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Computed Tomography / Tomodensitométrie

Dual-Energy Multidetector Computed Tomography With Iodine Quantification in the Evaluation of Portal Vein Thrombosis: Is It Possible to Discard the Unenhanced Phase?

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Portal vein thrombosis (PVT) consists in the partial or total occlusion of portal vein lumen or its tributaries by a thrombus [1].

Liver cirrhosis and hepatocellular carcinoma (HCC) are the main causes of PVT [1]. A study based on postmortem examinations showed that prevalence of portal vein thrombosis was 4.5% in cirrhotic patients without HCC and 14.3% in patients with HCC [2].

Two pathophysiological mechanisms underlie PVT.

Benign thrombosis is determined by slow portal blood flow, reflecting the mechanisms underlying peripheral venous thrombosis, and it is histologically characterized by fibrin clot and absence of platelets [1]. Although once bland PVT represented an absolute contraindication for liver transplantation, recent studies have shown that between patients who had undergone transplantation those with partial benign thrombosis had not dissimilar survival rates [3].

On the other hand malignant thrombosis derives from direct vessel wall involvement by parenchymal tumour and it is related to advanced stage of disease with very limited therapeutic chances, representing an absolute contraindication for liver transplantation [3].

Nowadays imaging represents the most common and safe method for PVT characterization with reduced need for histopathologic proof, a procedure that carries some risks in patients with advanced liver disease.

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Several imaging techniques can be employed for PVT characterization. Despite the fact that contrast-enhanced and colour Doppler ultrasonography [4–6] and magnetic resonance with diffusion-weighted imaging are reported as highly accurate techniques [7,8], multislice computed tomography (MSCT) is the most used imaging technique for characterization of PVT and its underlying causes [9–11].

Conventional MSCT study protocol includes an unenhanced study for baseline density measurements in Hounsfield units (HU) and contrast-enhanced acquisition, in the arterial or venous phase, to evaluate the presence of intrathrombus enhancement, which is one of the most reliable imaging features in distinguishing between bland and neoplastic thrombus ($HU_{contrast\ phase} - HU_{unenhanced\ phase}$) [9,11].

Dual-energy CT (DECT) with iodine quantification offers an alternative approach independent from attenuation measurements, based on the presence of iodine in tissues, providing a more direct measure of lesion vascularization [12,13].

Recent studies [14] demonstrated that DECT with iodine quantification is a highly accurate noninvasive approach for PVT characterization in patients with hepatocellular carcinoma, yielding higher sensitivity and specificity compared with conventional enhancement measurements [14].

Another advantage of DECT is represented by the possibility of radiation dose reduction, using virtual unenhanced (VUE) instead of true unenhanced (TUE) images [15].

To our knowledge there are no studies that compare TUE and VUE images validating their reliability in this application field.

The aim of this study was to compare DECT VUE and single-energy (SE) TUE images and to calculate the potential

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dose reduction by omitting the conventional unenhanced scan in PVT characterization.

Materials and Methods

The Institutional Review Board approved this retrospective study conducted from data found in our institutional patient databases and archives. Signed consent from the patients was obtained.

Patients

All cirrhotic patients and those suspected to have HCC with <35 cm abdominal diameter or weighting less than 90 kg are routinely scheduled for DECT study at our institution.

A computerized search of our hospital information system (SuitEstensa Web; Esaote Biomedica, Indianapolis, IN) for patients who underwent DECT using the following keywords: *portal vein thrombosis*, *bland thrombus*, *neoplastic thrombus*, *dual energy CT*, and *hepatocellular carcinoma* yielded data for 94 patients with HCC and portal vein thrombosis from September 2008 to January 2013.

Patients were excluded from this study for the following reasons: 1) lack of histopathologic proof of HCC (patients n = 32); 2) PVT pathological diagnoses or reports on follow-up examinations were not available (n = 21); 3) CT data were not available for reconstruction (n = 2); 4) chronic PV occlusion with cavernous transformation precluding portal vein or thrombus identification (n = 6).

