

Radiation exposure for coronary artery calcium score at prospective 320 row multi-detector computed tomography

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Original Article

Abstract

Purpose: To date there is extensive data on the radiation dose for assessing coronary artery calcium scores (CACS) with 4-64 row multidetector MDCT. However with the advent of 320 row MDCT, the entire heart can be imaged in one beat and thus potentially reduce the radiation dose. The aim of this study was to evaluate radiation dose for CACS on low-dose prospective EKG-triggered 320 row MDCT. **Materials and Methods:** Informed consent for this retrospective HIPAA-compliant study was waived and approved by our institution's institutional review board IRB. One hundred and sixty eight consecutive patients (Male 133 (79%): female 35 (21%)), mean body mass index BMI 29±5 and mean heart rate 58± bpm) underwent coronary calcium scoring with prospective gating. The scan parameters were 300 mA, 120 kVp, volume scan length (VSL) 160 mm, gantry rotation 0.350 msec and 320 x 0.5 mm detectors at 320 MDCT. Beta blockers were given to patients in a case heart rate HR > 65 bpm. The effective dose (ED) estimates were calculated for all patients from the dose length product and the conversion factor k (0.014 mSv/mGy/cm) as recommended by current guidelines. **Results:** The mean SD radiation was 1.89±0.79 mSv. Overall the range varied from 0.28-2.48 mSv. The radiation was significantly less in females as compared to males (2.02±0.73 vs. 1.41±0.87, p<0.0001). No differences were noted whether HR was <60 vs. ≥60 bpm (1.87±0.79 vs. 1.77±0.84 mSv, p=0.45). On the other hand a higher radiation was noted among obese individuals as compared to those with BMI<30 (1.84±0.82 vs. 1.91±0.80 mSv, p=0.62). **Conclusion:** Radiation dose obtained from 320-MDCT is similar to those obtained with 4-64 row MDCT. Further studies are needed to assess the feasibility of further lowering the tube current and tube voltage.

Keywords: Calcium Score; Coronary Artery; MDCT; Radiation

Introduction

Vascular calcification is a constituent of atherosclerosis and in case of coronary arteries this is a strong indicator of presence of coronary artery disease (CAD).^{1,2} Several studies have

shown that the amount of coronary artery calcium (CAC) correlates with the risk for severe cardiac events, detection and quantification of CAC therefore can be a valuable diagnostic tool in the workup of patients with suspected coronary artery disease.³⁻⁵ Overall, the presence of CAC is highly sensitive and moderately specific for detection of CAD. The negative predictive value of a CAC score of zero (0) can be as high as 99% and is associated with a 0.1% annual risk of cardiovascular events^{6,7} and over 99% survival for 10 years.⁸ CAC as detected and quantified using noninvasive cardiac computed tomography (CCT) represents a reliable linear anatomic estimate of total plaque burden⁹ and is represented clinically as a "calcium score."

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In 1990, Agatston et al. described a method to determine the amount of coronary calcium from tomographic images.¹⁰ This method depends on the area and the maximum CT density of the calcification detected by electron beam computed tomography (EBCT). EBCT has been regarded the standard of reference method for detection and quantification of coronary calcium, and studies indicating the risk for coronary artery disease are based on EBCT investigations.^{8, 11, 12} Calcium score investigations are increasingly performed by using multi-detector CT (MDCT) techniques. It has been shown that MDCT calcium scores correlate well with that of EBCT.¹³⁻¹⁷

MDCT technology has evolved with the current 320 row MDCT, offering improved coverage in the z axis and better temporal & spatial resolution. These technical improvements in scanners lead to better radiation dose efficiency and improved image acquisitions of non-invasive CCTA at high quality with less radiation. The aim of this study was to evaluate radiation dose for CAC scoring on low-dose prospective EKG-triggered CCTA using 320 row MDCT.

Methods and Materials

Patient Characteristics

Informed consent for this retrospective HIPAA-compliant study was waived and approved by our institution's IRB. Retrospective review of CCTA data-base yielded 168 consecutive patients who had undergone CCTA between March 2008 and December 2009 using prospective ECG gating on 320 MDCT (Toshiba Aquilion One Dynamic volume CT, Tochigi-ken, Japan). At our institution as part of the protocol CCS is also performed on all patients. The indication for CCTA comprised the assessment of the coronary arteries or bypass grafts, chest pain, and visualization of cardiac anatomy before or after electrophysiological procedures. Typical sized patients were defined by a body mass index (BMI calculated as weight in pounds divided by height in inches) of 20-35. One hundred and sixty eight consecutive patients (Male 133 (79%): female 35 (21%), mean BMI 29±5 and mean heart rate 58± bpm) underwent coronary calcium scoring with prospective gating. Beta blockers were given to patients in case HR > 65 bpm (Table 1).

