Spectral CT Demonstration of the Superior Mesenteric Artery:

Comparison of Monochromatic and Polychromatic Imaging

Jingzhen He, MD, PhD, Xiangxing Ma, MD, Qing Wang, MD, Jingli Fan, MD, Zhiyuan Sun, MD

Rationale and Objectives: To investigate the performance of spectral computed tomography (CT) in depiction of the superior mesenteric artery (SMA) compared to conventional polychromatic CT.

Materials and Methods: This prospective study had institutional review board approval, and written informed consent was obtained. Fifty patients underwent spectral CT examination using gemstone spectral imaging with a single-tube, fast dual-tube voltage-switching technique. Spectrum analysis was used to select the monochromatic images that provide the optimal contrast-to-noise ratio (CNR) for SMA angiography. The CNR for SMA at the selected monochromatic level was compared with that from the conventional polychromatic images. Image quality and visibility of the branch order of SMA were also assessed and compared.

Results: The monochromatic images at 50 keV (mean 50.09 $\pm$ 1.98) provided the optimal CNR for SMA angiography. At this energy level, the monochromatic images had higher (20.8 vs 9.2) CNR than the polychromatic images, and the image quality was superior to conventional polychromatic images ($P < .05$). Fourth to fifth (mean 4.3) and third to fourth (mean 3.5) order branches of SMA were demonstrated at monochromatic and polychromatic images, respectively.

Conclusions: Gemstone spectral imaging with monochromatic images at 50 keV by spectral CT could improve the CTA image quality and demonstrate more branch order in depiction of normal SMA compared to conventional polychromatic imaging.

Key Words: Superior mesenteric artery; spectral CT; CT angiography; monochromatic imaging.

Computed tomography (CT) angiography (CTA) has rapidly emerged as a noninvasive imaging modality of choice to evaluate vasculature and vascular conditions in the abdomen (1–4). Multidetector CT (MDCT) has played a crucial role in the widespread acceptance of CTA as a noninvasive alterative to catheter angiography. The key to improve CTA imaging quality is to enhance the contrast between the artery and soft tissues. The image quality of CTA could be improved by increasing the contrast media injection rate or dosage (5–7), whereas increasing contrast could also increase the beam hardening artifacts with the conventional imaging using a polychromatic X-ray beam. Recently, one of the advancements of CT technology is the introduction of spectral CT, which not only provides material decomposed images but also generates a set of single-energy images from 40 to 140 keV. Since the attenuation of iodine, which is the active ingredient of the contrast media in the vessel, increases rapidly as photon energy decreases, it is thus feasible to optimize imaging condition for displaying arteries without increasing dosage of contrast media. The superior mesenteric artery (SMA) is one main branch of the abdominal aorta with many fine branches; high-order SMA branch depiction may contribute to the early diagnosis of vascular diseases such as atherosclerosis or arteritis. Spectral CT using a monochromatic X-ray beam may help to improve the image quality of SMA and show the smaller and deeper branches of the mesenteric artery. Therefore, the purpose of the study was to evaluate the effect of spectral CT on improving CTA image quality of the SMA.

MATERIALS AND METHODS

Patient Information

From October 2010 to May 2012, 50 consecutive patients who required mesenteric CTA scanned with gemstone spectral imaging (GSI) mode by spectral CT were included in our study. There were 22 men and 28 women with an age range of 18–73 years (mean age 41.8 years). These patients presented for a variety of reasons, including suspected aortic disease, primary or secondary cancer of the liver, and persistent abdominal pain. Subjects with any pathological conditions that may cause modifications of the vascular anatomy of SMA were excluded. Based on this criterion, 15 patients

Acad Radiol 2014; 21:364–368

From the Shandong University Qilu Hospital, Jinan, Shandong, China 250012 (J.H., X.M., Q.W., Z.S.); and Shandong Endemic Disease Institute, Jinan, Shandong, China 250012 (J.F.). Received September 5, 2013; accepted November 3, 2013. **Address correspondence to:** Q.W. e-mail: wangqing663@163.com

http://dx.doi.org/10.1016/j.acra.2013.11.004

were excluded (parasitic flow in hepatocellular carcinoma [n = 8], dissection of SMA [n = 3], and thrombosis of SMA [n = 4]). Therefore, 35 patients were included in this study. This prospectively study was approved by our institutional review board, and written informed consent was obtained from each participant before the study.

CT Technique

MDCT was performed by using GSI with a single-tube, fast dual-tube voltage (80 and 140 kVp) switching technique on a high-definition Discovery CT750 HD (HDCT, GE Healthcare, Milwaukee, WI, USA). In this scanning mode, the spectral CT reconstructions produced 101 sets of single-energy images from 40 keV to 140 keV and a polychromatic image set corresponding to 140-kVp tube voltages. All patients were positioned supine with feet first on the scanning table. After the acquisition of anteroposterior and mediolateral digital scout radiographs, each patient was scanned craniocaudally after intravenous contrast medium administration during the hepatic arterial and hepatic venous phases. To determine the scanning delay for hepatic arterial phase imaging, the time to peak aortic enhancement was assessed by using an automatic bolus-tracking technique with automated scan-triggering software (SmartPrep; GE Healthcare). Arterial phase scanning was started automatically 12 seconds after the trigger threshold (100 HU) was reached at the level of the supraceliac abdominal aorta.

