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Original Research Article

Algorithm for radiation dose reduction with helical dual source coronary computed tomography angiography in clinical practice

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KEYWORDS:
Algorithm for radiation dose reduction;
Coronary computed tomography angiography;
Dual-source computed tomography;
Radiation dose;
Low-kilovoltage;
Tube current modulation

BACKGROUND: Strategies to reduce the radiation dose of coronary computed tomography angiography (CCTA), while maintaining diagnostic image quality, are imperative for cardiac CT.

OBJECTIVE: We aimed to reduce radiation dose during helical dual-source CCTA by combining lower tube voltage, shortest possible full tube current (FTC) window, and minimal tube current outside the FTC window, and to develop a patient-based algorithm for applying these dose-reduction components.

METHODS: We compared FTC at 70% of the cardiac cycle (FTC70) to a 45% to 75% window (FTC45-75) using both 100 and 120 kVp (N=118). FTC70 was used in patients with heart rates <70 beats/min, no arrhythmia, age <65 years; 100 kVp was used in patients with body mass index (BMI) <30, a low coronary calcium score (CCS), and no stents. Objective and subjective image quality were assessed.

RESULTS: Compared with FTC45-75 at 120 kVp, radiation dose was reduced by 66% for FTC70 at 100 kVp (mean radiation dose: 4.4 ± 0.9 mSv) and by 43% for FTC70 at 120 kVp. 99% of 780 segments in the FTC70 group were of diagnostic quality. Noise, signal-to-noise ratio, and contrast-to-noise ratio were comparable between FTC70 and FTC45-75 for both 100 and 120 kVp. BMI, CCS and maximal heart rate variation were predictors of image quality. Tube voltage, FTC window width, scan length, and average heart rate were predictors of radiation dose.

CONCLUSIONS: A successful patient-based algorithm for radiation dose reduction during helical CCTA using DSCT has been developed and validated in clinical practice.

Conflict of interest: Ludovic Le Meunier is an employee of Siemens Medical Solutions, PET Division.

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Introduction

Increasing concern regarding radiation dose for patients undergoing coronary computed tomography angiography (CCTA)[1,2] has made it imperative to develop strategies to reduce the radiation dose of CCTA as much as possible while maintaining diagnostic image quality. Such strategies involve the development of an overall approach to selecting CCTA protocols that can be successfully applied to individual patients. Because of variations in scanner features, such protocols must also be tailored to the features of specific CT scanners. In addition to the possibilities provided by sequential acquisition, the dual-source CT (DSCT) (Definition scanner, Siemens Medical Solutions, Forcheim, Germany) provides 3 distinct dose-reducing strategies for CCTA with the use of helical acquisitions: (1) lowering the tube voltage from 120 to 100 kVp when the patient size allows, as with other 64-slice CT scanners, with radiation dose reduction of 39% to 51%[3,4]; (2) using the shortest possible full tube current (FTC) window with ECG-based tube current modulation[4–6]; and (3) reducing the tube current outside the FTC window from 20% to 4%.[6] However, these dose-reducing strategies cannot be applied indiscriminately to all patients undergoing CCTA without compromising image quality. The objective of this study was to use these 3 strategies to develop and evaluate a clinical algorithm for reducing radiation dose in CCTA in a consecutive group of patients referred for clinically indicated CCTA.

Methods

Patient population

Our study included 118 consecutive patients referred for CCTA from August to September 2007. The primary reason for CCTA was chest pain (56.8% of patients; Table 1). The second most common reason for testing was an equivocal previous nuclear stress test. We excluded from the analysis 5 patients with previous coronary bypass surgery because the scan length (coverage) in these patients was greater than that of the other patient groups. All patients gave written informed consent, and the study was approved by our institutional review board. Information regarding the presence of categorical cardiac risk factors was collected in all patients by the use of written questionnaires. Systemic arterial hypertension was defined as a self-reported history of high blood pressure or blood pressure ≥140/90 mm Hg. Smoking was defined as current or past smoking. Family history was defined as a coronary artery disease event occurring in a first-degree relative (men 55 years of age or younger and women 65 years of age or younger). A self-reported history of diabetes mellitus and/or a fasting glucose of 126 mg/dL or nonfasting glucose of 200 mg/dL or treatment with hypoglycemic medication defined the presence of diabetes. All the patients that were included in the study had complete data.

Algorithm for patient protocol selection

The window width for FTC was set either as a range 45% to 75% of the cardiac cycle (FTC45-75), encompassing end-systole, or simply at 70% (FTC70). With FTC70, FTC is applied for the shortest duration provided by the DSCT, starting at 70% of the R-R interval. Additionally, the tube current during the dose modulation period outside the FTC window was reduced to 4% of the maximal FTC, and an automated heart-rate dependent pitch[7] was applied for all patients. Tube voltage was set to 100 kVp or to 120 kVp based on patient body mass index (BMI) and weight.[3,4]

Table 1 Patient baseline characteristics

	Overall population (n = 118)	FTC70/100 kVp (n = 31)	FTC70/120 kVp (n = 21)	FTC45-75/100 kVp (n = 32)	FTC45-75/120 kVp (n = 34)	*P* value
Age, y	62 ± 12	60 ± 11	57 ± 10	64 ± 13	66 ± 13*	0.02
Men, n (%)	83 (70.3)	25 (81)	14 (67)	21 (65)	23 (57.5)	0.54
BMI, kg/m^2	27.0 ± 4.9	25.0 ± 3	28.7 ± 3.2†	24.6 ± 2.7	30.1 ± 6‡	<0.001
Weight, kg	80 ± 16	75.9 ± 11.1	84.7 ± 12.2§	73.1 ± 11.6	87.4 ± 20.1¶	0.0003
Hypertension, n (%)	64 (54.2)	10 (32.3)	12 (57.2)	18 (56.3)	24 (70.6)	0.02
Diabetes mellitus, n (%)	20 (16.9)	4 (12.9)	5 (23.8)	3 (9.4)	8 (23.5)	0.33
Hypercholesterolemia, n (%)	71 (60.2)	17 (54.8)	14 (66.7)	18 (56.3)	22 (64.7)	0.75
Smokers, n (%)	12 (10.2)	5 (16.1)	1 (4.8)	2 (6.3)	4 (11.8)	0.48
Family history of CAD, n (%)	45 (38.1)	12 (38.7)	7 (33.3)	13 (40.6)	13 (38.2)	0.96
Tested for chest pain, n (%)	67 (56.8)	14 (45.2)	10 (47.6)	20 (62.5)	23 (67.6)	0.21
CCS	356 ± 727	116 ± 237	472 ± 760‖	136 ± 215	750 ± 1155**	<0.001

CAD indicates coronary artery disease; CCS, coronary calcium score.
*P = 0.01 with FTC70/120 kVp.
†P < 0.007 with FTC45-75/100 kVp.
‡P < 0.001 with FTC70/100 kVp and FTC45-75/100 kVp.
§P = 0.03 with FTC45-75/100 kVp.
¶P = 001 with FTC45-75/100 kVp and P = 0.01 with FTC70/100kVp.
‖P = 0.007 with FTC45-75/100 kVp.
**P < 0.001 with FTC70/100 kVp and FTC45-75/100 kVp.