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Coronary calcium scores are systematically underestimated at a large chest size: A multivendor phantom study

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ABSTRACT

Objective: To evaluate the effect of chest size on coronary calcium score (CCS) as assessed with new-generation CT systems from 4 major vendors.

Methods: An anthropomorphic, small-sized (300 × 200 mm) chest phantom containing 100 small calcifications (diameters, 0.5–2.0 mm) was evaluated with and without an extension ring on state-of-the-art CT systems from 4 vendors. The extension ring was used to mimic a patient with a large chest size (400 × 300 mm). Image acquisition was repeated 5 times with small translations and/or rotations. Routine clinical acquisition and reconstruction protocols for small and large patients were used. CCS was quantified as Agatston and mass scores with vendor software.

Results: The small-sized phantom resulted in median (interquartiles) Agatston scores of 10 (9–35), 136 (123–146), 34 (30–37), and 87 (85–89) for Philips, GE, Siemens, and Toshiba, respectively. Mass scores were 4 mg (3–9 mg), 23 mg (21–27 mg), 8 mg (8–9 mg), and 20 mg (20–20 mg), respectively. Adding the extension ring resulted in reduced Agatston scores for all vendors (17%–48%) and mass scores for 2 vendors (11%–49%). Median Agatston scores decreased to 9 (5–10), 79 (60–80), 27 (24–32), and 45 (29–53) units, and median mass scores

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remained similar for Philips at 4 mg (4–6 mg) and Siemens at 8 mg (7–8 mg) and decreased for the other vendors to 13 mg (11–14 mg) and 10 mg (8–13 mg), respectively.

Conclusion: This multivendor phantom study showed that CCS can be underestimated up to 50% (49%–66%) for Agatston scores and 49% (36%–59%) for mass scores at a larger chest size, which may be relevant for women and large patients. However, CCS underestimation by chest size differs considerably by vendor.

1. Introduction

Coronary calcification is a strong predictor for future cardiovascular events.[1–3] Therefore, CT is commonly used for assessing the coronary calcium score (CCS) as part of individual risk evaluation. The number of CCS examinations is expanding rapidly and it is already the most common type of CT screening in the United States.[4] Recent American Heart Association guidelines recommend CCS for asymptomatic individuals at low-to-intermediate and intermediate cardiovascular risk.[5] It is expected that this recommendation will result in a further increase in the number of CCS examinations.

Previous studies have shown that obesity is associated with higher CCS,[6–8] and increased body weight is also associated with poorer CT image quality.[9–11] This might influence calcium scoring as body weight is positively correlated with chest size.[12,13] Furthermore, women have relatively more thoracic fat and breast tissue. With the expanding prevalence of obesity and growing number of CCS examinations, it is essential to assess whether the CCS derived in patients with a large chest size is accurate. Because the tube voltage of CCS acquisition protocols is fixed at 120 kV, raised CCS could be caused by either overestimation due to poor image quality at an increased body size or due to actually increased amount of coronary calcification in obese individuals. However, the effect of chest size has not been evaluated yet on routinely used protocols of current state-of-the-art CT systems. The purpose of the present study is to evaluate the effect of chest size on CCS as assessed with new-generation CT systems from the 4 major vendors.

2. Methods

2.1. Phantom

An anthropomorphic chest phantom (QRM Thorax, QRM GmbH, Möhrendorf, Germany) was used that consisted of artificial lungs, a spine, and a cylindrical recess. A cardiac phantom was placed within this cylindrical recess, which contained 100 small cylindrical calcifications varying in size and density.[14] Calcification diameters ranged from 0.5 to 2.0 mm and densities ranged from 90 to 540 mg hydroxyapatite per cm^3. Image acquisition was performed without and with an extension ring (QRM Thorax; Fig. 1). The phantom dimensions without extension ring were 300 mm × 200 mm and with extension ring 400 mm × 300 mm, respectively. The density of the extension ring was comparable to fat density (approximately −100 Hounsfield units). The phantom without extension ring was used to mimic a patient with a small chest size and the extension ring was used to mimic a patient with a large chest size. Retrospective analysis of clinically acquired cardiac CT data found that these dimensions match true patient chest sizes. In 26 patients who underwent a cardiac CT examination, the lateral dimensions ranged from 340.1 mm in a patient weighing 67 kg to 522.1 mm in a patient weighing 120 kg.

2.2. CT protocol

Image acquisition was performed using state-of-the-art CT systems from 4 major vendors (Brilliance iCT, Philips Healthcare, Best, the Netherlands; Discovery CT 750 HD, GE Healthcare, Waukesha, WI; SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany; and Aquilion ONE Vision, Toshiba Medical Systems, Otawara, Japan). Routine acquisition protocols for small patients were used for the phantom without extension ring, and routine acquisition protocols for large patients were used for the phantom with extension ring (Table 1). Vendor-recommended protocols were used with a fixed tube voltage of 120 kV and different tube currents based on body size. For 2 vendors, preset mAs values were used (Philips and GE), and for the other 2 vendors, mAs modulation was applied (Siemens and Toshiba). Prospectively electrocardiography-triggered sequential modes were used with a simulated heart rate of 60 beats/min. Image acquisition was repeated 5 times with small translations of approximately 2 mm and/or rotations of approximately 2° to assess the effects of interscan variation. CCS was quantified as Agatston and mass scores with semiautomatic software from the same manufacturer as the CT system. Size-specific calcium calibration factors as provided by the software were used for mass scoring. Images were reconstructed with vendor-recommended filtered back projection kernels.

2.3. Reference scores

Measured scores were compared with previously reported reference scores as obtained by scanning the phantom multiple times with an electron beam tomography system.[14] The reference Agatston score was 92.1 ± 36.7, and the reference mass score was 20.6 ± 6.5 mg. The physical mass of all calcifications in the phantom is 50.2 mg.

2.4. Noise measurements

Noise levels were measured in all reconstructions using regions of interest of the same size at the same location within every reconstruction. Standard deviations of the regions of interest were used as a measure of noise. These