MDCT Technique

Aquilion ONE is a cone beam MDCT with 320 rows of 0.5 mm detector array capable of covering 160 mm of anatomy in the z-direction in one rotation without table movement. However, Aquilion ONE has two operating modes, the 64-row, and the 320-row modes. Under the 64-row mode, Aquilion ONE functions just like another 64 MDCT scanner in which both axial scans and helical scans are available with a maximum beam width (BW) of (64 × 0.5 mm = 32 mm).

The 320-row mode, at present, functions primarily as a cardiac scanner (volume scan mode). Under the volume scan mode, the unit acts as an axial scanner and can cover up to 160 mm per rotation. For cardiac scanning the BW coverage is usually 120, 140 or 160mm depending on the length of the heart. The tabletop translation movement is disabled via software control during image acquisition under the volume scan mode and the data set is acquired in one 360-degree rotation and image is reconstructed from 180 degrees using the remaining 180 degrees for cone beam correction.

The scan parameters during CACS measurement were 300 mA, 120 kVp, volume scan length (VSL) 160mm, gantry rotation 0.350 msec and 320 x 0.5mm detectors at 320 MDCT (Table 2).

TABLE 1: Summary of patient's characteristics

Patient's Characteristics	Values
Total subjects (n)	168
Mean Age (SD) years	61±10
Male: Female	133:35
Mean BMI (SD)	29±4
Current Smoker No/total (%)	13/168 (7.7%)
Past smoker No/total (%)	74/168 (44%)
Hypertension No/total (%)	112/168 (66.6%)
Hyperlipidemia No/total (%)	121/168 (72%)
Diabetes No/total (%)	23/168 (13.7%)
Family H/O of CAD (%)	113/168 (67.2%)
H/O CAD (%)	91/168 (54.1%)
H/O of MI (%)	55/168 (32.7%)

Abbreviations: SD = Standard Deviation; No = Number; H/O = History of; CAD = Coronary Artery Disease; MI = Myocardial Infarction

TABLE 2: Scanning parameters and radiation dose for Coronary artery calcium score at 320 MDCTA

Scanning parameters & Radiation	Values
Typical collimation	(64 x 5) x 0.5 mm (160mm)
Rotation time	350 sec
Tube voltage	120 kVp
Tube current-time product	300 mA
Scan length (mm)	160 mm
Mean radiation dose (SD)	1.89 (0.79)

Abbreviations: SD = Standard Deviation

Radiation Dose measurement

Radiation dose is calculated from the parameters included the volume CT dose index (CTDI vol) and dose length product (DLP). The CTDI value can be calculated as a mathematical integral under the radiation dose profile of a single rotation scan that would produce one tomographic image at a fixed table position. CTDI vol is the average radiation dose over a specific investigated volume. The dose length product (DLP) can be calculated by multiplying CTDI vol with re-

spective scan length. DLP shows the radiation a patient is exposed to by the entire CT. This was the primary parameter in our study (Table 2).

CT dose index volume (CTDI vol) and dose length product (DLP) were recorded as direct data output from prospective ECG gated examinations. Scanner provided a protocol summary containing dose-length product for each image series. The effective radiation dose was derived from the summed dose-length product multiplied by the European working group for guidelines on Quality criteria in computed tomography conversion coefficient ($k = 0.014 \text{ mSv/mGy} \times \text{cm}$).

Statistical Analysis

The statistical software packages used for data analysis were Stata\MP 10.0 (Stata, college station, Tex).

Results

The mean \pm SD radiation was $1.89 \pm 0.79 \text{ mSv}$. Overall the range varied from 0.28-2.48 mSv. The radiation was significantly less in females as compared to males ($2.02 \pm 0.73 \text{ vs. } 1.41 \pm 0.87$, $p < 0.0001$). No differences were noted whether HR was $<60 \text{ vs. } \geq 60 \text{ bpm}$ ($1.87 \pm 0.79 \text{ vs. } 1.77 \pm 0.84 \text{ mSv}$, $p = 0.45$). On the other hand a higher radiation was noted among obese individuals as compared to those with BMI <30 ($1.84 \pm 0.82 \text{ vs. } 1.91 \pm 0.80 \text{ mSv}$, $p = 0.62$) (Figure 1).

