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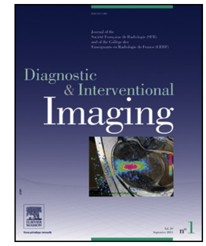

ORIGINAL ARTICLE / *Vascular imaging*

Lower extremity CT angiography at 80 kVp using iterative model reconstruction

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KEYWORDS
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Radiation dose

Abstract
Purpose: To evaluate the use of 80 kVp and iterative model reconstruction (IMR) in lower extremity computed tomography angiography (CTA).
Materials and methods: Sixty patients were randomly assigned to Group A or Group B (both $n = 30$) to further undergo CTA. Group A received Protocol 1 (P1) with 120 kVp, 180 mAs, and 100 mL of contrast agent with filtered back-projection (FBP). Group B received Protocol 2 (P2) and Protocol 3 (P3) with 80 kVp, 140 mAs and 75 mL of contrast agent with hybrid iterative reconstruction (P2) and IMR (P3). Mean intravascular attenuation (MIA), image noise, contrast-to-noise ratio (CNR), and signal-to-noise ratio (SNR) were compared. Radiologists assessed image quality on a 5-point scale, and radiation was compared between both groups.
Results: Group A had 9 men and 21 women (mean age, 68.2 ± 9.3 years [range: 53—85 years]), and Group B had 20 men and 10 women (mean age, 64.8 ± 10.4 years [range: 37—81 years]). The MIA of P2 and P3 were significantly larger than that of P1 ($P < 0.01$). The CNR and SNR of P3 were significantly higher than those of P1 and P2 ($P < 0.01$). The interobserver agreement had Kappa values of 0.78, 0.77, and 0.81 for P1, P2, P3, respectively. The mean CT volume dose index and dose-length product of Group B were lower than those of Group A ($P < 0.01$).
Conclusion: Lower extremity CTA using 80 kVp and IMR is useful for lower radiation and contrast agent dose while preserving image quality. IMR can also provide better image quality for small-caliber vessels below the knee than HIR.

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Computed tomography angiography (CTA) is widely used in patients with lower extremity arteriosclerosis obliterans, thus providing accurate criteria for treatment decision [1,2]. However, lower extremity CTA is associated with high radiation exposure and high doses of contrast agent for patients due to the necessity of completing an extensive scanning from the abdomen to the feet. Therefore, new methods are being studied to reduce the dose of radiation and contrast agent while obtaining a relatively satisfactory image quality [3–6]. Among various methods for reducing the radiation dose, low tube voltage appears as the most effective, while also permitting a reduction in contrast agent dose due to generating higher vascular enhancement [7]. However, low tube voltage also increases the noise due to the reduction of transmitted radiation, whichcan potentially affect the image diagnostic quality [5,8,9].

Currently, the filter back-projection (FBP) algorithm is widely used, which is a very fast and robust reconstruction technique. However, there is a noticeable increase in image noise with the decreasing tube voltage [10–12]. Iterative reconstruction (IR) is an alternative image reconstruction method to FBP that can reduce radiation doses with similar quality image indexes such as noise compared to routine-dose FBP [13–18]. Previous reports have shown that CTA using low tube voltage with hybrid IR (HIR), which is a raw-data-based iterative method and consists of a dual-model (noise and anatomical) technique, can decrease the dose of radiation and contrast agent without compromising image quality [19–21]. The knowledge-based iterative model reconstruction (IMR) is a recently developed image reconstruction algorithm that uses a knowledge-based approach to optimize a penalty-based cost function while accurately incorporating the geometry and physical characteristics of a CT scanner [10]. Studies have shown that IMR can significantly improve both qualitative and quantitative image quality compared with FBP and HIR [22–25]. However, the feasibility of IMR with low tube voltage and reduced contrast agent in lower extremity CTA is still unknown, and there are also no reports about comparing the image quality between IMR and HIR in lower extremity CTA with low tube voltage. Therefore, we hypothesized that lower extremity CTA using IMR at 80 kVp can provide at least equivalent if not better qualitative and quantitative image quality compared to FBP at 120kVp and HIR at 80 kVp.

