Texas Heart Institute Journal

Clinical Investigation

Radiation Doses in Patients Undergoing Computed Tomographic Coronary Artery Calcium Evaluation With a 64-Slice Scanner Versus a 256-Slice Scanner

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Computed tomographic coronary artery calcium scanning enables cardiovascular risk stratification; however, exposing patients to high radiation levels is an ongoing concern. New-generation computed tomographic systems use lower radiation doses than older systems do. To quantify comparative doses of radiation exposure, we prospectively acquired images from 220 patients with use of a 64-slice GE LightSpeed VCT scanner (control group, n=110) and a 256-slice GE Revolution scanner (study group, n=110). The groups were matched for age, sex, and body mass index; statistical analysis included t *tests and linear regression.*

The mean dose-length product was 21% lower in the study group than in the control group (60.2 ± 27 vs 75.9 ± 22.6 mGy•cm; P *<0.001) and also in each body mass index subgroup. Similarly, the mean effective radiation dose was 21% lower in the study group (0.84 ± 0.38 vs 1.06 ± 0.32 mSv) and lower in each weight subgroup. After adjustment for sex, women in the study group had a lower dose-length product (50.4 ± 23.4 vs 64.7 ± 27.6 mGy•cm) than men did and received a lower effective dose (0.7 ± 0.32 vs 0.9 ± 0.38 mSv) (*P*=0.009). As body mass index and waist circumference increased, so did doses for both scanners.*

Our study group was exposed to radiation doses lower than the previously determined standard of 1 mSv, even after adjustment for body mass index and waist circumference. In 256-slice scanning for coronary artery calcium, radiation doses are now similar to those in lung cancer screening and mammography. ***(Tex Heart Inst J 2022;49(2):e186793)***

Citation:
Madaj P, Li D, Nakanishi R, Andreini D, Pontone G, Conte E, O'Rourke R, Hamilton-Craig C, Nimmagadda M, Kim N, Fatima B, Dailing C, Shaikh K, Shekar C, Lee JH, Budoff MJ. Radiation doses in patients undergoing computed tomographic coronary artery calcium evaluation with a 64-slice scanner versus a 256-slice scanner. Tex Heart Inst J 2022;49(2):e186793. doi: 10.14503/THIJ-18-6793

Key words:
Coronary angiography/methods; coronary artery disease/diagnostic imaging; multidetector computed tomography/instrumentation; predictive value of tests; prospective studies; radiation dosage; radiation exposure/prevention & control; risk factors; vascular calcification/diagnostic imaging

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Coronary artery disease is a leading cause of morbidity and death worldwide. Detailed diagnostic images are used to measure atherosclerotic burdens in individuals at risk.[1] Coronary artery calcium (CAC) imaging enables personalized evaluation of cardiovascular risk across demographic categories and independent of traditional risk factors.[2] The American College of Cardiology/American Heart Association guidelines state that "measuring CAC is likely to be the most useful of the current approaches to improving risk assessment among individuals found to be at intermediate risk after formal risk assessment."[3] Accordingly, CAC can be used to evaluate cardiovascular risk in asymptomatic adults who are at intermediate risk (10-year risk, 10%–20%) and in individuals with diabetes (both class IIa indications), and in individuals at low-intermediate risk (class IIb indication).[4,5]

Even though 40% of adults are at intermediate risk of atherosclerotic cardiovascular disease, the high radiation doses associated with CAC imaging are concerning and have inhibited widespread screening.[3] Therefore, reducing radiation doses from advanced computed tomographic (CT) technology and developing safer protocols are important goals.

The Revolution CT (GE Healthcare)—a wide-volume scanner with 256 detector rows, 16-cm cranial-caudal coverage, intelligent motion-correction software, and 280-ms gantry rotation time—has shown promising results. It enables the acquisition of whole-heart images in high resolution within a single heartbeat, with prospective triggering. Incorporating the next generation of Adaptive Statistical Iterative Reconstruction (ASIR-V) with the scanner lowers radiation levels needed to acquire images. Sulaiman and colleagues[6] found that using hybrid iterative reconstruction with lower radiation was as effective as full-dose back projection for CAC scoring.

To evaluate the quality of images produced with lower radiation doses, we used the multicenter, prospective CONVERGE Registry[7] to compare the 256-slice Revolution CT scanner with the 64-slice LightSpeed VCT scanner (GE Healthcare) in patient cohorts matched for age, sex, and body mass index (BMI).

