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Original Research Article

Stent evaluation in low-dose coronary CT angiography: Effect of different iterative reconstruction settings

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ABSTRACT

Background: Different iterative reconstruction (IR) techniques compensate increased noise from lower tube current-time product settings, yet the differences between IR settings remain unclear.
Objective: Aim of this study was to test whether different IR settings have a clinically relevant influence on image quality and on the diagnostic accuracy of low-dose CT angiography in patients with a stent.
Methods: Forty-two patients with 73 coronary stents were prospectively enrolled. Data were acquired with dual-source CT, and images were reconstructed with standard filtered back projection (FBP) and raw data-based IR with different settings (I3, I4, I5). Quantitative parameters, including CT-attenuation, noise, signal-to-noise ratio, contrast-to-noise ratio, as well as the presence of in-stent stenosis $> 50\%$ were determined. All patients had invasive angiography as reference standard.
Results: Mean effective dose was 0.32 ± 0.02 mSv. Image noise decreased significantly compared with FBP (I3 = 29%; I4 = 38% and I5 = 45%), whereas signal-to-noise and contrast-to-noise ratios increased significantly (all IR settings $P < .01$). Subjective image quality was superior with all IR settings ($P < .01$). FBP sensitivity, specificity, positive predictive value, and negative predictive value were 83%, 71%, 36%, and 96% per stent compared with 100%, 76%, 44%, and 100%, respectively, in IR reconstructions independent of the IR setting applied.
Conclusion: In low-dose coronary CT angiography, higher IR settings significantly improved subjective and objective image quality but had no effect on accuracy.

1. Introduction

Coronary CT angiography (CTA) has emerged as an accurate noninvasive method for ruling out coronary artery stenosis. Low-dose protocols are increasingly used in clinical routine, applying high-pitch or sequential prospectively triggered scans at lower tube voltage settings (80 or 100 kV). However, the clinical application of coronary CTA to identify in-stent

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stenosis in patients after coronary interventions remains challenging and demands high image quality.[1] To evaluate stents, dedicated convolution kernels are often used, which increase spatial resolution at the cost of increased image noise.[2] Iterative reconstructions (IRs) are a rather old method for image optimization. It was used for image reconstruction in the first CT scanners and is being increasingly applied in clinical CT now.[3] The standard technique to reconstruct CT data for the past decades was filtered back projection (FBP).[4] In contrast IR algorithms perform corrections on the basis of loop-wise raw data to adjust spatial resolution and image noise independently.[5]

These algorithms suffer from slow processing performance because of the large amount of data to be computed. As a less time-consuming alternative, image-based statistical IR was developed. It avoids extensive mathematical modeling with computational elaborate raw data operations. The resulting images show strongly reduced image noise but an uncommon, "plastic-like" texture.[6] With adaptive statistical IRs, the user can create and adjust combinations of iteratively and conventionally (FBP) reconstructed images to benefit both conventional image texture and reduced image noise by blending both images linearly.[7] A similar approach is IR in image space (IRIS), an IR algorithm, which aims to reduce artifacts and noise while maintaining spatial resolution and a more familiar texture.[8]

The latest image reconstruction systems provide raw data-based IR algorithms (model-based IR[9]; sinogram-affirmed IR, SAFIRE[10]) with acceptable processing time. It has been suggested recently that SAFIRE is able to improve the diagnostic accuracy of low-dose coronary CTA.[11] SAFIRE offers 5 different settings that define the specific parameters of the underlying noise modeling and regularization algorithm. The "strength" of the algorithm determines the level of noise reduction; higher numbers denote increased noise reduction. The aim of this study was to test whether different IR settings have a clinically relevant influence on image quality and on the diagnostic accuracy of low-dose CTA in patients with a stent.

2. Methods

Forty-two (34 men, 8 women) symptomatic patients with previous coronary stent implantation were included in this study. Inclusion and exclusion criteria have been reported previously.[11] Stent-specific exclusion criteria were previous stent-in-stent placement, as well as stent implantation in bifurcation lesions. All patients gave written informed consent, and the study was approved by the institutional review board.

All patients with a heart rate >65 beats/min received 100 mg of atenolol orally 45 to 60 minutes before coronary CTA. If the heart rate in inspiration remained >65 beats/min at the time of the scan, up to 4 doses of 5 mg of metoprolol were given intravenously to reach a target heart rate <60 beats/min. Patients who did not reach the target heart rate after β-blockage were examined with the scan protocol described in 2.1. without further pharmacologic intervention. All patients received 0.8 mg of isosorbide dinitrate sublingually before dual-source CT (DSCT) examination.

2.1. DSCT data acquisition

Patients were examined in the supine position during inspiratory breathhold with the use of a DSCT system (Somatom Definition Flash; Siemens Healthcare, Forchheim, Germany) with a gantry rotation time of 0.28 second, tube voltage of 80 kV, and tube current of 165 reference mAs, slice collimation of 128 × 0.6 mm, craniocaudal scan direction. In all patients a prospectively electrocardiogram-triggered axial scan mode was used, triggered at 70% of the R–R interval, without "padding."

All patients received contrast material (60 mL, 370 mg iodine/mL; Ultravist 370; Bayer Healthcare, Berlin, Germany), followed by 50-mL bolus that consisted of 20% of contrast agent and 80% saline with a flow rate of 6 mL/s with the use of a dual-head power injector (CT Stellant; Medrad Inc, Indianola, PA). Circulation time was assessed by test bolus measurements. Two seconds were added to the test bolus peak to take into account the starting delay of CTA.[11]

2.2. Image reconstruction

Image reconstruction was performed with both standard FBP and IR techniques. For IR, a SAFIRE (Siemens Healthcare) was used which applies a noise-modeling technique that is based on raw data.

In SAFIRE raw data-based iterations for artifact reduction and image-based iterations are combined to allow for an anisotropic 3-dimensional regularization function.

In each image pixel, the local image noise is estimated in different directions by analysis of the statistical significance of the raw data contributing to that pixel. Space variant is adapted to the local noise level.[12]

SAFIRE offers 5 different settings that define the specific parameters of the underlying noise model and regularization. The strength of the algorithm determines the level of noise reduction; higher numbers denote increased noise reduction. The strength is not related to the number of iteration loops. In our study all data sets were reconstructed with 3 different IR settings (I3, I4, I5). Even lower settings (I1, I2) were initially evaluated in a pilot study and discarded because of little effects in noise reduction.

For both FBP and IR, soft and sharp kernels (B26f, I26f, B46f, I46f) were used to reconstruct images at a slice thickness of 0.6 mm and increment of 0.4 mm. Soft kernels (B26 and I26) were used for noise and for calculating signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR), and sharp kernels (B46 and I46) were used for stent evaluation of subjective image quality and diagnostic accuracy. Subsequently, the image data sets were transferred to a 3-dimensional workstation (SyngoVia; Siemens Healthcare) for further evaluation.

2.3. Image quality

To assess the image quality after FBP and IR, both subjective and objective parameters were evaluated independently by 2 radiologists blinded to the reconstruction technique and all clinical data.

Subjective image quality was assessed after FBP and IR with the use of a 5-point Likert scale. Image noise, contour