Original Investigation

Minimized Radiation and Contrast Agent Exposure for Coronary Computed Tomography Angiography: First Clinical Experience on a Latest Generation 256-slice Scanner

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Rationale and Objectives: The aim of the study was to evaluate the impact of the latest coronary computed tomography angiography (CCTA) techniques allowing a radiation- and contrast-sparing protocol on image quality in unselected patients referred for exclusion of suspected coronary artery disease (CAD).

Materials and Methods: This prospective study was approved by the local ethics committee, and all patients provided written informed consent. Between March and June 2015, 89 consecutive patients (61% male; mean age 55 ± 11 years) referred for exclusion of CAD by 256-slice CCTA using prospective electrocardiogram triggering were included. Tube voltage (80–120 kVp), tube current (180–310 mA) as well contrast agent volume (25–45 mL) and flow rate (3.5–5 mL/s) were adapted to body mass index. Signal intensity was measured by placing a region of interest in the aortic root, the left main artery, and the proximal right coronary artery. Image noise was measured in the aortic root. Two independent blinded readers semi-quantitatively assessed the image quality regarding motion, noise, and contrast on a 4-point scale.

Results: Median contrast agent volume and median effective radiation dose were 35 mL (interquartile range, 30–40 mL) and 0.5 mSv (interquartile range, 0.4–0.6 mSv), respectively. Mean attenuation in the aortic root was 412 ± 89 Hounsfield units. Diagnostic image quality was obtained in 1050 of 1067 (98.4%) coronary segments and, on an intention-to-diagnosis basis, in 85 of 89 (95.5%) patients. Below a cut-off heart rate of 67 beats/min, only 1 of 974 (0.1%) coronary segments was nondiagnostic.

Conclusion: A radiation- and contrast-sparing protocol for CCTA on a latest generation 256-slice computed tomography scanner yields diagnostic image quality in patients referred for CAD exclusion in daily clinical routine.

Key Words: Coronary computed tomography angiography; radiation; low-dose contrast agent volume; ultra-low-dose radiation exposure.

INTRODUCTION

Coronary computed tomography angiography (CCTA) has become an important and robust noninvasive imaging tool for the exclusion of significant coronary artery disease (CAD). However, its growing clinical use has raised concerns about the potential induction of malignancies due to the increased burden of radiation exposure for patients (1). Furthermore, the debate on the potential risks associated with cardiovascular imaging has recently been extended to additional components, and contrast agents have been identified as significant contributors of potential risk. In fact, the rate of death and serious acute adverse events due to contrast agent exposure is not negligible and outweighs the radiation-related risks (2). As a consequence, various technological advances have evolved not only to reduce radiation exposure (3), but also to save contrast agent volume (4), potentially enabling a CCTA imaging approach with a combined low radiation and low contrast agent volume exposure.

Acad Radiol 2016; ■:■■–■■

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http://dx.doi.org/10.1016/j.acra.2016.03.015

The introduction of prospective electrocardiogram (ECG) triggering (5), including its adaption to high-pitch helical scanning (6,7), has paved the way for a substantial reduction of radiation exposure from initially over 20 mSv with conventional helical acquisition (8) to approximately 2 mSv in current daily clinical routine (5). Nevertheless, prospective triggering is prone to image quality degradation if the patient's heart rate is irregular or high (ie >62 beats/min at a gantry rotation time of 350 ms) (5). Wide-volume 256-slice scanners with 16-cm cranial-caudal coverage and fast gantry rotation time of 280 ms permit acquisition of the whole heart within a single heartbeat, which not only eliminates misalignment artifacts (9), but also results in decreased radiation dose by precluding redundant radiation from overlapping of sequential axial scans (10) and allows for a reduction of contrast agent volume because of shorter acquisition time (4). Furthermore, a more powerful X-ray generator enables acquisition at tube voltages of 100 kVp or below, thereby offering a further reduction of radiation dose, while yielding higher contrast than the standard 120 kVp technique because the X-ray output energy is closer to the iodine K-edge of 33 keV (11).

