Radiation Dose Levels of Retrospectively ECG-Gated Coronary CT Angiography Using 70-kVp Tube Voltage in Patients with High or Irregular Heart Rates

Mathias Meyer, MD, Holger Haubenreisser, MD, Uwe. Joseph Schoepf, MD, Rozemarijn Vliegenthart, MD, PhD, Melissa M. Ong, MD, Christina Doesch, MD, Sonja Sudarski, MD, Martin Borggrefe, MD, Stefan O. Schoenberg, MD, Thomas Henzler, MD

Abbreviations and Acronyms

cCTA coronary computed tomography angiography
ECG electrocardiographic
DSCT dual-source computed tomography
ROI region of interest
BDP best diastolic phase
BSP best systolic phase
CNR contrast-to-noise-ratio
DLP dose length product

Rationale and Objectives: Despite ongoing technical refinements, coronary computed tomography angiography (cCTA) remains challenging in its diagnostic value by electrocardiographic (ECG) misregistration and motion artifacts, which commonly occur in patients with atrial fibrillation and high or irregular heart rates. The aim of this study was to evaluate the radiation dose and the number of inconclusive coronary segments at cCTA using retrospective ECG gating at 100 and 70 kV.

Materials and Methods: With institutional review board approval, 154 patients (median age 54 years, 98 men) with high or irregular heart rate prospectively underwent retrospectively ECG-gated cCTA without tube current modulation on a third-generation dual-source computed tomography (DSCT) system at 70 kV ($n = 103$) or on a second-generation DSCT system at 100 kV ($n = 51$). Images were reconstructed in best diastolic phase (BDP), best systolic phase (BSP), and in all phases (APs) at 10% intervals across the R-R cycle. Objective and subjective image qualities were evaluated as well as the presence of motion artifacts with the three different reconstruction approaches.

Results: The mean heart rate was 93 ± 16 bpm. The mean effective radiation dose was 4.5 mSv for 70 kV compared to 8.4 mSv for 100 kV ($P < 0.05$). At BDP reconstruction, 71% ($n = 110$) of the patients showed motion artifacts in one or more coronary segments. At BSP reconstruction, the number of patients with motion artifacts decreased to 37% ($n = 57$). In contrast, if images were reconstructed with the AP approach, all vessels and coronary segments were evaluable with both cCTA protocols.

Conclusions: Retrospectively ECG-gated cCTA at 70 kV results in 52% decreased radiation dose. Further using the AP algorithm allowed for diagnostic evaluation of all coronary segments for stenosis, in contrast to BDP or BSP phase alone.

Key Words: Computed tomography; computed tomography angiography; coronary arteries; radiation dose; retrospective ECG gating.

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From the Institute of Clinical Radiology and Nuclear Medicine, University Medical Center Mannheim, Medical Faculty Mannheim, Heidelberg University, Theodor-Kutzer-Ufer 1-3 D-68167 Mannheim, Germany (M.M., H.H., M.M.O., S.S., S.O.S., T.H.); DZHK (German Centre for Cardiovascular Research) partner site Mannheim, Germany (M.M., H.H., C.D., S.S., M.B., S.O.S., T.H.); Department of Radiology and Radiological Science, Medical University of South Carolina, 171 Ashley Ave, Charleston, South Carolina 29425, United States (U.J.S.); University of Groningen, University Medical Center Groningen, Center for Medical Imaging—North East Netherlands, Department of Radiology, Hanzeplein 1, 9713 GZ Groningen, Netherlands (R.V.); First Department of Medicine, University Medical Center Mannheim, Medical Faculty Mannheim, Heidelberg University, Theodor-Kutzer-Ufer 1-3 D-68167 Mannheim, Germany (C.D., M.B.). Received February 28, 2016; revised August 2, 2016; accepted August 4, 2016. **Address correspondence to:** M.M. e-mail: mathias.meyer@medma.uni-heidelberg.de

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INTRODUCTION

Despite ongoing technical refinements, coronary computed tomography angiography (cCTA) remains limited in its diagnostic value by electrocardiographic (ECG) misregistration and motion artifacts, which most commonly occur in patients with atrial fibrillation and high and irregular heart rates. Accordingly, a substantial share of currently available studies investigating the diagnostic accuracy of this test exclude nonevaluable coronary segments from their data analysis (1). Thus, in *real life*, diagnostic accuracy of cCTA may be significantly lower compared to the results of clinical trials. From a statistical viewpoint, when gauging cCTA's true diagnostic performance, it may be more appropriate to apply 3×2 tables that include nonevaluable coronary segments as a separate cell compared to including them in the "false negative" or the "false positive" cell of a 2×2 table, as is common in clinical trials (1).