Patients and Methods

Consecutive patients (n=220) were enrolled in the CONVERGE Registry in accordance with an institutional review board–approved protocol. All provided written informed consent. The study group included 110 patients who underwent CAC evaluation with use of the Revolution scanner; the control group included 110 who were evaluated with use of the LightSpeed VCT. Scanning was performed at centers in Torrance, California; Milan, Italy; and Brisbane, Australia. All CAC images were acquired by certified cardiac CT technicians.

Scanning Protocol

In the control group, the LightSpeed settings in prospective triggering mode were as follows: tube voltage, 120 kV potential (kVp); tube current, 430 mA; gantry rotation time, 350 ms per rotation with 227 ms in temporal resolution; and 2.5-mm slice thickness. Electrocardiographic triggering ensured that each image was acquired at the same point in diastole, corresponding to 75% of the R-R interval. Tube current ranged from 122 to 740 mA on the basis of the patient's BMI.[7,8] Complete coronary artery views were obtained without injected contrast medium, and at least 35 consecutive images were acquired at 2.5-mm intervals beginning 1 cm below the carina and progressing caudally to include the coronary arteries.

In the study group, images were acquired from the Revolution's volumetric single-heartbeat CT scanner. Tube voltages were 120 kVp. Tube current ranged from 122 to 740 mA on the basis of the patient's BMI.[7,8] A medium field of view was selected. The 280-ms gantry rotation time had a minimum temporal resolution of 140 ms. The z-axis field of view (the long axis of the patient) was from the mid ascending aorta to the upper abdomen; collimation was selected on the basis of each patient's heart size as displayed in anteroposterior and lateral surface images. The scanner's 16 cm of z-axis coverage (no patient needed >16 cm) precluded table movement during axial volumetric scanning.

Both scanners had a 25-cm field of view during acquisition. The iterative reconstruction level for low dosage was set at 50%. One cardiologist (MJB) at our central reading center in California read each CT scan.

Dose-length product (DLP), reported in mGy·cm, measures CT-tube radiation output and exposure that is the length of radiation output along the z-axis. The effective dose of radiation (*ED*) is calculated as follows:

$$ED\ (\text{mSv}) = DLP\ (\text{mGy·cm}) \times k\ (\text{mSv/mGy·cm}),$$

where k is the conversion coefficient for the organ affected. For the heart,

$$k = 0.014\ \text{mSv/mGy·cm}.$$

Statistical Analysis

We used MatchIt R version 4.3.0 (RDocumentation) with nearest matching for age and BMI, and with exact matching for sex. The study and control groups were compared by using t tests and linear regression analysis. We stratified the BMI subgroups as follows: normal weight, 18.5–24.9; overweight, 25–29.9; and obese, ≥30. Further subgroup linear regression analysis was performed on clinical variables within each group. A P value <0.05 was considered statistically significant. We used SAS version 9.4 software (SAS Institute Inc.) for statistical analysis.

Results

The clinical characteristics of the control and study groups were similar (Table I). The mean DLP was 21% lower in the study group than in the control group (60.2 ± 27 vs 75.9 ± 22.6 mGy·cm; P <0.001), and this was true in each BMI study subgroup. After adjustment for sex, the mean DLP was lower in women than in men (50.4 ± 23.4 vs 64.7 ± 27.6 mGy·cm; P <0.009) (Table II). Regression analysis of the study group revealed a significant incremental increase in DLP as BMI increased (all P <0.001) (Table III). A significant incremental increase in DLP was seen in patients with large waist circumferences (Table IV).

Finally, the 256-slice CT scanner produced qualitatively superior images, enabling better evaluation as a result of thorough coverage, spatial resolution, and temporal resolution (Figs. 1 and 2).

TABLE I. Characteristics and Results in 220 Patients Undergoing Coronary Artery Calcium Scanning

Variable	64-Slice (n=110)	256-Slice (n=110)	*P* Value
Age (yr)	61.2 ± 11.2	60.7 ± 13.1	0.79
Weight (kg)	83.6 ± 16.3	84.1 ± 18.9	0.85
Body mass index	28.2 ± 5.1	27.8 ± 5.6	0.58
DLP, mGy•cm (ED, mSv)	75.9 ± 22.6 (1.06 ± 0.32)	60.2 ± 27 (0.84 ± 0.38)	<0.001
Body mass index subgroups			
Normal weight (18.5–24.9)	67.3 ± 23 (0.94 ± 0.32)	39.6 ± 13.1 (0.55 ± 0.18)	<0.001
Overweight (25–29.9)	70.7 ± 12.9 (0.99 ± 0.18)	58.6 ± 20.4 (0.82 ± 0.29)	0.0024
Obese (≥30)	90.6 ± 28.7 (1.27 ± 0.4)	64.4 ± 23.1 (0.90 ± 0.32)	<0.001

DLP = dose-length product; ED = effective radiation dose

Data are presented as mean ± SD. *P* <0.05 was considered statistically significant.

