Original Investigation

Optimal Adaptive Statistical Iterative Reconstruction Percentage in Dual-energy Monochromatic CT Portal Venography

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Rationale and Objectives: The aim of this article was to study the influence of different adaptive statistical iterative reconstruction (ASIR) percentages on the image quality of dual-energy computed tomography (DECT) portal venography in portal hypertension patients.

Materials and Methods: DECT scans of 40 patients with cirrhosis (mean age, 56 years) at the portal venous phase were retrospectively analyzed. Monochromatic images at 60 and 70 keV were reconstructed with four ASIR percentages: 0%, 30%, 50%, and 70%. Computed tomography (CT) numbers of the portal veins (PVs), liver parenchyma, and subcutaneous fat tissue in the abdomen were measured. The standard deviation from the region of interest of the liver parenchyma was interpreted as the objective image noise (IN). The contrast-noise ratio (CNR) between PV and liver parenchyma was calculated. The diagnostic acceptability (DA) and sharpness of PV margins were obtained using a 5-point score. The IN, CNR, DA, and sharpness of PV were compared among the eight groups with different keV + ASIR level combinations.

Results: The IN, CNR, DA, and sharpness of PV of different keV + ASIR groups were all statistically different ($P < 0.05$). In the eight groups, the best and worst CNR were obtained in the 60 keV + 70% ASIR and 70 keV + 0% ASIR (filtered back-projection [FBP]) combination, respectively, whereas the largest and smallest objective IN were obtained in the 60 keV + 0% ASIR (FBP) and 70 keV + 70% combination. The highest DA and sharpness values of PV were obtained at 50% ASIR for 60 keV.

Conclusions: An optimal ASIR percentage (50%) combined with an appropriate monochromatic energy level (60 keV) provides the highest DA in portal venography imaging, whereas for the higher monochromatic energy (70 keV) images, 30% ASIR provides the highest image quality, with less IN than 60 keV with 50% ASIR.

Key Words: Dual-energy CT; ASIR; keV; BMI; Portal vein.

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INTRODUCTION

Computed tomography portal venography (CTPV) is used for the evaluation of portal-systemic collateral circulations of patients with liver cirrhosis (1–3). It provides therapeutic relevant information, such as portal vein lesions, the status of the portal-systemic collateral circulation, including the diameter, location, and extent of esophageal and gastric varicosis, spleno-renal and para-umbilical veins, as well as the underlying hepatic disease (2,3). In addition, CTPV is frequently used for the presurgical vascular evaluation of patients with upcoming liver transplantation (4).

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However, the image quality of CTPV is commonly influenced by several factors. First, beam-hardening artifacts are frequently an obstacle to the image quality of CT angiography (5). Second, patients who undergo CTPV often suffer from severe hepatic disease accompanied with portal vein thrombosis, which might influence the image quality of CTPV (6). Furthermore, because renal dysfunction is commonly present in patients with severe hepatic disease, a reduction of contrast agent dosage is frequently required, which may result in decreased imaging conditions (7,8). In addition, the portal venous imaging quality may be affected by the cardiac function and the body mass index (BMI) of the patient, making the timing of the optimal contrast enhancement difficult (9,10).

A previous study has shown that compared to conventional linear mixing imaging, the nonlinear blending technique of dual-energy computed tomography (DECT) could improve the image quality of portal venous using the dual-source DECT (11).

The single-source dual-energy computed tomography (ssDECT) scanning mode uses a single tube with rapidly (0.5 ms) switching tube voltages of 140 and 80 kVp during a single rotation allowing to reconstruct image sets of 101 different keV virtual monochromatic spectral (VMS) images (12). Monochromatic images generate fewer beam-hardening artifacts and better contrast compared to conventional 120 kVp single-energy computed tomography (SECT), as demonstrated by previous phantom and clinical studies (13,14).

Image noise (IN) in spectral CT imaging depends on the photon energy level. An increased contrast resolution at lower photon energies is thereby often accompanied by a higher IN (15). Numerous studies demonstrated the value of iterative reconstruction algorithms such as adaptive statistical iterative reconstructions (ASIR) for the reduction of IN in CT (16,17). The optimal ASIR percentage depends on the imaging tasks and the tube voltage used for the scan to balance IN and the sharpness of structures (17–19). With the newer generation spectral CT scanner, ASIR is enabled for energy levels above 60 keV.

