J of Nuclear Medicine Technology, first published online October 11, 2019 as doi:10.2967/jnumed.119.229500

Lower Radiation Dosing in Cardiac Computed Tomographic Angiography: the CONVERGE Registry

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

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Abstract

Intro

Coronary artery disease is the leading cause for morbidity and mortality. Tools have been developed to accurately diagnose and evaluate coronary artery disease. Coronary computed tomographic angiography (CCTA) scans provide detailed imaging along with analysis to in order to deliver precise analysis and prognostic information. We sought to evaluate the radiation doses of the 256 detector CT scanner to a 64 slice scanner across a similar profile of patients.

Methods

Consecutive patients were screened, enrolled, and consented for the Converge Registry study, in accordance with the Institutional Review Board (IRB) approved protocol. 110 patients underwent CCTA using the GE Revolution 256 detector CT scanner. We matched patients by age, gender and body mass index (BMI) who underwent 64 slice CT scanning.

Results

We compared 110 patients in each group. We found that mean dose length product (DLP, presented also in the tables below in millisieverts (mSv)) was significantly lower in the Revolution 256 detector group compared to the 64 slice control group ($p<0.05$). The radiation dose was reduced 32% with use of Revolution 256 detector scanner for BMI between 18.5 and 24.9 (DLP=111.2 vs 76.1; 1.56 vs 1.07 mSv; $p<0.05$). For each BMI subgroup, there was a significant decrease in dose. Regression analysis found that with the increase in BMI both scanners experienced a significant increase in DLP.

Conclusion

We are able to demonstrate that the 256 slice CT scanner is able to provide CCTA scans at significantly lower radiation doses compared to the 64 row scanner at different BMI groups, with all other variables

accounted for. Lower radiation exposures along with lower contrast requirements can provide quality imaging with high diagnostic accuracy and less risk to the patient.

Key words: Cardiac Computed Tomographic Angiography, Radiation dosing, Radiation Safety, Coronary Artery Disease

Word count: 3681

Authors: 13

Manuscript

Introduction:

Coronary artery disease is the leading cause for morbidity and mortality around the world. Tools have been developed to accurately diagnose and evaluate coronary artery disease (CAD), to allow physicians to directly target both atherosclerosis and significant stenosis. Coronary computed tomographic angiography (CCTA) scans provide detailed imaging along with analysis to in order to deliver precise analysis and prognostic information to a clinician and patient. Due to its high negative predictive value for coronary artery disease, it has become a gatekeeper for the assessment of patients with chest pain of recent onset (1). At times, these modalities can be combined with other imaging techniques (e.g. myocardial perfusion scanning, fractional flow reserve (FFR)) to provide additional diagnostic information, even in the acute setting (2,3). Patients and clinicians are increasingly concerned with the amount of radiation used in medical imaging. With advances in imaging technology and techniques, CCTA can be obtained with more diagnostic information at lower radiation doses (including structural information along with information about atherosclerosis and obstruction) (4-7). A new wide volume scanner with 256 detector rows, 16-cm cranial-caudal coverage and fast gantry rotation time of 280ms, allows acquisition of the whole heart within a single heartbeat with prospective triggering (Revolution CT, GE Healthcare). Additionally, this scanner uses a new iterative reconstruction algorithm (ASIR-V) which can allow for lower mA acquisition techniques. These technologies allow for lower dose imaging. It is worth noting that Cardiac CTA has been shown to be more accurate compared to other imaging modalities (e.g.) nuclear imaging for assessment of obstructive disease in both the acute and outpatient setting (8). Hamilton-Craig et al and Dedic et al described the use of CCTA in the acute care setting allowing for less outpatient testing and lower medical costs (9,10). We sought to evaluate the radiation doses of the 256 detector CT scanner (GE Revolution, Milwaukee WI), to a 64 slice scanner

(VCT, General Electric, Milwaukee WI) across a similar profile of patients, matched across similar age, gender, and patient size from each group.

Methods:

110 consecutive patients were screened, enrolled, and consented for the Converge Registry study, in accordance with the Institutional Review Board (IRB) approved protocol. These 110 patients underwent CCTA using the GE Revolution 256 detector CT scanner. We matched patients by age, gender and body mass index (BMI) who underwent 64 CT slice scans (VCT Scanner, GE, Milwaukee, WI) as the control group. The scans were conducted at multiple sites including the United States, Italy, and Australia. All studies were read by two expert physicians, with adjudication by consensus if there were disagreements related to stenosis or plaque severity or image quality. General Electric provided funding to collect scans to create the Converge Registry. The manufacturer has no input on the science or manuscript preparation, that is solely under the control of Dr Budoff and his investigative team.