TABLE II. Comparison of 110 Patients Undergoing 256-Slice Computed Tomographic Coronary Artery Calcium Scanning Based on Sex

Variable	Women (n=35)	Men (n=75)	*P* Value
Age (yr)	59.3 ± 16	61.4 ± 11.6	0.49
Weight (kg)	75.6 ± 18.5	88 ± 17.9	<0.001
Body mass index	28.4 ± 7.4	27.5 ± 4.5	0.53
Waist circumference (in)	33.3 ± 6.1	34.8 ± 3.2	0.24
DLP, mGy•cm (ED, mSv)	50.4 ± 23.4 (0.7 ± 0.32)	64.7 ± 27.6 (0.9 ± 0.38)	0.009

DLP = dose-length product; ED = effective radiation dose

Data are presented as mean ± SD. *P* <0.05 was considered statistically significant.

TABLE III. Body Mass Index and Radiation Dose in 110 Patients Undergoing 256-Slice Computed Tomographic Coronary Artery Calcium Scanning

Body Mass Index Subgroup	No.	DLP, mGy•cm (ED, mSv)	β (SE)	95% CI	*P* Value
Normal weight (18.5–24.9)	26	39.6 ± 13.1 (0.55 ± 0.18)	Referent	—	—
Overweight (25–29.9)	51	58.6 ± 20.4 (0.82 ± 0.29)	18.1 (4.5)	9.4–26.9	<0.001
Obese (≥30)	33	64.4 ± 23.1 (0.9 ± 0.32)	24.8 (5)	15–34.6	<0.001

β = linear regression coefficient; DLP = dose-length product; ED = effective radiation dose

Radiation dose values are expressed as mean ± SD. *P* <0.05 was considered statistically significant.

Discussion

We found that the faster rotation speed afforded by the 256-slice scanner reduced the radiation dose exposure by 21% compared with the 64-slice scanner. Whole-heart coverage was acquired in one rotation (one heartbeat) by virtue of 16-cm z-axis coverage and no table movement, whereas 64-slice acquisition took 5 heartbeats because of 4-cm z-axis coverage. In the Multi-Ethnic Study of Atherosclerosis cohort, which included multiple CT scanners, the mean effective dose in CAC scans was <1 mSv.[8,9] In our study, substantially less radiation than this was needed, and our results were significant after adjustment for BMI and waist circumference. During 256-slice scanning, patients with a normal BMI were exposed to a mean dose of only 0.55 ± 0.18 mSv.

Dose reduction was aided by iterative reduction algorithms. Tatsugami and colleagues[10] reduced doses as

TABLE IV. Waist Circumference and Radiation Dose in 110 Patients Undergoing 256-Slice Computed Tomographic Coronary Artery Calcium Scanning

Waist Circumference (in)	**DLP,** mGy•cm (ED, mSv)	**β** (SE)	**95% CI**	***P* Value**
≤40 (men; n=44); ≤35 (women; n=21)	53.3 ± 22.3 (0.75 ± 0.31)	Referent	—	—
>40 (men; n=31); >35 (women; n=14)	58.5 ± 17.8 (0.82 ± 0.25)	14.9 (6.9)	1.4–28.4	0.03

β = linear regression coefficient; DLP = dose-length product; ED = effective radiation dose

Radiation dose values are expressed as mean ± SD. P<0.05 was considered statistically significant.