Previous phantom and clinical studies have shown that VMS images at approximately 70 keV yielded the lowest IN (20), which was also used routinely as the diagnostic imaging set in our hospital.

However, IN is only one of the factors characterizing image quality, and the interaction between different ASIR percentages and different VMS images of different keV levels may affect image quality differently, which, to the best of our knowledge, has not been studied to date.

Therefore, the objective of this study was to study the influence of different ASIR percentages on image quality of spectral CT images at two different energy levels (60 and 70 keV) to find the optimal ASIR-keV combination for CT portal venography.

MATERIAL AND METHODS

Patient Population

Ethical approval for this study was obtained from the institutional review board of our hospital, and written informed consent was obtained from all patients.

A total of 43 patients with cirrhosis who underwent an ssDECT examination between September and December 2014 were selected for the study. The diagnosis of cirrhosis was confirmed by clinical and laboratory examinations. Three cases with a thrombus in the main stem, or branches of the portal vein were excluded, resulting in 40 patients who were finally included in this study (23 male and 17 female patients with ages ranging from 29 to 83 years; mean age, 55.85 ± 12.1 years). The study population consisted of 19 cases (47.5%) of cirrhosis secondary to hepatitis B, 4 cases (10%) of cirrhosis secondary to hepatitis C, 13 cases (32.5%) of alcoholic cirrhosis, and 4 cases (10%) of primary biliary cirrhosis. Among them, 22 cases were accompanied by ascites. With regard to liver function in terms of the Child-Pugh classification, eight cases (20%) were in grade A, 21 cases (52.5%) in grade B, and 11 cases (27.5%) in grade C. The mean BMI, calculated as weight in kilograms divided by height in meters squared, was 24.80 ± 4.14 kg/m^2.

Imaging Technique

All CT scans were performed on a 64-detector ssDECT scanner (Discovery 750 HD, GE Healthcare, Milwaukee, WI), which can be operated in either SECT or ssDECT mode. All patients underwent three-phase (non-enhanced [NE], arterial phase [AP], and portal venous phase [PVP]) CT scans. Approximately 30 min before the CT scan, 600 mL of water was introduced as a negative oral contrast medium. The NE CT was performed using the conventional SECT scan mode with 120 kVp, auto mAs for a noise index of 12 at a 5-mm slice thickness. The AP and PVP scans were performed using a single tube, fast dual kVp (80 kVp and 140 kVp) switching scan technique with 0.8-s tube rotation time and 600 mA tube current. Other parameters for both the conventional SECT and the DECT scans were: helical with pitch of 0.984:1, 40-mm detector coverage, and 35-cm display field of view. The scan coverage of NE and AP was from the diaphragmatic dome to the lower poles of both kidneys. The scan coverage of the PVP was from 2 cm above the bifurcation of the tracheae to the lower sides of both kidneys with a head-to-toe scan mode.

The nonionic contrast media Iohexol (Omnipaque 350, GE healthcare, Shanghai) 500 mgI/kg body weight (1.4 mL/kg) was injected in 30 s with a power injector through the median cubital vein. AP scans were triggered 20 s after the attenuation in the descending aorta reached 100 Hounsfield units (HU) on the monitoring scan. PVP scans began 30 s after the end of the AP scan. A total of 20-mL saline was injected following the contrast injection at the same rate.

Data Post-processing

The monochromatic PVP images at 60 keV and 70 keV were retrospectively reconstructed on the CT system console by a CT technician at four different ASIR percentages (0%, 30%, 50%, and 70%, with 0% indicating the conventional filtered back-projection [FBP] reconstruction) both at 5.0-mm and 0.625-mm slice thickness. The 16 datasets were all transferred to an Advantage workstation (AW 4.6, GE Healthcare, Milwaukee, WI). The images of 5.0-mm slice thickness were used for the data measurements and those of 0.625 mm were used for the CTPV reformation with maximum intensity projection (MIP) and multiple planner reconstruction (MPR).

Objective Image Quality Assessment (Quantitative Assessment)

The eight CT images at 5.0-mm slice thickness with different keV and ASIR combinations from the same patient were displayed randomly on the AW 4.6 workstation with the gemstone spectral imaging (GSI) viewer. The right portal vein level was selected and the mean CT attenuations (HU) and standard deviations (SD) of the liver parenchyma, the right portal vein, and subcutaneous fat in the same level were measured using a circular or elliptical region of interest (ROI) (Fig. 1). All measurements were independently performed by two

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