Scan Protocol:

Patient Preparation

Certified cardiac CT technicians scanned all study participants. For all scans, the patients received an oral β-blocker (metoprolol), intravenous β-blocker (metoprolol), or both needed to achieve a goal heart rate (HR) of less than 70 beats per minute (bpm). Sublingual nitroglycerin (0.4 mg) was given immediately before angiographic image acquisition.

CT Scan Protocol and Image Acquisition

64 Row Acquisition

All CCTA scans were performed with a 64-multidetector row Lightspeed VCT scanner (GE Healthcare). Individuals presenting with baseline heart rates greather than 65 beats/min were administered oral

beta-blocker therapy as the preferred method for slowing down the heart rate. Intravenous administration was used when patients had persistent HR > 65 bpm while on the scanner table, using metoprolol at 5 mg increments to a total possible dose of 30 mg to achieve a resting heart rate less than 65 beats/min. Following a scout radiograph of the chest (anteroposterior and lateral), a timing bolus (using 10 to 20 ml contrast) was performed to detect time to optimal contrast opacification in the axial image at a level immediately superior to the ostium of the left main artery. Nitroglycerine 0.4 mg sublingually was administered immediately before contrast injection.

During CCTA acquisition, 80-ml iodinated contrast (Visipaque, GE Healthcare, Buckinghamshire, United Kingdom) was injected using a triple-phase contrast protocol: 60-ml iodixanol, followed by 40 ml of a 50:50 mixture of iodixanol and saline, followed by a 50-ml saline flush.

All 64-CTCA examinations were performed with a LightSpeed VCT scanner (GE Healthcare) and prospective gating, using a commercially available protocol (SnapShot Pulse, GE Healthcare) and the following scanning parameters: slice acquisition 64 x 0.625 mm, smallest X-ray window (only 75% of the RR-cycle), z-coverage value of 40 mm with an increment of 35 mm, gantry rotation time 350 ms, tube voltage 120 mV, and effective mA 350 to 780 mA. Scanning was performed from 10 mm above the left main origin (determined on calcium scan) to the diaphragm. By choosing the smallest possible window at only one distinct end-diastolic phase of the RR-cycle (i.e. 75%), we ascertained the lowest achievable effective dose delivery with 64 CTCA. The amount of radiation used to evaluate both intensity and scan length was registered in DLP (miliGray-centimeters). Later converted to millisieverts using a factor of 0.014.

256 Row Acquisition

Images were acquired using the volumetric single-beat CT scanner (Revolution CT; GE Healthcare), which provides 0.28-second gantry rotation, intelligent motion correction software, high-definition spatial resolution, and 16-cm detector array. The field of view (z axis) included the mid–ascending aorta to the

upper abdomen. No table movement occurred during axial volumetric scanning because of the 16 cm of z-axis coverage. The z-axis collimation was selected based on the scout images demonstrating the heart size. No patient required more than 16-cm z-axis coverage. Tube voltages used fixed at 120 kilovolt potential (kVp), to provide comparable radiation. Tube current ranged between 122 and 740 mA. A medium field of view was selected for all patients. The gantry rotation time was 0.28 seconds, with a minimum temporal resolution of 140 milliseconds. The scanner is equipped with an "autogating" capability, which automatically adjusts HR-dependent settings for triggered acquisition and gated reconstruction. Autogating was used to automatically acquire diastolic phases for lower HRs and both systolic and diastolic phases for higher HRs. Electrocardiographic dose modulation, which reduces mA for nontarget phases, was used in these high HR acquisitions. All acquisitions were prospectively gated. Studies were done using approximately 50-80 milliliters of contrast. Each scan was done in a single-beat acquisition within 1 cardiac cycle, regardless of the HR. Motion correction software (SnapShot Freeze; GE Healthcare) was used for correcting motion artifacts in patients with higher HRs. The amount of radiation used to evaluate both intensity and scan length was registered in DLP (miliGray-centimeters). Later converted to millisieverts using a factor of 0.014.

