Original Investigation

Evaluation of a High Concentrated Contrast Media Injection Protocol in Combination with Low Tube Current for Dose Reduction in Coronary Computed Tomography Angiography: A Randomized, Two-center Prospective Study

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Rationale and Objectives: The study aimed to prospectively evaluate the radiation dose reduction potential and image quality (IQ) of a high-concentration contrast media (HCCM) injection protocol in combination with a low tube current (mAs) in coronary computed tomography angiography.

Materials and Methods: Eighty-one consecutive patients (mean age: 62 years; 34 females; body mass index: 18–31) were included and randomized-assigned into two groups. All computed tomography (CT) examinations were performed in two groups with the same tube voltage (100 kV), flow rate of contrast medium (5.0 mL/s), and iodine dose (22.8 g). An automatic mAs and low concentration contrast medium (300 mgI/mL) were used in group A, whereas effective mAs was reduced by a factor 0.6 along with HCCM (400 mgI/mL) in group B. Radiation dose was assessed (CT dose index [$CTDI_{vol}$] and dose length product), and vessel-based objective IQ for various regions of interest (enhancement, noise, signal-to-noise ratio, and contrast-to-noise ratio), subjective IQ, noise, and motion artifacts were analyzed overall and vessel-based with a 5-point Likert scale.

Results: The CT attenuation of coronary arteries and image noise in group B were significantly higher than those in group A (ranges: 507.5–548.1 Hounsfield units vs 407.5–444.5 Hounsfield units; and 20.3 ± 8.6 vs 17.7 ± 8.0) ($P \leq 0.0166$). There was no significant difference between the two groups in signal-to-noise ratio, contrast-to-noise ratio, and subjective IQ of coronary arteries (29.4–31.7, 30.0–37.0, and medium score of 5 in group A vs 29.4–32.4, 27.7–36.3, and medium score of 5 in group B, respectively, $P \geq 0.1859$). Both mean $CTDI_{vol}$ and dose length product in group B were 58% of those of group A.

Conclusions: HCCM combined with low tube current allows dose reduction in coronary computed tomography angiography and does not compromise IQ.

Key Words: Dose reduction; high concentration contrast media; coronary computed tomography angiography; mAs; image quality.

INTRODUCTION

Coronary artery disease (CAD) is one of the leading causes of morbidity and mortality worldwide. With the advancement in technology efforts to increase the accuracy in diagnosing CAD, coronary computed tomography angiography (CCTA) is an efficient and reliable modality for CAD diagnosis and is well established in routine clinical practice (1–6). Over the last decade, radiation concerns in radiology have been increased since the annual medical radiation dose per capita increased about sixfold to 3.0 mSv

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(7). CT represents only about 7% of all diagnostic imaging examinations using ionizing radiation, but it is responsible for more than 50% of the cumulative radiation exposure in Western countries (8). Currently, several technical improvements for radiation dose reduction in computed tomography (CT) have been developed. The use of a low kilovoltage (kV) is one of these options to reduce radiation dose in CCTA. Lower tube voltage causes a higher attenuation for iodinated contrast media (CM) and thus a higher enhancement in the coronary arteries is observed (9). At the same time, noise is considerably increased since low kV also reduces the total number of emitted X-ray photons, which needs to be compensated by a parallel increase of the effective mAs. A fundamental principle in radiation dose reduction protocols follows the approach to keep constant in the signal-to-noise ratio (SNR) (10). Because of the higher iodine signal achieved in low kV exams, a higher noise can be acceptable, which means that the compensatory increase in mAs needs to be moderate (9). An alternative or additional option, with same radiation dose reduction principle as low kV does, is to enhance the signal by increasing the iodine contrast. Likewise, this would allow for a (further) reduction of the reference mAs compared to an exam with a standard iodine contrast. CCTA is a typical "first pass" examination where the iodine delivery rate (IDR) becomes a crucial contrast injection parameter to determine enhancement (11,12). Using high-concentration contrast media (HCCM) is a possible approach to achieve high vessel signal in CT angiography by increasing the IDR, which may compensate for a reduced radiation dose and maintain the diagnostic image quality. Therefore, the combination of increased concentration of CM and reduced tube current-time product is an interesting concept to save radiation dose and to reserve image quality. This concept has been applied in CT angiography of the aorta and the pulmonary arteries (8,13,14), but not yet in CCTA. Specifically, sufficient overall image quality in CCTA is mandatory for adequately visualizing smaller vessels, so concerns may exist that big radiation dose reduction concepts might be limited.

