was no significant difference in diagnostic confidence between 80 kVp, 140 kVp, and mixed tube potential arterial datasets ($p>0.05$). Image quality was adequate for all datasets, with increased quality at higher tube potential (80 versus 140 kVp, $p=0.001$; mixed versus 140 kVp, $p=0.001$; 80 kVp versus mixed, $p=0.0024$). Significant ED reduction was observed between 140 and 80 kVp datasets ($p<0.001$).

CONCLUSIONS: The 140 kVp dataset provided higher image quality. The 80 kVp images were more sensitive in detecting HCC. VU images are adequate in replacing SU images. The ED of the 80 kVp dataset was significantly lower.

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Introduction

Several published studies have previously described the advantages of increased attenuation of iodinated contrast agents and reduced radiation dose achievable with low tube voltage computed tomography (CT) protocols for vascular and abdominal applications.[1–8] Unfortunately, a lower tube voltage is associated with significant decreases in signal-to-noise ratio with detrimental effects on image quality that should be adequately compensated by tube current adaptation.[9] In light of these considerations, the clinical indications, diagnostic accuracy, and practicality of low tube voltage CT protocols are still a matter of debate. One approach to addressing this issue is through intra-individual comparative studies using dual-energy CT (DECT). This technology permits simultaneous acquisition of the same anatomical region by using two orthogonal X-ray tubes working at different voltages (80 and 140 kVp). Potentially, this approach represents a feasible option to obtain and compare information on the roles of the contrast agent and tissue attenuation at different photon energies, including also the possibility to generate virtual 120 kVp datasets (a digital combination of the 80 and 140 kVp acquisitions) and virtual unenhanced (VU) images.

Previous studies have demonstrated the applicability and potential advantages of this approach for abdominal imaging,[2–4] particularly for the diagnosis of liver tumours.[5,6] Unfortunately, most previous have papers dealt with only one or a few aspects of DECT, and each paper dealt with a different population, and thus, with different lesions. The aims of the present study were to comprehensively evaluate the image quality and diagnostic accuracy of different DECT datasets for the identification of hepatocellular carcinoma (HCC), to assess the diagnostic reliability of VU images, and to quantify the variations of radiation dose at different tube voltages.

Material and methods

This retrospective unicentric study was approved by local institutional review board and followed the principles of the Declaration of Helsinki and subsequent amendments. All patients provided written informed consent. Between February and July 2013, 30 consecutive patients (20 men and 10 women; mean age 69 years, range 36–88 years) with chronic liver disease referred by the Department of Gastroenterology, underwent abdominal DECT for the evaluation of focal liver lesions identified at routine surveillance ultrasound. Chronic hepatitis or cirrhosis were related to viral infection (hepatitis C [n=14], hepatitis B [n=4], both [n=2]), alcohol abuse (n=3), alcohol + hepatitis C virus infection (n=3), or cryptogenic (n=4). Sixteen patients were classified as Child–Pugh class A, 11 as class B, and three as class C.

DECT

All examinations were performed on a dual-source 128 section CT system (Somatom Definition, Siemens, Forcheim, Germany) featuring an automatic exposure control system (CareDose4D). Patients were positioned off-centre, in order to allow complete inclusion of the liver within the field-of-view of tube B, operating at 80 kVp in dual-energy acquisition mode. The scan region extended from the liver dome to the inferior renal pole. The acquisition protocol included a single-source unenhanced scan, a dual-energy hepatic-arterial scan, a single-source portal-venous scan, and a single-source delayed-phase scan. The single-source scans were acquired at 120 kVp, 200 mAs quality reference, pitch 1 and 0.5 seconds gantry rotation, whereas the dual-energy arterial scan was acquired at 140 kVp and 86 mAs quality reference for tube A and 80 kVp and 468 mAs quality reference for tube B, with pitch 0.85 and 0.5 seconds gantry rotation. Images were reconstructed at 3 mm section thickness and reconstruction intervals for diagnostic evaluation and quality assessment; images at 1 mm section thickness and reconstruction were also made available for three-dimensional (3D) post-processing.

High-concentration iodinated contrast agent (iomeprol, Iomeron 400, Bracco, Milan, Italy) was administered intravenously (1.5 ml/kg at 4 ml/s followed by a 40 ml saline flush) using an automated injector (Stellant, Medrad, Indianola, PA, USA). The optimal delay for the dynamic acquisitions was determined by means of bolus-tracking, with a delay of 18 seconds between the aortic peak enhancement (150 HU) and the acquisition of the arterial phase, and 25 and 180 seconds, respectively, for the portal-venous and equilibrium phases.[10,11] Automated tube current modulation was adopted for all scan phases. Raw data from the dual-energy arterial phase acquisition were reconstructed on a dedicated workstation (Leonardo Syngo CT 2008G, Siemens) to generate three contrast-enhanced datasets (80 kVp, 140 kVp and mixed 80/140 kVp with 0.3 blending factor) and a virtual unenhanced (VU) dataset.

Analysis of image quality of arterial datasets

The image quality of arterial phase datasets was evaluated qualitatively and quantitatively by two experienced abdominal radiologists (M.A. and M.D.M., both with 8 years of experience in liver imaging) on all three datasets of images, using a four-point scale (1, good; 2, fair; 3, poor; 4 not interpretable). Factors taken into consideration for the assessment of image quality included image sharpness, image noise, and artefacts, as previously described.[9,12]

Quantitative analysis was performed by an independent observer with 1 year of experience in liver CT (F.B.) on the three datasets placed side by side: nine circular regions of interest (ROIs; 1 cm^2) were drawn in both hepatic lobes above, below and at the plane of the portal vein (areas of focal parenchymal changes, large vessels, and prominent artefacts were avoided), while manually drawn ROIs were traced on hypervascular liver lesions.

The lesion-to-liver contrast-to-noise ratio (LLCNR) was calculated with the following formula:

$$\text{LLCNR} = (\text{ROI lesion} - \text{ROI liver})/\text{SD-noise})$$

where ROI lesion is the mean attenuation of the lesion, ROI liver is the mean attenuation of the liver parenchyma,