# Effects of Dose Reduction on Diagnostic Image Quality of Coronary Computed Tomography Angiography in Children Using a Third-Generation Dual-Source Computed Tomography Scanner

Moustafa Rashed, MBBS[a], Puja Banka, MD[a,c], Ashita Barthur, MD[a], Robert D. MacDougal, PhD[b], Rahul H. Rathod, MD[a,c], Andrew J. Powell, MD[a,c], and Ashwin Prakash, MD[a,c,*]

**Performing coronary computed tomography angiography (CCTA) using third-generation dual source computed tomography (3G-DSCT) scanners results in radiation dose reduction without sacrificing image quality in adults. The largest dose reductions have been reported with prospectively gated, high-pitch imaging. However, there are limited data to determine if these benefits extend to pediatric patients. We evaluated image quality and radiation dose range of CCTA performed in children using a 3G-DSCT scanner. A retrospective review of 44 children (median age 10 years, range 0.6 to 17) who underwent imaging to evaluate coronary artery origins (n = 27), Kawasaki disease (n = 12) or other coronary abnormalities (n = 5) were performed. General anesthesia was used in 9/44 (20%) patients and a β blocker was administered in 19/44 (43%). Prospectively gated high-pitch scanning was most frequently used (n = 24). Other techniques used included prospectively-gated "step and shoot" (n = 14), retrospectively gated (n = 2) and nongated high-pitch scan (n = 4). Median effective radiation doses were lowest for prospectively gated high-pitch scans (0.5 mSv, range 0.4 to 0.7). Overall coronary artery image quality grade (1—excellent and 4—nondiagnostic) was acceptable for all electrocardiography-gated techniques, with no significant differences between high-pitch and "step-and-shoot" scan types (median 1, range 1 to 3 vs median 1, range 1 to 4, p = 0.22). Image quality grade was diagnostic (1 to 3) for all proximal coronary segments but rare distal segments were nondiagnostic (0.8% segments for gated high-pitch scan). In conclusion, CCTA can be performed in children using 3G-DSCT scanners with acceptable image quality. Prospectively gated high-pitch scans deliver the lowest radiation dose without reduction in image quality compared with conventional scan techniques.** **© 2018 Elsevier Inc. All rights reserved.** **(Am J Cardiol 2018;00:1−5)**

The recent availability of third-generation dual-source computed tomography (3G-DSCT) scanners has resulted in improvements in coronary CT angiography (CCTA). In adult patients, marked reduction in radiation dose has been reported without significant reduction in image quality.[1−3] Building on prior technical gains, 3G-DSCT scanners are able to offer the largest reduction in radiation doses by further reducing the kilovoltage peak (kVp) in larger patients due to higher power x-ray generators and improved x-ray tubes. Vessel contrast increases as kVp is decreased due to improved overlap of the x-ray spectrum with the k-edge of iodine. Thus, contrast to noise ratio is maintained at a lower dose by decreasing kVp and increasing tube current.[4] Additionally, newer model-based iterative reconstruction techniques are utilized to reduce image noise.[5] Although the usefulness of newer 3D-DSCT scanners has been demonstrated in adult patients by several investigators, there are limited data to determine if these benefits extend to pediatric patients, who have smaller sized coronary arteries and often, higher heart rates.[6] Because the potential adverse effects of radiation exposure are higher in children, the use of these newer techniques could be beneficial in this age group.[7] Therefore, we evaluated image quality and radiation dose of CCTA performed in children using a 3G-DSCT scanner.

A retrospective review of consecutive children (age <18 years) who underwent CCTA using a 3G-DSCT scanner at Boston Children's Hospital between October 2015 and October 2016 was performed. Only patients in whom evaluation of coronary arteries was the primary referral question were included. The Department of Cardiology's Scientific Review Committee and Boston Children's Hospital's Committee on Clinical Investigation gave permission for a retrospective review of existing clinical data. Clinical and demographic data were abstracted from the electronic medical record.

CCTA was performed using a 3-G DSCT scanner (Somatom Force, Siemens Healthcare, Forchheim, Germany). Patients with resting heart rate (HR) >70 bpm and without contraindications to β-blockade received a single dose of oral or intravenous metoprolol (1 mg/kg body weight) as previously described.[6,8] In children <8 years of age who were unable to breath-hold, imaging was often performed under

[a]Department of Cardiology, Boston Children's Hospital, Boston, Massachusetts; [b]Department of Radiology, Boston Children's Hospital, Boston, Massachusetts; and [c]Department of Pediatrics, Harvard Medical School, Boston, Massachusetts. Manuscript received April 10, 2018; revised manuscript received and accepted June 15, 2018.

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*Corresponding author: Tel.: +1 914 374 4965; fax: +1 617-739-3784.
*E-mail address:* ashwin.prakash@cardio.chboston.org (A. Prakash).