The objective of this study was to test and assess whether radiation dose can be reduced with a "high contrast—low mAs" approach without compromising image quality in a vessel-based assessment. The hypothesis of this study was that a high IDR protocol using high concentration CM would enable us to lower the tube current time product and radiation exposure compared to a standard injection protocol while maintaining image quality.

MATERIALS AND METHODS

Study Population

This prospective randomized two-center study was approved by the institutional review board of these two centers, and written informed consent was obtained prior to each examination from all patients. Between June 2015 and November 2016, a total of 100 patients with an indication for a CCTA exam were prospectively included in the study. Exclusion criteria were (1) known reduced cardiac function (New York Heart Association [classification] IV) to minimize the influence of cardiac output; (2) severe renal insufficiency (estimated creatinine clearance below 30 mL/min, using the Cockcroft-Gault equation); (3) history of hypersensitivity to iodinated contrast agents; (4) insufficient peripheral vein conditions that would not allow to inject the CM at the protocol flow rate; (5) patients with coronary stents, as stents may increase the CT attenuation of the lumen and influence the qualitative or quantitative image quality assessment through possible artifacts from stents; and (6) patients with severe arrhythmia, such as atrial fibrillation.

Imaging and Injection Protocols

Patients were prospectively randomized and assigned into two groups. Group A patients received a CM with an iodine concentration of 300 mgI/mL (Ultravist, Bayer HealthCare, Leverkusen, Germany), and group B patients received a CM with an iodine concentration of 400 mgI/mL (Iomeron 400, Bracco Sine, Shanghai, China).

All CT examinations were performed with a 2×128-row dual-source CT scanner (Somatom Definition Flash, VA44A Siemens Healthcare, Forchheim, Germany). To avoid motion artifacts, 25–50 mg of β-blockers were sublingually administered if patients had a resting heart rate greater than 85 beats per minute at 60 minutes before the CT scan. Prior to the CCTA study, a nonenhanced scan with prospective electrocardiographic gating was performed to measure the coronary artery calcium score (sequential scan with 16×2.5 mm collimation; tube current, 140 mA; tube voltage, 120 kV).

Both CMs were warmed up to 37°C and injected with a dual head power injector (Stellant, Medrad, Bayer HealthCare, Shanghai, China) into an antecubital vein through a 20G closed intravenous catheter system (BD Intima II, BD Vialon, Suzhou, China). The same iodine dose (22.8 g) at the same flow rate (5.0 mL/s) was administered for all patients. Thus, group A patients received 76 mL of Iomeprol of Ultravist 300 at an IDR of 1.5 grI/s, whereas group B patients received 57 mL of Iomeprol 400 at an IDR of 2.0 grI/s. The CM injection was followed by a saline flush (20 mL of 0.9% sodium chloride solution) administered at the same flow rate used for the CM injection.

A bolus tracking technique was used to minimize the influence of cardiac output, and CM detection was monitored at a region of interest (ROI) placed in the ascending thoracic aorta; the beginning threshold of the scan was set at 100 Hounsfield units (HU). Scan was started 4 seconds after reaching the threshold; clinical safety was monitored until 1 hour after the examination.

All CCTA data sets were acquired using prospectively ECG-triggered axial acquisition at 30–80% of the R-peak-to-R-peak interval. Detector configuration was $2 \times 128 \times 0.6$ mm, gantry rotation time Flex 0.28 s, slice 0.75 mm, increment 0.5 mm, tube voltage 100 kV, and automated tube current