The purpose of this study was to evaluate the feasibility of using 80 kVp and IMR in lower extremity CTA.

Material and methods

Patients

Sixty consecutive patients with suspected lower extremity arteriosclerosis obliterans were enrolled between October 2016 and July 2017. The clinical data collected included age, gender, body weight, and height. The exclusion criteria were allergy to iodinated contrast agent, renal insufficiency, and history of stenting or bypass surgery in lower limb arteries. Based on a random-number table, all patients were randomly assigned into a control group (Group A, $n = 30$) using 120 kVp for CTA and an experimental group (Group B, $n = 30$) using 80 kVp. This study was approved by our institutional review board. Written informed consent was obtained from all participating patients.

CT scanning protocol

All CTA examinations were performed using a 256-sections CT scanner (Brilliance iCT®; Philips Healthcare, Cleveland, OH, USA). Scanning was performed in a craniocaudal direction from the distal abdominal aorta to the foot. Scanning parameters included: detector collimation, 128 × 0.625 mm with dynamic z-focal spot; gantry rotation time, 0.27 s; and matrix, 512 × 512 pixels. The automatic tube current modulation (ATCM) (Doseright index®; Philips Healthcare) was used in both groups. Reference tube current-time product was 180 mAs in Group A and 140 mAs in Group B. A dual-head power injector (Ulrich REF XD 2051®; Ulrich Medical GmbH, Ulm, Germany) via a 20-gauge intravenous cannula (inserted into a superficial vein positioned in the right antecubital fossa) was used. Group A, as a control, used 100 mL of contrast agent (iohexol, Shuangbei 350®, Beilu Pharmaceutical Co., Ltd. Beijing, China) injected at a flow rate of 4 mL/s followed by infusion of normal saline (40 mL) at the same flow rate. Group B used 75 mL of the same contrast agent. The time it takes for the contrast agent to reach the distal vessel is usually late for lower extremity arteriosclerosis obliterans, so the flow rate was decreased to 3 mL/s in order to maintain continuous intra-arterial contrast agent during the CT scanning. For both groups, the bolus-tracking technique was used, and the monitor region was placed at the lumbar 3 vertebral body level. Scans were initiated 20 s after attenuation reached 200 Hounsfield units (HU).

Image reconstruction

The CT data of Group A were reconstructed with Protocol 1 (P1) via FBP, whereas those of Group B were reconstructed with Protocol 2 (P2) via HIR (iDose4®, Philips Healthcare, Cleveland, OH, USA) and Protocol 3 (P3) via IMR. The iDose4® system offers seven levels to control or reduce the amount of image noise at a given tube output; levels 1–7 provide noise reduction factors of 0.89–0.45 [19]. Similarly, the prototype provides three levels for IMR, and levels 1–3 provide 60%, 70%, and 80% noise reduction, respectively [26]. In our study, iDose4® at level 4 and IMR at level 1 were applied to image reconstruction, which are routinely used at our institute. Images were reconstructed in transverse sections with a slice thickness of 1.5 mm and increment of 1.0 mm. Next, all datasets were transferred to a dedicated workstation (IntelliSpace Portal®, Philips Healthcare). Maximum intensity projections (MIP) and curved planar reformations (CPR) were performed for each patient.

Evaluation of objective image quality

All experimental measurements were performed by an experienced radiologist with 10 years of CTA experience. The intravascular attenuation was measured on the axial images at the following locations: abdominal aortic bifurcation (AAB), bilateral common iliac arteries (CIA), common femoral arteries (CFA), middle superficial femoral arteries (MSFA) and middle popliteal artery (MPA). Within the vessels, the region of interest (ROI) was defined as large as