CT Coronary Angiography Without Heart Rate Control With Adaptive Cardio Sequence Prospective ECG-Triggered Using the second generation Dual-source CT#An Initial Study

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Purpose

To evaluate the feasibility of using the second generation dual-source CT to obtain good quality images in adaptive prospective ECG-Triggered coronary angiography (CCTA) without heart rate control.
Methods and Materials

1. Clinical data: Ninety four (94) cases of clinically suspected coronary artery diseases underwent coronary angiography using flash-speed dual-source undergraduate CT (Flash DSCT) in our department from June to August of 2010. Among these, 56 were males and 38 were females, with an average age of 61±11 years (35 to 82 years) and mean heart rate of 87.2±13.7/min (43~142 beats/min). No patient was using metoprolol tartrate or alike to control heart rate one week before the examination. Case exclusion criteria: 1) allergic to iodine contrast medium, kidney and/or renal insufficiency (serum creatinine levels >120 µmol/L), cardiac dysfunction; (2) coronary artery stenting or coronary artery bypass; (3) body mass index (BMI) > 30 kg/m²; and 4) unable to hold breath. All patients were well informed and consents were obtained prior to examination.

2. CCTA scan method and parameter:

Scan Preparation: No metoprolol or other drugs was used to decrease heart rate before scanning. An 18G needle was embedded in the middle vein of right elbow. The skin was cleaned and ECG lines were put in standard positions. Prior to scanning, patients received sublingually one dose of nitroglycerin aerosol spray (Jingwei Pharmaceutical Co., Ltd., Shandong, China) to expand the coronary artery. All patients were trained to hold abdominal breath and bundled in the abdomen to reduce respiratory motion artifacts.

Scanning equipment and parameters: All patients were scanned on a flash-speed DSCT machine (SOMATOM Definition Flash, Siemens Medical Solutions, Germany). First, a routine positioning scanning was performed with breath holding and the reconstruction phase corresponding to ECG heart rate changes was then chosen. Flash CCTA imaging scan mode was used to determine the scanning scope with non-ionic contrast medium iopromide (370mgI/ml) applied through binocular high-pressure injector (Ulrich Missouri XD 2001-D, Germany). A bolus of contrast agent was injected (5 ml/s) through cubital vein, followed by injection of 20 ml saline at the same rate for pre-scanning. Regions of interest were set in the aortic root for the measurement of time to peak enhancement. This time plus 4s was set as coronary CTA scan delay time. Flash-speed adaptive prospective ECG-gated sequence scan (Flash CorAdpSeq scan) was then initiated with cubital vein injection of contrast agent at a 5 ml/s flow rate (total 50 ml), followed by injection of 40 ml saline (5 ml/s flow rate). Scan parameters: The flying focus technology was adopted, with the detector collimator 128×0.6 mm, the thickness of level collection 3 mm, tube rotation time 0.28s, tube voltage 100 kV, and reference tube current 390 mAs. On the basis of the tube voltage, scanning effective current was further adjusted automatically according to the BMI and the thickness of scanning position (136 ~ 241 mAs). At the same time, the automatic exposure control system (CARE Dose 4D) was started for real-time dynamic adjustment based on heart rate, with automatic re-slice
thickness 0.75mm, spacing 0.5mm, and scan pitch 0.28~0.33. The data were rebuilt and transferred automatically to the workstation (Syngo MMWP VE36A).

**Image post-processing:** Circulation software was employed for vascular reconstruction, with convolution function value set at medium-smooth B20f and single image matrix 512×512. Volume data, including maximum intensity projection (MIP), multiplanar reformation (MPR), and volume rendering (VR) were processed for image reconstruction in the post-processing workstation. The images were adjusted consistently in window width (650HU), window level (250HU), brightness (80%), transparency (80%), and magnification (1X).

**Radiation dose assessment:** Volume CT dose index (CTDImvol, in units of mGy) and dose length product (DLP, in units of mGy×cm) were automatically generated by the machine and recorded for each patient during examination. Effective dose (ED, in units of mSv) was calculated using the formula \( ED = DLP \times C \), where \( C \) is the conversion factor \( (C = 0.014) \). CTDImvol and ED were presented as mean±SD.

**Image assessment and statistical analysis:** Image quality was evaluated in a double-blind manner and scored by 2 experienced radiologists. Coronary artery was segmented according to the American Heart Association's Guiding Principles. The right coronary artery includes segments 1-4 (proximal, middle, distal and posterior descending artery) and left coronary artery includes segment 5 (left main coronary artery), segments 6-10 (left anterior descending artery proximal, middle and distal, the first diagonal branch), and segments 11-15 (left circumflex artery proximal, middle and distal, the first obtuse marginal branch). Image quality assessment criteria were: 5 points, images had clear coronary edge and no motion artifacts; 4 points, images had slightly blurred edges and only mild motion artifacts; 3 points, images had moderate edge blurry and mild motion artifacts without significant split, therefore not impairing the diagnosis; 2 points, images with edge blurry and clear motion artifacts; and 1 point, images with coronary lumen unidentifiable and thus undiagnosable. Images of 3 points and higher scores were regarded as diagnosable.

