Original Investigation

CT Angiography in Patients with Peripheral Arterial Disease: Effect of Small Focal Spot Imaging and Iterative Model Reconstruction on the Image Quality

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Rationale and Objectives: We investigated the effects of small focal spot (SFS) imaging and iterative model reconstruction (IMR) on the image quality of computed tomography angiographs (CTA) in patients with peripheral arterial disease.

Materials and Methods: We divided 60 consecutive patients with suspected or confirmed peripheral artery disease into two equal groups. One group underwent large focal spot scanning under our standard CTA protocol with hybrid iterative reconstruction (iDose[4]) (protocol 1), and the other underwent scanning with the SFS protocol and IMR (protocol 2). Quantitative image quality parameters, ie, arterial computed tomography attenuation, image noise, and the contrast-to-noise ratio, were compared and the visual image quality (depiction of each vessel) was scored on a 5-point scale.

Results: There was no significant difference in the arterial attenuation among all evaluated slice levels. The mean image noise was significantly lower under protocol 2 and the contrast-to-noise ratio was significantly higher at all slice levels. The visual scores assigned to the two protocols for the depiction of large vessels, such as the abdominal aorta and iliac artery, were comparable. However, the mean visual scores for small vessels in the lower extremities were significantly higher under protocol 2.

Conclusion: CTA with SFS and IMR yielded significantly better qualitative and quantitative image quality especially for small vessels.

Key Words: CT angiography; peripheral arterial disease; iterative reconstruction; small focal spot; image quality.

INTRODUCTION

Peripheral artery disease (PAD) is a common, chronic, progressive health problem (1). It affects up to 8.5 million (7.2%) Americans in their 40s and is associated with significant morbidity and mortality (2). The 5-, 10-, and 15-year morbidity and mortality rates from all causes in patients with PAD are approximately 30%, 50%, and 70%, respectively. Coronary artery disease is the most common cause of death among patients with PAD (40%–60%); cerebral artery disease accounts for 10%–20% of deaths (3). Early diagnosis and appropriate medical intervention can mitigate limb-specific symptoms, improve the quality of life, and decrease systemic cardiovascular risks (4).

Digital subtraction angiography (DSA) is considered the reference standard for diagnosing PAD. However, it is invasive and carries limitations and risks (5). Computed tomography angiography (CTA), a less invasive and safer examination, is an alternative to DSA and has gained widespread clinical acceptance for diagnosing PAD (5). Although CTA of lower extremities is more sensitive, specific, and accurate for assessing the location and extent of peripheral artery stenosis than DSA (6), its spatial resolution is inferior to DSA, and the visualization of small vessels, such as the peripheral small artery and collateral vessels, is suboptimal.

The focal spot size in the x-ray tube defines the spatial resolution of a CT system (7). Many CT tubes feature small and large focal spot (SFS and LFS) sizes. The SFS size facilitates

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more detailed imaging but at the cost of x-ray intensity. Most conventional CT protocols employ the LFS because SFS imaging restricts the x-ray tube power to the lower output level to prevent overheating of the tube. Advances in CT technology have surmounted this limitation because the newer detector systems make more efficient use of the available tube power. In addition, the latest x-ray generators with advanced x-ray tube cooling systems can deliver a higher tube current (mA) to the SFS; this yields an x-ray intensity similar to LFS imaging. Furthermore, the iterative reconstruction (IR) techniques allow the use of protocols with a lower tube current (8). SFS imaging benefits from this advance.

Iterative model reconstruction (IMR) is the latest advance in the field of reconstruction techniques. The IMR uses a knowledge-based approach to accurately determine the data and image statistics and the system models, which depict the geometry and physical characteristics of the CT scanner, and yields improved image quality (9,10).

Under the hypothesis that the combination of SFS and IMR improves small vessel visualization on CTA in patients with PAD, we investigated the effects of SFS and IMR on the image quality of CTA scans.

MATERIALS AND METHODS

We obtained institutional review board (IRB) approval and prior written informed consent from all patients participating in this prospective study (Hospital IRB Number: #29-03).