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general anesthesia with endotracheal intubation. In patients who were scanned under general anesthesia, a continuous infusion of intravenous esmolol (when not contraindicated) was titrated to achieve a HR <80 bpm. The system provided a 2 × 192 × 0.6 mm collimation and a gantry rotation duration of 250 ms. Automatic exposure control (Siemens CARE Dose) and automatic kV selection algorithm (Siemens CARE kV) were utilized as previously described.[9] The kVp selection algorithm selected the lowest possible kVp to optimize vascular imaging and to minimize radiation exposure. A prospectively triggered high-pitch spiral acquisition (pitch factor 3.2) during diastole was the default acquisition technique for patients with a stable and low HR (<80 bpm). For patients with a HR 80 to 100 bpm, a prospectively triggered "step-and-shoot" technique was most commonly used, and the acquisition window was selected based on HR. Retrospectively gated imaging with dose-modulation during the cardiac cycle was used in patients in whom ventricular function assessment was also necessary. Finally, a nongated high-pitch spiral acquisition was used in uncooperative children or those with HR >100 bpm. Cross-sectional images were reconstructed using the advanced modeled iterative reconstruction algorithm (levels 2 to 3, Siemens Healthcare, Forchheim, Germany) with a 0.6 mm slice thickness, 0.3 mm increment, and a medium soft convolution kernel (Bv36 or Bv40). Effective radiation dose was calculated from the dose-length product, using region-specific tables for the chest conversion factor.[10]

Contrast agent transit time was estimated using a test bolus technique utilizing 0.3 ml/kg of iopamidol (370 mg iodine/ml, Isovue 370, Bracco Imaging, Konstanz, Germany) injected in a peripheral vein via a dual-head power injector, followed by a saline flush of 1 to 1.5 ml/kg. Image acquisition was performed during injection of 1 ml/kg of contrast followed by 1 ml/kg of saline flush. Intravenous cannula size and injection rate varied by age as follows: <3 years 22 G cannula, 2 ml/s; 3 to 12 years 20 G cannula, 3 to 4 ml/s; >12 years 18 G cannula, 5 to 6 ml/s.

Segmental coronary artery image quality was graded by a single blinded observer using a semi-quantitative grading scale as previously described (1—excellent image quality without artifacts; 2—good image quality, minor artifacts with preserved evaluability; 3—fair image quality, artifacts present but able to rule-in or rule-out stenosis; and 4—nondiagnostic).[1] Coronary segments with a diameter <2 mm were excluded from grading. Median image quality grade was calculated per patient, and separately for coronary segments as shown in Table 3. To calculate interrater agreement, a blinded second rater assigned image quality grade in 15 patients.

Statistical analyses were performed using commercially available software (Stata version 12.0, StataCorp, LP, College Station, TX). Median image quality grade for scan techniques were compared using the Student's *t* test. Predictors of image quality grade were identified using multivariable ordered logistic regression (for ordinal outcomes).

## Results

Clinical and demographic characteristics of included patients are summarized in Table 1. All patients were below 18 years of age. The most common reason for referral was a suspected or known diagnosis of a congenital coronary anomaly.

As seen in Table 2, a prospectively triggered high-pitch scan was the most common imaging technique used, followed by a step-and-shoot technique. Retrospectively gated and nongated high-pitch scans were used sparingly. Beta blockers were used to lower the HR in 19/44 (43%) and scanning was performed under general anesthesia with endotracheal intubation in 10/44 (23%) patients.

Radiation dose parameters for the scanning techniques are compared in Table 2. Most (90%) patients were scanned at 70 kVp. High-pitch scans (prospectively triggered or ungated) delivered the lowest effective radiation doses. Compared with the step-and-shoot technique, gated high-pitch scans had a lower CT volume dose index (p = 0.002), dose-length product (p = 0.002), and effective radiation dose (p = 0.001). The effective radiation dose for high-pitch scans was <0.8 mSv in all patients and the median dose was roughly 50% of the dose delivered during a "step-and-shoot" scan.

Image quality grades assessed segmentally are summarized in Table 3. Patients scanned using retrospectively gated and ungated high-pitch scans were excluded from this analysis due to small sample sizes in those groups. As seen in Table 3, segmental image quality grade was good for both prospectively triggered high-pitch and "step-and-shoot" scans. Image examples are shown in Figures 1 and 2. All proximal coronary artery segments had diagnostic image quality grades (<4) but rare distal coronary segments were nondiagnostic. For all comparisons, image quality grade for the high-pitch technique was similar to the "step-and-shoot" technique. In multivariable analysis (Table 4), better image quality was associated with lower heart rate but not with age, the CT volume dose index or scan type. This relation persisted when this analysis was repeated in patients scanned with a gated high-pitch scan only.

A small subset of young children (n = 4, median age 2.8 years) with extremely rapid heart rates (median HR 133 bpm, range 98 to 140) was scanned using an ungated high-pitch scan. The primary indication for these scans was assessment of coronary artery origins. While the sample size of this subgroup is too small for meaningful statistical comparison, the proximal coronary arteries were visualized adequately in all 4 patients (proximal image quality grade 2

Table 1
Patient characteristics (n = 44)

| Parameter | Value |
|---|---|
| Median age (years) | 10.0 (0.6-17) |
| Females | 20 (45%) |
| Body weight (kg) | 37.9 (4.0-105.1) |
| Indication for Examination | |
| Congenital coronary anomaly (suspected or confirmed) | 21 (48%) |
| Kawasaki disease with coronary aneurysms | 12 (27%) |
| Congenital heart disease with associated coronary abnormality | 9 (20%) |
| Coronary artery fistula | 2 (5%) |

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