Aside from technological advances in computed tomography (CT) hardware, iterative reconstruction algorithms have been reported to permit a further and substantial reduction in radiation dose (12,13). Most recently, a latest generation adaptive statistical iterative reconstruction algorithm (ASiR-V, GE Healthcare, Waukesha, WI, USA) has been proposed to yield substantial noise reduction for CCTA acquired at low tube voltage and current.

The aim of the present study was to evaluate the impact of latest CCTA techniques allowing a radiation- and contrast-sparing protocol on image quality in unselected patients referred for exclusion of suspected CAD.

METHODS

Patient Population

We prospectively included 89 consecutive patients who were referred for exclusion of CAD with CCTA due to stable symptoms from March to June 2015. Patients with additional clinical questions requiring extension of the scan coverage beyond the heart (eg patients with suspected aortic vessel disease) were excluded. Further exclusion criteria were known hypersensitivity to iodinated contrast agents and renal insufficiency (glomerular filtration rate <60 mL/min). The study was approved by the local ethics committee (KEK-ZH-Nr. 214–0632), and all patients provided written informed consent. The University Hospital Zurich holds a research agreement with GE Healthcare.

Image Acquisition

All patients underwent single-beat contrast-enhanced CCTA during breath-hold at inspiration with prospective ECG triggering at 75% of the R-R interval on a latest generation 256-slice CT scanner (Revolution CT, GE Healthcare, Waukesha, WI, USA). Up to 30 mg of metoprolol (Beloc Zok, Astra Zeneca, London, UK) was administered intravenously before the examination if the heart rate was higher than 65 beats/min to obtain optimal image quality for CCTA (7). Patients received 0.4 mg of sublingual isosorbiddinitrate (Isoket, Schwarz Pharma, Monheim, Germany) 2 min before the CCTA scan.

TABLE 1. BMI-adapted Scan and Contrast Protocol

BMI (kg/m^2)	Voltage (kV)	Current (mA)	Dose (mL)	Flow Rate (mL/s)
≤20.0	80	180	25	3.5
20.1–22.4	100	180	30	4.0
22.5–24.9	100	215	30	4.0
25.0–27.4	100	270	35	4.5
27.5–29.9	100	310	40	5.0
≥30.0	120	310	45	5.0

BMI, body mass index.

Iodixanol (Visipaque 320, 320 mg/mL, GE Healthcare, Buckinghamshire, UK) was injected into an antecubital vein followed by 50 mL of saline solution via an 18-gauge catheter. Contrast agent volume (25–45 mL) and flow rate (3.5–5 mL/s) were adapted to body mass index (BMI) (Table 1) according to our clinical standards (14). Similarly, for CCTA acquisition, tube voltage (80–120 kVp) and tube current (180–310 mA) were adapted to BMI (Table 1). A collimation of 256 × 0.625 mm with a z-coverage of 12–16 cm was used with a display field of view of 25 cm. All scans were acquired in high-resolution mode with an in-plane spatial resolution of 0.23 × 0.23 mm. Gantry rotation time was 280 ms.

CT raw data were reconstructed with a novel ASiR-V (GE Healthcare) using a high-definition kernel. Radiation dose for CCTA was determined by the dose-length product multiplied by a conversion factor of $0.014\ mSv \times mGy^{-1} \times cm^{-1}$ (8). Heart rate variability was defined as the maximum beat-to-beat variability detected over a default 30-s window, excluding premature heartbeats (eg extrasystolic beats).

An unenhanced CT for calculation of calcium scoring was acquired on the same CT scanner (Revolution CT) using the following scan parameters: prospective ECG triggering, 2.5-mm slice thickness, 120-kV tube voltage, 200-mA tube current, and a large field of view of 50 × 50 cm. From this scan, Agatston scores for each coronary vessel were computed with commercially available software (Smartscore 4.0, GE Healthcare) and summed to yield the total coronary artery calcium, as previously reported (15).

Quantitative Image Analysis

On a dedicated workstation (Advantage Workstation 4.6, GE Healthcare), for every patient, the aortic root was examined at the level of the left main coronary artery on an axial image using a circular region of interest (ROI) with a 20-mm diameter to measure mean attenuation (representing signal) and