Clinical Evaluation and Potential Radiation Dose Reduction of the Novel Sinogram-affirmed Iterative Reconstruction Technique (SAFIRE) in Abdominal Computed Tomography Angiography

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Rationale and Objectives: Computed tomographic angiography is the standard in routine follow-up after endovascular aneurysm repair, causing radiation exposure; thus, dose-saving strategies should be applied. The aim of this study was to evaluate the novel sinogram-affirmed iterative reconstruction (SAFIRE) algorithm in terms of clinical usability and potential reduction of radiation exposure.

Materials and Methods: Forty-six patients underwent computed tomographic angiographic follow-up after endovascular aneurysm repair. Data were acquired using a dual-source computed tomographic scanner running both x-ray tubes at the same voltage (120 kV). Raw data were reconstructed using projections of both tubes with filtered back projection (FBP) and of only one tube with FBP and SAFIRE, corresponding to synthetic acquisition with half the radiation dose of the clinical routine radiation dose. Image sets were objectively compared regarding signal-to-noise ratio and edge sharpness. Two radiologists independently assessed a set of subjective criteria, including diagnostic usability, depiction of contrasted vessels, and image noise.

Results: Half-dose (HD) SAFIRE images showed significantly higher signal-to-noise ratios compared to full-dose FBP images ($P < .001$), while having equal edge sharpness ($P = .56$). Most of the subjectively assessed parameters, such as diagnostic usability and depiction of contrasted vessels, were rated similar for HD SAFIRE and full-dose FBP images. Full-dose FBP images depicted fine anatomic structures more clearly ($P < .05$), while HD SAFIRE data sets showed less noise ($P < .01$). HD FBP images performed worse on all criteria ($P < .001$). Interrater agreement was good ($\kappa = 0.74$–0.80).

Conclusions: Using the SAFIRE algorithm, the radiation dose of high-contrast abdominal computed tomographic angiography is reducible from routine clinical levels by up to 50% while maintaining good image quality and diagnostic accuracy.

Key Words: Iterative reconstruction; SAFIRE; CT; CTA; dose reduction.

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Endovascular aneurysm repair (EVAR) of infrarenal abdominal aortic aneurysm has become an attractive alternative to open surgery. However, this method can result in a variety of complications, including endoleak, graft migration, graft wire fracture, graft thrombosis, graft stenosis, graft kinking, and graft infections (1,2). Consequently, long-term follow-up is mandatory to identify and treat complications. Among other imaging modalities, contrast-enhanced computed tomographic (CT) angiography (CTA) has become the gold standard because of its availability, cost-effectiveness, objectivity, and high sensitivity (2,3). Routine follow-up includes CT examinations recommended at 1, 3, 6, and 12 months after the procedure, and yearly thereafter, resulting in a substantial cumulative radiation dose burden with an attributable lifetime cancer risk (4). To keep patients' radiation dose as low as reasonably achievable and

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to minimize cumulative radiation exposure, several dose-saving strategies have proven beneficial, such as lowering the x-ray tube voltage, modulating and adapting the tube current, increasing the iodine concentration of the contrast media (5–9), and, more recently, optimizing postprocessing algorithms.

With respect to the latter approach, efforts have been made to improve image quality computationally. Iterative reconstruction techniques have been promising candidates for many years but were limited by computing power and consequent unreasonably long reconstruction times (10). Compared to traditional filtered back projection (FBP) reconstruction, in which spatial resolution is directly correlated with image noise (11), iterative reconstruction is able to decouple spatial resolution and image noise to a certain extent. Although resolution and edge sharpness are maintained, image noise in low-contrast areas is reduced (12). Several studies have demonstrated the benefit of iterative reconstruction in different body regions using iterative reconstruction in image space (13–16). A new development in this field is the so-called sinogram-affirmed iterative reconstruction (SAFIRE) technique (Siemens Healthcare, Forchheim, Germany) for CT raw data, which uses a refined noise-modeling technique supported by the raw data (sinogram data), with the aims of reducing noise and maintaining image sharpness. SAFIRE estimates the local noise content in each image pixel by analyzing the raw data contributing to this pixel and removes it from the current image data set.

Until now, there have been few studies published evaluating its feasibility. In coronary CTA, it has been shown that SAFIRE can significantly reduce the required radiation dose while maintaining image quality (17,18). Winklehner et al (19) proposed that radiation dose can be reduced by 50% in body CTA using SAFIRE, with image quality similar to full-dose (FD) FBP reconstructed images. Furthermore, abdominal low-dose CT images reconstructed with SAFIRE did not have a significant loss of diagnostic value (20). The aim of this study was to validate these results, extending the field of application to abdominal CTA after EVAR and estimating potential dose savings.

MATERIALS AND METHODS

Patients

Forty-six patients, who had undergone clinically indicated routine abdominal CT angiographic follow-up after EVAR between September 2010 and February 2011, were retrospectively included in this study. The patient cohort included one woman and had a mean age of 69.2 ± 10.1 years. Demographic patient data and CT acquisition parameters are shown in Table 1. Institutional review board approval was obtained for this retrospective study with a waiver of the requirement for informed consent.

TABLE 1. Patient and CT Angiographic Acquisition Characteristics (*n* = 46)

Variable	Value
Men	45
Age (y)	69.2 ± 10.0 (46–89)
CT angiographic number after EVAR	2 (1–8)
Interval between EVAR and CT angiography (d)	113 (1–2274)
Anterior-posterior cross-section* (cm)	28.7 ± 3.3
Lateral cross-section (cm)*	35.2 ± 2.9
Scan parameters	
Tube voltage (kV)	120/120
Effective tube current–time product (mAs)	212.2 ± 68.8
CTDI (mGy)	17.9 ± 5.6
Scan length (mm)	535.7 ± 113.6
DLP (mGy · cm)	1008.8 ± 492.9
Pitch	1.1
Collimation (mm)	2 × 64 × 0.6
ED (mSv)	15.1 ± 7.4

CT, computed tomographic; CTDI, computed tomographic dose index; DLP, dose-length product; ED, effective radiation dose; EVAR, endovascular aneurysm repair.

Data are expressed as mean ± standard deviation (range) or as median (range).

*Cross-sections were measured at the level of the regions of interest.

CT Image Acquisition

Patients were scanned using a second-generation dual-source CT system (Somatom Definition Flash; Siemens Healthcare), which has two tube detector systems with fields of view of 33 and 50 cm. Depending on the patient's weight and kidney function, 90 to 120 mL contrast media (Ultravist 370, 370 mg iodine/mL; Bayer Pharma AG, Berlin, Germany) and 40 mL saline chaser were injected through an 18-gauge antecubital vein catheter at a flow rate of 3 mL/s using a dual-syringe injector (CT Stellant; Medrad, Indianola, PA). Acquisition parameters were 2 × 64 × 0.6 mm detector collimation with z-flying focal spot and 0.5-second rotation time. Radiation exposure was adjusted in real time during the examination using automatic anatomic exposure control (CARE Dose 4D; Siemens Healthcare) with a quality reference tube current–time product of 230 mAs. The examination was performed in dual-source mode using both x-ray tubes with identical tube currents and tube potentials for data acquisition; thereby the clinical routine tube current was halved for each x-ray tube. The optional high-pitch flash mode was not applied. Bolus tracking was used to start the craniocaudal acquisition with a 4-second delay after the CT number exceeded 130 Hounsfield units (HU) in a small region of interest within the descending aorta. The scan range was adjusted to cover the abdomen, or the thorax and abdomen, depending on the referring physician's request.

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