Image Reconstruction

For both scanner types, data reconstruction was performed using 0.625-mm thin reconstructions with intervals ranging at 60% to 80%, and most of data were reconstructed at 75% of the R-R phase. For all of the CT examinations, 50% of adaptive statistical iterative reconstruction (ASIR-V) percent levels were used. All images were transferred to an external workstation (AW 4.4, GE Healthcare). All studies were read by two expert physicians as previously mentioned. Both scanners used a 25 cm field of view for acquisition of CCTA's.

Statistical Analysis:

Participants were matched from the Converge registry with a control group of similar demographics (age, gender, and BMI). Statistical Analysis was performed using a t-test and regression analysis comparing the Converge study group vs a control group of similar clinical variables (age, gender, BMI). Further subgroup analysis was also performed of clinical variables within the Converge group. DLP doses were converted to mSv using a factor of 0.014.

Results:

We compared 110 patients in each group (256 detector and 64 detector). We found that mean radiation dose measured in dose length product (DLP); converted to millisieverts (mSv); was significantly lower in the Revolution 256 detector (wide volume) group compared to the VCT (64 slice) control group ($p<0.05$) (see table I). The radiation dose was reduced 32% with use of Revolution 256 detector scanner for BMI between 18.5 and 24.9 (DLP=111.2 vs 76.1; 1.56 vs 1.07 mSv; $p<0.05$). For each BMI subgroup, there was a significant decrease in dose using 256 as compared to 64 detector imaging. Regression analysis found that with the increase in BMI (table 2), both scanners experienced a significant increase in DLP (and radiation exposure) for BMI 18.5 to 24.9 compared to 25 to 29.9 and BMI >30, all $p<0.05$.

Discussion:

We are able to demonstrate that the 256 row GE Revolution Scanner is able to provide CCTA scans at lower radiation doses compared to the 64 row scanner, with all other variables controlled for (gender, age and body mass index). As previous studies have demonstrated, with improved technology, lower radiation exposures along with lower contrast requirements can provide quality imaging with high diagnostic accuracy with less risks to the patient (11,12). The 256 slice CT scanner allows improved image quality and clinical capabilities through the convergence of coverage, spatial resolution, and

temporal resolution advantages over the 64 slice CT scanner. The rotation speed is faster (280 milliseconds versus 350 milliseconds with the 64 slice) which reduces patient exposure by at least 20% (see table 1). Furthermore, the whole heart coverage allows the heart to be imaged in one rotation (one heartbeat) due to 16 cm z-axis coverage with no table movement, as compared to the 5 beat acquisition of the 64 slice scanner (due to z axis coverage of only 4 cm. Improved imaging protocols and technology can aid in obtaining adequate imaging despite body habitus or arrhythmias. Zhao et al were able to demonstrate that evaluation of CCTA images can take place even with patients with arrhythmias (e.g. atrial fibrillation) with high diagnostic accuracy (13). It is worth further noting the dose reduction is independent of iterative dose reduction algorithms. ASIR-V allows for more advanced modeling as it de-emphasizes the system optics modeling, enabling reconstruction speed similar to filtered back projection, and was used on both systems, so the dose reduction associated with use of 256 detector scanning is incremental to this technique (14). With the use of a new generation CT scanner along with accompanying protocols, we are able to obtain CCTA's at significantly lower radiation doses. Physicians' along with patients' concerns should be alleviated to that of radiation dosing. Studies have shown that CCTA imaging can be acquired with as low as 1.1 $\pm$ 0.4 mSv (15-17). Schmermund et al and Dogan et al along with multiple other studies were able to demonstrate the reduction in radiation dose, attributed to a combination of improvements in data acquisition protocols and patient preparation as well as installation of new CT scanners with advanced technology over a 5 year period (18-20). These studies demonstrated lower radiation doses during CCTA imaging acquisition with newer protocols/equipment.

The use of CCTA has the potential to significantly alter the management of CAD. The AHA statement on assessment of coronary artery disease by cardiac CT provides a Class IIa recommendation for the use of CCTA in the assessment of obstructive disease in symptomatic patients (21). Studies have demonstrated CCTA to be the most accurate of non-invasive imaging modalities; especially when compared to

