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Iterative Reconstruction to Preserve Image Quality and Diagnostic Accuracy at Reduced Radiation Dose in Coronary CT Angiography

An Intraindividual Comparison

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OBJECTIVES This study sought to determine whether a 50%-reduced radiation dose protocol using iterative reconstruction (IR) preserves image quality and diagnostic accuracy at coronary computed tomography angiography (CTA) as compared with a routine dose protocol using traditional filtered back projection (FBP).

BACKGROUND IR techniques show promise to decrease radiation requirements at coronary CTA. No study has performed a direct head-to-head, intraindividual comparison of IR algorithms with FBP vis-à-vis diagnostic accuracy and radiation dose at coronary CTA.

METHODS Sixty consecutive subjects (45 men, 53.3 $\pm$ 9.4 years of age) prospectively underwent coronary catheter angiography (CCA) and 2 coronary CTA scans. One coronary CTA acquisition used routine radiation dose settings and was reconstructed with FBP. For another scan, the tube current–time product was reduced by 50%, and data were reconstructed with IR. Studies were blindly and randomly interpreted. Image quality, radiation dose, and diagnostic accuracy were compared using CCA as the reference standard.

RESULTS Sensitivity and specificity for diagnosing $\geq$50% coronary artery stenosis on a per-segment level were 88.5% and 92.1% with FBP and 84.2% and 93.4% with IR, respectively. On a per-patient level, sensitivity and specificity were 100% and 93.1% with FBP and 96.8% and 89.7% with IR, respectively (all $p > 0.05$). With FBP versus IR, the area under the receiver-operating characteristic curve was 0.903 (95% confidence interval [CI]: 0.881 to 0.922) and 0.888 (95% CI: 0.864 to 0.909) on a per-segment level, and 0.966 (95% CI: 0.883 to 0.996) and 0.932 (95% CI: 0.836 to 0.981) on a per-patient level, respectively ($p = 0.290$ and 0.330). Compared with FBP, the iterative series showed no significant ($p > 0.05$) differences in image quality analyses. Median dose–length product was 52% lower for the IR protocol compared with the FBP protocol (109.00 [interquartile range: 82.00 to 172.50] mGy·cm vs. 52.00 [interquartile range: 39.00 to 84.00] mGy·cm, $p < 0.001$).

CONCLUSIONS Compared with a routine radiation dose FBP protocol, 50% reduced dose acquisition using IR preserves image quality and diagnostic accuracy at coronary CTA. (J Am Coll Cardiol Img 2013;6:1239–49) © 2013 by the American College of Cardiology Foundation

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Concerns over radiation doses from coronary computed tomography angiography (CTA) have hastened efforts at dose optimization. Conventional filtered back projection (FBP), the traditional method of image reconstruction at computed tomography (CT), incurs a trade-off between spatial resolution and image noise (1), which limits the options for further reduction of the radiation dose. Because of improved computer power, several different iterative CT reconstruction techniques have become available over recent years that show promise of decoupling the relationship between radiation requirements and spatial resolution to some extent, and as a common hallmark, of substantially reducing image noise (1–5). Accordingly, these algorithms are currently under intense evaluation with the aim of further reducing radiation requirements without incurring a loss in diagnostic image quality.

The iterative reconstruction (IR) algorithm used in this study primarily operates in the raw data domain. It uses initial voxel attenuation coefficients to predict projection data and compares these predictions with actual data. Attenuation is iteratively modified until the error between actual and estimated data is acceptable. Several iterations and updated correction loops aim at improving image quality and suppressing image noise, with the goal of enabling the use of lower radiation dose protocols, while maintaining diagnostic quality. Reduced radiation, achieved through manipulation of tube voltage and current, decreases the density and energy of penetrating photons. Decreased photon density and energy result in higher image noise, subsequently corrected with IR, reducing radiation requirements. Several benefits of IR algorithms for use with coronary CTA and other CT applications have been described (1–7). However, an intraindividual comparison of the performance of IR algorithms with FBP protocols vis-à-vis diagnostic accuracy and radiation dose requirements at coronary CTA has not been performed to date.

Accordingly, we undertook this prospective investigation to test, in the same patient population, our hypothesis that IR algorithms, applied to reduced radiation dose acquisitions, can maintain image quality and diagnostic accuracy at coronary CTA compared with coronary catheter angiography (CCA) with substantial radiation dose reduction over traditional FBP.

ABBREVIATIONS AND ACRONYMS

BMI = body mass index
CAD = coronary artery disease
CCA = coronary catheter angiography
CTA = computed tomography angiography
CI = confidence interval
CT = computed tomography
DLP = dose–length product
ECG = electrocardiogram
FBP = filtered back projection
IR = iterative reconstruction
ROC = receiver-operating characteristic

METHODS

Patient population. This single-center study was approved by our hospital's institutional ethics committee. From May to October 2012, a total of 64 consecutive symptomatic patients (45 men, age 53.3 ± 9.4 years) who had been clinically referred for elective CCA because of suspected coronary artery disease (CAD) were approached for participation, after permission of their attending physician of record had been obtained. Inclusion criteria were subject age between 30 and 70 years and sinus rhythm. Subject exclusion criteria were known CAD, history of prior percutaneous intervention or bypass surgery, prior reaction to iodinated contrast materials, impaired renal function (serum creatinine >120 μmol/l), inability to hold their breath; and acute coronary syndrome. Of the 64 patients approached for participation, 4 refused, so that the final study cohort consisted of 60 patients who provided written informed consent.

CT scanning protocols. One or 2 days before their scheduled CCA procedure, all patients underwent coronary CTA on a second-generation dual-source CT scanner (SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany). Acquisition parameters were: 2 × 64 × 0.6-mm detector collimation and 280-ms gantry rotation time. All studies were acquired in a craniocaudal direction at end-inspiration. Attenuation-based tube current modulation (CARE Dose4D, Siemens Healthcare) was applied per default. For contrast medium enhancement, automated bolus tracking was used in a region of interest within the ascending aorta, with a signal attenuation trigger threshold of 100 Hounsfield units (HU) and a 6-s scan delay. We used a triple-phase contrast medium injection protocol, which consisted of 50 to 60 ml of undiluted contrast agent (iopromide [Ultravist] 370 mgI/ml, Bayer Healthcare, Berlin, Germany) followed by a

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