Generally, greater robustness of this test is desirable, especially when atherosclerosis is present, to minimize downstream investigations due to inconclusive cCTA studies. Retrospectively ECG-gated cCTA without ECG-controlled tube current modulation is the most robust cCTA imaging technique (2,3). This technique allows reconstruction of images at any desired phase of the heart cycle and the removal of image data acquired during irregular heartbeats, which can lead to ECG misregistration and motion artifacts. Moreover, this technique allows accurate assessment of cardiac function facilitating prediction of mortality as recently shown by an analysis from the multinational CONFIRM registry (4).

However, the advantages of this technique so far have come at the expense of a comparatively high radiation dose. Therefore, most practitioners have abandoned this *old-school* acquisition technique (5). Recently introduced third-generation dual-source computed tomography (DSCT) systems allow the routine use of 70-kV tube voltage at cCTA acquisition of adult patients (6). Using a tube voltage of 70 kV has the advantage of a significant increase in the contrast-to-noise ratio (CNR) of contrast-filled vessels due to the lower mean photon energy that is closer to the K-edge of iodine, as well as a considerable reduction of the radiation dose (6).

Therefore, the goal of the present study was to evaluate radiation dose and the number of inconclusive coronary segments at cCTA using retrospective ECG gating at 70 and 100 kV with second- and third-generation DSCT.

MATERIALS AND METHODS

Patients

This prospective single-center study was approved by our institutional review board and written informed consent was obtained from all patients. From May 2013 to October 2014, a total of 154 patients, including 98 men with a median age of 59 years (range, 44–89 years) were enrolled in this study. All patients had been referred for cCTA to rule out coronary artery stenosis. The inclusion criteria were as follows: mean heart rate before cCTA > 85 bpm or known arrhythmia. All patients had a body mass index (BMI) <30 kg/m^2. No contraindications for computed tomography (CT) or CT contrast agents were present in this cohort. According to our institutional guidelines, all patients had been previously classified as having an intermediate to moderate risk for coronary artery disease (7). From May 2013 to September 2013, 51 consecutive patients underwent retrospectively ECG-gated cCTA on a second-generation DSCT system at 100 kV. As soon as the third-generation DSCT system became available, 103 consecutive patients were examined with this system and underwent retrospectively ECG-gated cCTA at 70 kV (from September 2013 to October 2014). Patients with a cCTA diagnosis of significant (ie, ≥70%) coronary artery stenosis subsequently underwent catheter coronary angiography as part of their clinical care.

CT Technique

All CT examinations were performed with a third-generation DSCT system (SOMATOM Force; Siemens Healthcare Forchheim, Germany) or with a second-generation DSCT (SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany). Before the cCTA study, a noncontrast medium-enhanced prospectively ECG-triggered CT acquisition was performed in all patients to obtain a coronary calcium score. The present study was performed at 120 kV, a quality reference of 80 mAs, and collimation of 38×1.2 mm.

The retrospectively ECG-gated cCTA spiral acquisition performed on the third-generation DSCT system included the following parameters: 0.25-second gantry rotation time, $2 \times 192 \times 0.6$ mm detector collimation, 290 reference mAs, 70-kV tube voltage, and pitch of 0.15. The scan parameters with second-generation DSCT for the retrospectively ECG-gated cCTA spiral acquisition were as follows: 0.28-second gantry rotation time, $2 \times 128 \times 0.6$ mm detector collimation, 220 reference mAs, 100-kV tube voltage, and pitch of 0.17. ECG-controlled tube current modulation was turned off in all patients. However, automated anatomic tube current modulation (CARE Dose4D, Siemens Healthcare) was used per default in all patients.

Contrast medium timing was accomplished by using bolus tracking with a region of interest (ROI) placed within the descending aorta. Once a threshold of 100 HU had been exceeded (protocol triggering at 70 kV) within an ROI in the descending aorta, the scan automatically started after an additional delay of 5 seconds. The contrast agent administered was 400 mg/100 mL of iomeprol (Iomeron 400; Bracco Imaging S.p.A., Milan, Italy), diluted with saline via the dual-syringe injector (Stellant Medrad; Bayer Healthcare, Indianola, PA) to a concentration of 75% contrast to 25% 0.9% NaCl, for a total of 60 mL injected at a flow rate of 5 mL/s. This was followed by a pure saline chaser of 30 mL injected at the same flow rate. With second-generation DSCT, an undiluted