functional tests in detecting obstructive coronary artery disease (22,23). In the multi-center PROMISE study, the prevalence of normal test results and incidence rate of cardiac events in patients was significantly lower among patients randomized to CTA in comparison with patients randomized to functional testing (33.4% versus 78.0%, and 0.9% versus 2.1%, respectively; both *P*<0.001) (24). In a study by Lee et al, after adjusting for confounding risk factors, obstructive CAD remained an independent predictor of major adverse cardiac events (hazard ratio 3.11 [95% CI 2.00-4.86]; *P* < 0.001]). Their prediction model for detecting adverse events improved significantly (C-index 0.788 [95% CI 0.747-0.829]; *P* = 0.0349) when adjusted to traditional risk factors (e.g. age, male, hypertension, hyperlipidemia, smoking, estimated glomerular filtration rate, and HbA_{1c}) (25). The CCF/SCCT/ACR/AHA/ASE/ASNC/SCAI/SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography guidelines lists CCTA as an appropriate modality in the evaluation of low to intermediate pre-test probability of CAD patients along with the evaluation post- CABG along with structural disease (26). This study and others demonstrate that the prognostic and diagnostic information can be obtained without compromising image quality irrespective of heart rate, heart rhythm or obesity, all obtainable at lower radiation doses (27).

Multiple trials consistently show the safety of a negative coronary CT angiogram to identify patients for discharge from the emergency department with low rates of major adverse cardiovascular events, at significantly lower cost, and greater efficiency in terms of time to discharge; providing definitive evidence for the use of coronary CTA in the emergency department in patients with a low-to-intermediate pretest probability of coronary artery disease (28). Meyersohn et al demonstrated a significant reduction in radiation doses with higher generation CT scanners in the emergency room setting (29). With these improvements in technology with greater coverage, centers can reduce the radiation dose as well as the amount of contrast given to a patient during CCTA imaging acquisition. For example, Van Cauteren et al was able to demonstrate up to a 50% iodine dose reduction in image

acquisition (30). Doses can go even lower with use of lower killivolts (kVp), further reducing doses well below background radiation exposures and even lower than calcium scoring, which is fixed at 120 kVp (31,32). One doesn't need to alter scanning techniques to obtain similar imaging at lower radiating doses (33,34).

Limitations

We matched patients by age, gender and BMI to approximate similar cohorts to compare 256 to 64 row imaging. We chose not to scan the same patients with both protocols, however we did match for age, gender and BMI. More prospective studies using larger sample sizes need to further be conducted for further study CCTA radiation doses.

Conclusion

We are able to demonstrate that the Revolution 256 Scanner is able to provide CCTA scans at lower radiation doses compared to the 64 scanner. This allows clinicians to obtain more clinically relevant information at significantly lower doses- aiding in making appropriate clinical diagnosis, decision-making, and alleviating further patient concerns regarding radiation dosing.

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Table 1. Demographic and clinical characters (Converge vs CTA data)

	CTA (n=110)	Converge (n=110)	*P*-value
Age, yrs	60.2 ± 12.5	61.1 ± 12.5	0.615
Female	34(31.5)	35 (31.8)	0.957
Weight, kg	83.5 ± 17.0	83.3 ± 17.1	0.949
BMI	28.7 ± 6.1	27.2 ± 4.4	0.326
Total CTA DLP (for 110 patients)	141.0 ± 78.8	113.5 ± 53.6	
	(1.97 ± 1.10)	(1.59 ± 0.75)	0.0037
CTA DLP stratified by BMI			
Normal weight	111.2 ± 84.7	76.1 ± 49.0	0.044
(BMI 18.5 to 24.9)	(1.56 ± 1.19)	1.07 ± 0.69	
Overweight	133.0 ± 55.1	112.4 ± 52.1	0.047
(BMI 25 to 29.9)	(1.86 ± 0.77)	(1.57 ± 0.73)	
Obese	169.2 ± 74.1	142.3 ± 28.9	0.0004
(BMI > 30)	(2.37 ± 1.04)	(1.99 ± 0.40)	

Dose in dose length product (DLP), in parentheses in millisieverts (mSv)

Table 2 . Association between CTA DLP levels and BMI §

	CTA DLP (n=110)	β (SE)	95% C.I	P-value
18.5<=BMI<=24.9	76.1 ± 49.0 (1.07 ± 0.69)	0 Ref		
¶				
25<=BMI<=29.9	112.4 ± 52.1 (1.57 ± 0.73)	28.3 (11.1)	6.5,50.1	0.011
30<=BMI	142.3 ± 28.9 (1.99 ± 0.40)	53.8 (11.9)	28.2,75.8	<0.001

¶ Adjusted for age, gender

§ Converge (cases) vs. CTA (controls)

Dose in (dose length product) DLP, in parentheses (mSv) (millisievert)