Study Population

Between December 2014 and January 2016, we enrolled 60 consecutive patients (41 men and 19 women; mean age: 73.4 years) with suspected or confirmed PAD. All underwent CTA. The inclusion criteria were no lower limb amputation, no renal failure (estimated glomerular filtration rate <30 mL/min/1.73 m^2), no hemodialysis, and no history of allergic reactions to iodinated contrast material. The enrolled patients were randomized and scanned under one of two CTA protocols based on a random-number table. One group ($n = 30$) underwent scanning with our standard CTA protocol with LFS (protocol 1) and the other group ($n = 30$) underwent scanning under the SFS protocol (protocol 2). Patient characteristics are summarized in Table 1.

CT Scanning and Contrast Infusion Protocols

All CT examinations were performed on a 256-slice CT system (Brilliance iCT; Philips Healthcare, Cleveland, OH). The parameters were detector configuration, 128 × 0.625 mm; slice thickness, 1.0 mm; section interval, 0.5 mm; gantry rotation time, 0.75 seconds; beam pitch, 0.59; tube voltage, 100 kVp; and reference tube current time product, 231 mAs (effective mAs) with auto-modulation (Dose Right; Philips Healthcare). CTA data were acquired in the craniocaudal direction from the suprarenal aorta to the ankles. Using a double-head power injector (Auto Enhance A-250; Nemoto Kyorindo, Tokyo, Japan), iopamidol (iodine concentration 300 or 370 mgI/mL [Iopamiron 300 or 370; Bayer HealthCare, Osaka, Japan]) was injected via a 20-gauge catheter inserted into an antecubital vein. The amount of contrast material was adjusted to the body weight of each patient (500 mgI/kg) and injected at a fixed injection duration of 25 seconds. Contrast administration was followed by the injection of 40 mL of a saline solution delivered at the same injection rate as the contrast medium. An automatic bolus-tracking program was used to time the start of scanning for each phase after contrast material injection. Monitoring was at the L1 vertebral body level; a region of interest (ROI) cursor (1.0–2.0 cm^2) was placed on the abdominal aorta. Data acquisition started 15 seconds after triggering. The acquisition parameters for protocols 1 and 2 are summarized in Table 2.

TABLE 1. Patient Demographics

	LFS Protocol ($n = 30$) (Protocol 1)	SFS Protocol ($n = 30$) (Protocol 2)	*P* Value
Sex (male/female)	21/9	20/10	0.72
Age (y)	72.8 ± 8.6	74.1 ± 9.3	0.55
Body height (cm)	157.6 ± 7.9	158.9 ± 8.3	0.53
Body weight (kg)	61.2 ± 13.0	59.7 ± 15.9	0.70
Body mass index (kg/m^2)	24.5 ± 4.3	23.4 ± 4.6	0.34
eGFR (mL/min/1.73 m^2)	33.1 ± 30.4	32.5 ± 30.8	0.94

eGFR, estimated glomerular filtration rate; LFS, large focal spot; SFS, small focal spot.
Note: Data are mean ± standard deviation.

TABLE 2. Imaging and Contrast Material Parameters of the LFS and the SFS Protocols

	LFS Protocol (Protocol 1)	SFS Protocol (Protocol 2)
CT scanner	256-slice CT (Brilliance iCT, Philips Healthcare)	
Collimation	128 × 0.625 mm	
Tube voltage	100 kVp	
Effective tube current	231 eff. mAs (reference) with auto-modulation	
Rotation time	0.75 s/rot	
Helical pitch	0.585	
Total amount of contrast medium	500 mgI/mL	
Injection duration	25 s	
Bolus tracking trigger	150 HU (abdominal aorta)	
Scan delay	15 s	
Image reconstruction	iDose[4]	IMR
Section thickness/interval	1.0/0.5 mm	

CT, computed tomography; IMR, iterative model reconstruction; LFS, large focal spot; SFS, small focal spot.