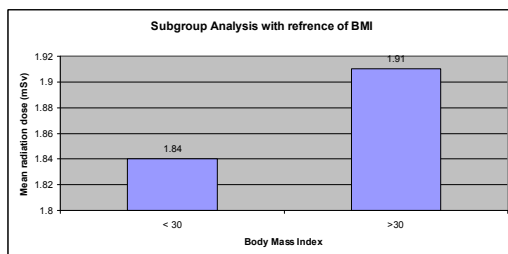


FIG. 1: Subgroup analysis of radiation dose with reference of BMI for patients that underwent Coronary calcium score with 320 MDCTA.

Discussion

CAC scoring being a screening tool requires the use of low radiation techniques in order to outweigh the potential risks associated with the examination. A major disadvantage is the radiation exposure with the use of Computed Tomography (CT) and radiation dose has been the single most significant concern in the context of widespread clinical applications of CCTA. Medical radiation exposure has risen more than 700% between 1980 and 2006, largely contributing to increased public awareness of medical radiation burden.¹⁸ As a reference for radiation exposure it should be noted that annually background accounts for 82 %, and man made for 18 % of the total radiation exposure to the general population.

Amongst medical x-rays such as diagnostic studies, computed tomography of the chest, abdomen and pelvis accounts for 58 %, nuclear medicine studies for 21 %, and consumer products for 18 % of all man made exposure. CCTA contributes about 1.5 % to the overall CT dose.¹⁸ Emergence of the 320 row detector CT scanner allows for even faster image acquisition for CCTA which will likely further increase the use of CCTA and be associated with a corresponding rise in radiation exposure to the public in the future.¹⁸ Calcium scoring is usually routinely performed in addition to contrast enhanced MDCTA with single rotations and prospective gating. Our measurements for the calcium score protocol at 120 kVp compare favorably to those of prior investigations using prospective gating.^{16, 19} Our data along with those of others also indicate that occurrence of deterministic skin effects secondary to MDCTA with the dual source and 320-detector row scanner is fundamentally inconceivable, even in the setting of performance of multiple studies in a short time span in the same individual as deterministic effects have a threshold between 2,000 and 20,000 mGy, depending on the severity.¹⁷

It is believed that transient erythema, the earliest radiation effect, is unlikely to occur with radiation doses of less than 4000–5000 mGy.^{17, 20} Rutten *et al.* reported 2.6 mSv ED for CAC scoring with retrospectively gated 64 MDCTA but after application of maximum dose in a single phase of R-R interval and at heart rate $< 60 \text{ bpm}$, ED was reduced from 2.6 to 1.6 mSv.²¹ While at prospectively gated 64 MDCT using step and shoot method, Malago R *et al.* and Husmann L. *et al.* documented the ED of 1.547 and 1.1 mSv respectively for CAC scoring.^{22, 23} Mahnken *et al.* obtained a mean ED of 4.44 mSv (3.28-588) and 3.01 mSv (2.52-4.18) for women and men with BMI > 26 respectively using a four channel MDCT scanner but in comparison radiation was reduced by 11.6% for men and 24.8% for women using body weight-adapted tube current settings in case of patients with BMI below 25.²⁴ While Hunold *et al.* compared the ED for electron beam and four-detector MDCT using anthropomorphic phantom. ED using electron beam CT were 1.0 and 1.3 mSv for male and female respectively while ED were 1.5-5.2 mSv and 1.8-6.2 mSv for male and female respectively at 4 rows MDCT.²⁵

We must acknowledge several limitations of our study. First, it was a retrospective review of medical records and study design was not prospective. For the retrospective study design, we reduced the bias by selecting consecutive patients. We did not assess the factors affecting the diagnostic quality of these examinations, however, the goal of this study was to assess radiation dose associated with CAC if this were to be incorporated as a screening tool to reclassify risk in patients at intermediate risk based on traditional scores such as the Framingham and Procarn Algorithms.⁹

Conclusion

The 320-slice MDCT is a robust potential diagnostic tool for non-invasive coronary artery assessment with novel single rotation acquisition capabilities with single cardiac cycle. Dose optimization remains an exceedingly significant concern. Radiation dose obtained from 320-MDCT for measuring CAC is similar to those obtained with 4-64 row MDCT. Prospective studies are needed to assess the feasibility of further lowering the tube current, tube voltage, and optimizing the volume scan length to minimize radiation doses.

Conflict of interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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