Therefore, our final study cohort consisted of 33 patients (24 men, 9 women; mean age 62.4 ± 8.6 years; age range 48-79 years; mean body mass index 30.2 ± 6.9) who underwent contrast enhanced DE multidetector CT (MDCT) during late hepatic arterial phase and SE MDCT during basal and portal venous phases in the clinical setting of a histopathologically proven HCC (single nodular type, n = 18; multinodular type, n = 11; diffuse type, n = 2; massive type, n = 2).

CT Data Acquisition

All CT examinations were performed by using a dual-source CT system (Somatom Definition Dual Source; Siemens AG, Healthcare Sector, Forchheim, Germany), consisting of 2 X-ray tubes arranged on the gantry with a 90° angular offset and 2 detectors that respectively cover a 50 cm (tube A) and a 26 cm (tube B) field of view. These 2 tubes operate independently with regard to tube voltage and tube current.

Unenhanced and late hepatic arterial phases were obtained from the hepatic dome to the iliac crest, whereas portal venous phase acquisition was extended from the hepatic dome to the pubic symphysis.

Bolus tracking (CARE Bolus, Siemens Healthcare, Forchheim, Germany) technique was performed to obtain a right timing for late arterial or in-flow portal vein phase: scan has been started with a 15-second delay after arrival of the bolus in the abdominal aorta using an attenuation predefined threshold of +100 HU above the baseline [16]. SE portal venous acquisition was performed with a fixed time delay of 80 seconds.

All patients received a nonionic contrast medium (Iomeprol, 400 mg of iodine per milliliter, Iomeron 400; Bracco Imaging, Milan, Italy) at a dose of 1.4 mL (560 mg of iodine) per kilogram of body weight. The contrast medium was warmed to 37°C and administered with a dual-chamber mechanical power injector (Stellant D CT; Medrad, Indianola, PA) at a rate of 4-5 mL/s through an intravenous catheter inserted into an antecubital vein. This was followed by a 30 mL saline flush at the same injection rate.

Scanning parameters used for SE images acquisition were: 2 × 32 × 0.6 mm detector collimation; 120 kVp tube voltage; 250 mAs tube current quality reference; 0.70 pitch factor; 0.5 seconds gantry rotation time.

Scanning parameters used for DE acquisition were: 14 x 1.2 mm detector collimation; tube A: voltage 140 kVp, current-time product (mAs) 95; tube B: voltage 80 kVp, current time product (mAs) 510; 0.70 pitch factor; 0.5 seconds gantry rotation time. These scanning parameters corresponded to the vendor's suggestions. All acquisitions were obtained with an automatic exposure control system (Care Dose 4D; Siemens AG).

CT Data Reconstruction

From the SE data sets, 3 mm contiguous axial unenhanced and portal venous images were reconstructed with a smooth (B31f) convolution kernel.

From the DE data sets, 3 mm contiguous axial images, which approximate the image quality (IQ) of a standard 120 kVp scan of the abdomen, were obtained with a combination of image data averaging 30% from the low-kilovoltage tube B and 70% from the high-kilovoltage tube A (M0.3), using a dedicated DE convolution kernel (D30f).

All images were stored in a secondary workstation (Syngo Dual Energy version MMWP 2010A, Siemens AG).

DE postprocessing was performed using the Liver Virtual Non-Contrast application (Liver VNC; Siemens AG, Healthcare Sector, Forchheim, Germany) as an image-based analysis of the low- and high-energy kVp images. This software works with a 3-material decomposition algorithm that uses attenuation changes of soft tissue, fat, and iodine at different peak voltages. Assuming that every voxel in the abdomen is composed of fat, soft tissue, and iodine, the algorithm generates a map that encodes the iodine distribution in each voxel.

In each case the manufacturer default values for soft tissue and fat attenuation at 80 and 140 kVp were replaced by the patient's specific attenuation values, obtained by placing a large region of interest (ROI) over the paraspinal muscles and adjacent subcutaneous fat on both the 80 and 140 kVp datasets. Both these measurements were obtained at the level of the main portal vein.

Iodine was overlaid with 50% iodine overlay display to obtain colour-coded iodine overlay maps and was completely subtracted to obtain virtual unenhanced images [17,18].