The data obtained were presented as mean±SD (standard deviation) and SPSS for Windows 13.0 software was used for statistical analysis. The average heart rate, heart rate change, and image quality were analyzed using Pearson's correlation analysis. The mean heart rates were the average ventricular rates recorded by ECG during CTA examination and the heart rate changes were the difference between the maximum heart rate and the minimum heart rate recorded by ECG. Kappa test was run to assess the consistency of image quality evaluation by the 2 physicians. Kappa values of 0.81-1.0 meant strongly consistent, 0.61-0.8, relatively strongly consistent, 0.41-0.6, somewhat consistent, and <0.4, poorly consistent. P <0.05 was taken as statistically significant.
Results

*Heart rate change and image quality:* The heart rates of 94 patients ranged from 43-142 beats/min during scan, with an average heart rate of 87.2±13.7 beats/min and an average heart rate change of 16.4±19.2 times/min. In 94 cases, 52 had sinus rhythm, 26 exhibited premature heartbeats or arrhythmias and 16 cases showed atrial fibrillation. A total of 1410 vascular segments from 94 patients were included in the study, with a mean image quality score of 4.25±0.93. By the aforementioned score standard, 714 segments scored 5 (50.7%), 415 segments scored 4 (29.5%), 205 segments scored 3 (14.5%), 52 segments scored 2 (3.7%), and 24 segments scored 1 (1.6%). Coronary artery image quality had no significantly association with heart rates (r =- 0.165, P = 0.111) or heart rate changes (r = 0.103, P = 0.323).

*Consistency of image quality score by two physicians and radiation dose assessment:* In 1410 segments, 1334 segments (94.7%) met the imaging evaluation criteria (Figures 1-7) and 76 (5.4%) did not (Figure 8). For assessment of consistency in imaging evaluation and scores, Kappa test resulted in strong consistency between the two physicians (Kappa value = 0.895, P = 0.000).

Average CTDIvol was 11.84±1.76 mGy and ED average was 2.19±0.45 mSv#
Fig. 0: Figures 1-3. Images of a normal coronary artery from a female patient with atrial fibrillation. The patient, 54 year-old, had heart rates of 42-142 times/min (average 64 times/min). Image quality score was 5.0 and coronary artery appeared normal. Figure 1 showed ECG changes during scanning. Figure 2 exhibited a clear VR image of the left front descending branch of the coronary artery. Figure 3 displayed a clear MPR image of the right coronary artery.

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Fig. 0: Figure 2 exhibited a clear VR image of the left front descending branch of the coronary artery

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Fig. 0: Figure 3 displayed a clear MPR image of the right coronary artery.
**Fig. 0:** Figure 4 (VR image) clearly showed the position and size of the dissection.

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Fig. 0: Figures 4-5. Images of a coronary artery segment from a 45 years old male patient. The patients had sinus rhythm of 88-103 times/min (average 94 times/min) and regular heartbeats. Image quality score was 5.0 and there was a dissection in the mid-section of the right coronary artery.

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Fig. 0: The right coronary artery was severely stenotic (90%) in the distal part and mildly stenotic in the proximal part (25%). Figure 7 (MPR image) showed thickened vessel wall and luminal stenosis in the distal tube and calcification in the proximal wall.

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Fig. 0: Figures 6-7. Images of a narrowed coronary artery from a 51 year-old male patient. The patients had sinus rhythm of 77-88 times/min (average 84 times/min) and regular heartbeat. Image quality score was 5.0. and there was a dissection in the mid-section of the right coronary artery. The right coronary artery was severely stenotic (90%) in the distal part and mildly stenotic in the proximal part (25%). Figure 6 (VR image) and Figure 7 (MPR image) showed thickened vessel wall and luminal stenosis in the distal tube and calcification in the proximal wall.

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**Fig. 0**: Figure 8. A poor image of the coronary artery from a patient. The patient was male and 65 years old and had sinus rhythm and regular heartbeats of 64-70 beats/min (average 66 beats/min). Image quality score was 2 points and MPR image showed obvious artifacts and fuzzy wall due to bad breath holding during scanning.

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Conclusion

Flash adaptive prospective ECG-triggered sequence scan, without heart rate control, by dual-source CT can acquire assessable image quality of coronary artery with lower radiation dose. This technique has a potential to be used routinely in CCTA.
References


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