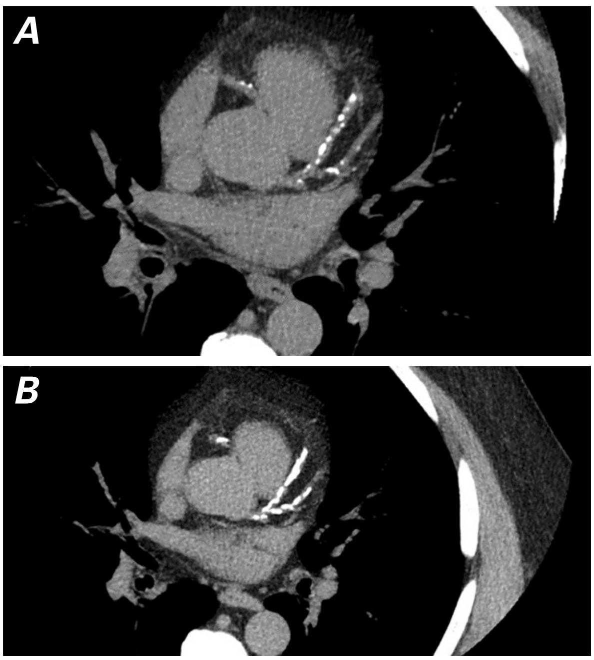

Fig. 1 *Computed tomographic coronary artery calcium scan (axial view) acquired during **A**) 64-slice scanning shows less coverage and inferior image quality when compared with **B**) 256-slice scanning.*

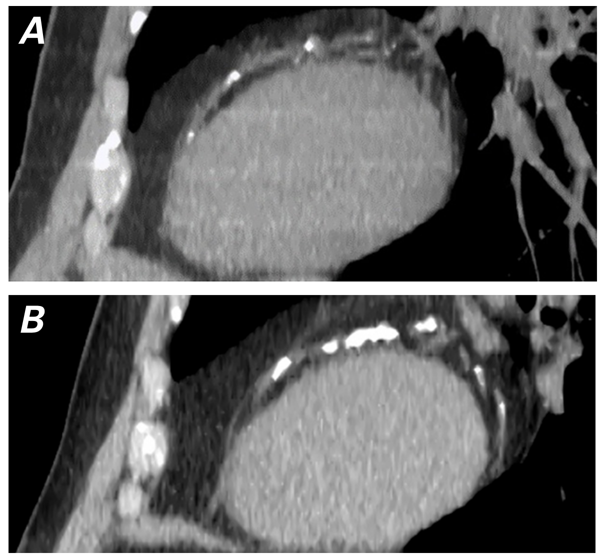

Fig. 2 *Computed tomographic coronary artery calcium scan (sagittal view) acquired during **A**) 64-slice scanning shows less coverage and inferior image quality when compared with **B**) 256-slice scanning.*

much as 67% through this method, and without substantially sacrificing image quality. Choi and colleagues[11] reduced doses as much as 74%, with acceptable image quality. Our results were similar to those of Sulaiman and associates,[6] whose advanced modeling decreased reliance on system-optics modeling. These newer protocols, which preclude the need to alter scanning techniques to acquire good-quality images at lower radiation doses,[10,12] should help to alleviate concerns about increased radiation, especially in regard to cancer risk.

Kim and associates[13] calculated cancer risk beginning with a median effective dose of 2.3 mSv and at levels >10 mSv—much higher than the 1 mSv generally reported in 64-slice scans, and higher still than the mean 0.84 ± 0.38 mSv in our study cohort. Scans can now be performed with doses lower than those resulting from everyday background radiation exposure (3–7 mSv annually, depending on geographic altitude).[1,9,13] The theoretically higher risk of long-term adverse effects has not been shown at the low doses associated with background radiation or CT scanning.[9] Clearly, the clinical benefits of CT scans supersede the risks from radiation exposure.

Scans can be used to track atherosclerosis, the effects of different therapies, and the progression of CAC, a predictor of all-cause death.[14-17] The radiation exposures from new-generation scanners now approximate exposures during other screening tests such as low-dose lung scans and mammography.[18-22] Future guidelines should be updated accordingly.

Limitations

Our study was performed across a similar patient profile and involved 2 types of scanners.[23] Larger sample sizes in future studies will enable further data randomization, statistical analysis, and validation. Images acquired from a wide variety of CT scanners will provide more detailed information on protocols and radiation dosing.

Conclusion

During CAC scans, the 256-slice Revolution CT scanner exposed patients to significantly lower radiation doses than did the 64-slice LightSpeed VCT and produced images of better quality. We think that these factors will improve clinical diagnosis and aid decision-making.

Published: 4 March 2022

Conflict of interest disclosures: Dr. Budoff receives grant support from the National Institutes of Health and from General Electric. No other author reports a conflict of interest.

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