The GSI scan parameters included helical 0.8-second tube rotation time, 40-mm detector coverage, pitch factor 0.985:1, and 45-cm Display Field Of View (DFOV). The nonionic contrast media iohexol (Omnipaque 300; GE Healthcare) at the dose of 1.5 mL/kg was injected with power injector at a rate of 4 mL per second through median cubital vein. The reconstruction thickness was 0.625 mm, at an interval of 0.625 mm.

GSI Image Postprocessing

The spectral CT reconstructions produced 101 sets of single-energy images from 40 to 140 keV. The monochromatic images with the slice thickness of 0.625 mm and spacing of 0.625 mm were sent to a workstation with special GSI viewer (GSI viewer 2.00 and GE VolumeShare 4 AW 4.4; GE Healthcare) for analysis. The contrast-to-noise ratio (CNR) measurements for the SMA were performed on both the polychromatic and monochromatic axial images. CNR was defined according to the formula: CNR = $(ROI_o - ROI_d)/SDn$, where region of interesting (ROI) denotes the SMA CT value, ROI_d denotes the CT value of the contrast tissue of the same slice, and SDn denotes the mean background image noise. The sacrospinal muscle was used as the contrast tissue. The standard deviation of the subcutaneous fat tissue in the abdomen was used as the mean image noise SDn. For all measurements, the size, shape, and position of the ROIs were kept constant between the two image sets by applying a copy-and-paste function at the workstation. The GSI Viewer software

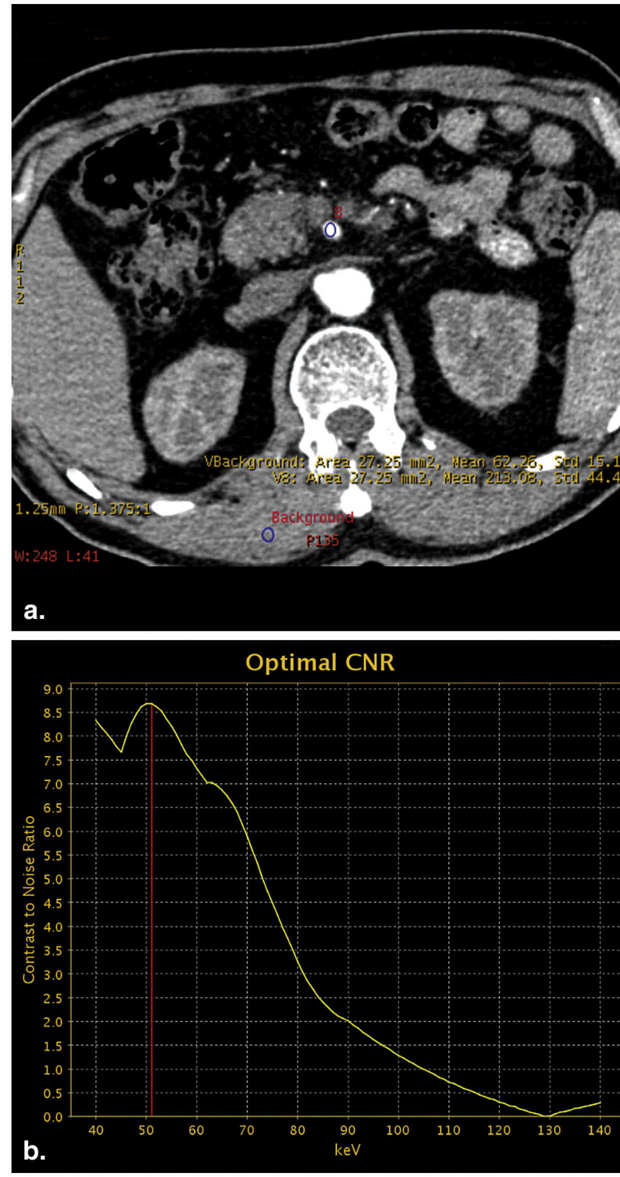

Figure 1. Optimal contrast-to-noise ratio (CNR) for superior mesenteric artery by spectrum analysis software. **(a)** The region in interest in superior mesenteric artery and sacrospinal muscle (contrast tissue) on an axial image. **(b)** Best CNR in the monochromatic images at about 50 keV based on the spectral curve.

package automatically calculated and displayed the CNR values for the 101 sets of monochromatic images. The keV of optimal CNR (Optimal CNR) for viewing SMA was selected using energy spectrum analysis software (Fig 1).

Image Reconstruction

Images with the optimal selected monochromatic level were transferred to an AW 4.4 workstation together with the polychromatic images for postprocessing by a single operator with 10 years' experience. Volume-rendered, arterial-phase CTA and multiplanar reformations (MPRs) were generated. We used a standard volume-rendering reconstruction