Published in final edited form as:

Eur J Radiol. 2010 April ; 74(1): 182–188. doi:10.1016/j.ejrad.2009.03.001.

Predictors of Image Quality of Coronary Computed Tomography in the Acute Care Setting of Patients with Chest Pain

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Abstract

Objective—We aimed to determine predictors of image quality in consecutive patients who underwent coronary computed tomography (CT) for the evaluation of acute chest pain.

Method and Materials—We prospectively enrolled patients who presented with chest pain to the emergency department. All subjects underwent contrast-enhanced 64-slice coronary multi-detector CT. Two experienced readers determined overall image quality on a per-patient basis and the prevalence and characteristics of non-evaluable coronary segments on a per-segment basis.

Results—Among 378 subjects (143 women, age: 52.9±11.8 years), 345 (91%) had acceptable overall image quality, while 33 (9%) had poor image quality or were unreadable. In adjusted analysis, patients with diabetes, hypertension and a higher heart rate during the scan were more likely to have exams graded as poor or unreadable (odds ratio [OR]: 2.94, p=0.02; OR: 2.62, p=0.03; OR: 1.43, p=0.02; respectively). Of 6,253 coronary segments, 257 (4%) were non-evaluable, most due to severe calcification (48%). The presence of non-evaluable coronary segments was associated with age (OR: 1.08 annually, 95%-confidence interval [CI]: 1.05–1.12 p<0.001), baseline heart rate (OR: 1.35 per 10 beats/min, 95%-CI: 1.11–1.67, p=0.003), diabetes, hypertension, and history of coronary artery disease (OR: 4.43, 95%-CI: 1.93–10.17, p<0.001; OR: 2.27, 95%-CI: 1.01–4.73, p=0.03; OR: 5.12, 95%-CI: 2.0–13.06, p<0.001; respectively).

Conclusion—Coronary CT permits acceptable image quality in more than 90% of patients with chest pain. Patients with multiple risk factors are more likely to have impaired image quality or non-evaluable coronary segments. These patients may require careful patient preparation and optimization of CT scanning protocols.

Keywords

cardiac computed tomography; coronary CT angiography; coronary artery disease; acute chest pain; image quality

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INTRODUCTION

Image quality is a prerequisite for high diagnostic accuracy of coronary computed tomography (CT). Standard 64-slice CT has been demonstrated to provide excellent image quality in a wide range of patients resulting in further improvements of diagnostic accuracy^{1–3}. However, despite improvement in temporal and spatial resolution, poor image quality has been associated with higher heart rates, extensive coronary calcification, inadequate contrast administration⁴.

Results from initial clinical trials in patients with acute chest pain in the Emergency Department (ED) indicate that noninvasive assessment of coronary artery disease (CAD) by coronary CT enhances the early triage of these patients^{5, 6}. High image quality is important to streamline image interpretation and efficient triage of patients with acute chest pain awaiting hospital admission. However, ED patients differ from those electively referred for coronary CT and may pose a specific challenge to the cardiovascular imager. Identification of predictors of non-diagnostic image quality related either to patient characteristics or to certain elements of the CT image acquisition would improve the selection of appropriate candidates for coronary CT angiography and most likely contribute to improved utilization of the technique in this clinical setting.

Thus, the aim of the study was to determine image quality in a large cohort of consecutive patients who underwent coronary CT for the evaluation of acute chest pain in the ED. Furthermore, we sought to identify demographic and protocol-related predictors of overall poor image quality and non-evaluable coronary segments.

METHODS

Subjects

The study was designed as a blinded, prospective observational cohort study to assess the utility of coronary CT in triaging patients who present to the ED with acute chest pain but without definitive evidence for a myocardial infarction (Rule Out Myocardial Ischemia by Computed tomography Angiography Trial - ROMICAT)⁵. Briefly, 412 consecutive adult patients presenting to the emergency department with acute chest pain but with no or non-diagnostic electrocardiographic changes and negative initial cardiac biomarkers who were awaiting admission to the hospital to rule out myocardial infarction were included. Patients were excluded for hemodynamic or clinical instability (systolic blood pressure <80 mmHg, clinically significant atrial or ventricular arrhythmias, persistent chest pain despite therapy), known allergy to iodinated contrast agent, or serum creatinine greater than 1.3 mg/dL, metformin treatment, hyperthyroidism, inability to provide informed consent, or interference with standard clinical care of patients.

For this study analysis, we excluded 34 subjects with a prior history of coronary artery bypass grafts because image parameters differ from standard cardiac MDCT protocol⁷.

MDCT Image Acquisition

All coronary CT imaging was performed with a 64-slice MDCT scanner (Sensation 64, Siemens Medical Solutions, Forchheim, Germany). In preparation for the scan, all patients with a heart rate greater than 65 beats per minute received beta-blocker therapy with metoprolol in 5 mg intravenously for a maximum of 25 mg, unless contraindications were present. Image acquisitions were performed during a breath hold in inspiration. Imaging parameters were slice collimation of 64 × 0.6 mm, a gantry rotation time of 330 ms, tube voltage of 120 kV, and an effective tube current of 850–950 mAs depending on patient body

size, with scan coverage from the carina to the diaphragm. Test bolus protocol was used to determine the optimal timing of peak contrast opacification at the level of the ascending aorta. Total contrast volume (80–100 ml, Iodhexodol 320 g/cm³, Visipaque, General Electric Healthcare, Princeton, NJ, USA) was dependent upon scan range and administered at an injection rate of 5 ml/s. The contrast injection was immediately followed by 40 mls of saline at the same rate of 5 ml/s. Dose saving algorithm with ECG-correlated tube current modulation was employed if the heart rate was <65 bpm and without heart rate variability (<5 bpm difference) or arrhythmia.

Image Post-processing

Overlapping transaxial images were reconstructed using a medium sharp convolution kernel (B25f) with an image matrix of 512×512 pixels, slice thickness of 0.75 mm, and increment of 0.4 mm using an ECG-gated half-scan algorithm with a resulting temporal resolution 165 ms in the center of rotation. Image reconstruction was retrospectively gated to the ECG. In the presence of remaining motion artifacts (i.e. due to heart rate irregularities during the acquisition), the reconstruction window was manually edited to achieve highest image quality. Three different phase reconstructions with the highest image quality were selected for analysis and transferred to an offline workstation (Leonardo; Siemens Medical Solutions, Forchheim, Germany).

Assessment of CT data sets was performed as a consensus reading by two experienced investigators blinded to the subject's clinical presentation and history with more than 3 years of experience.

Image Quality

Readers had full access to scroll through axial images, to interactively perform multiplanar reconstructions in thin slices (0.75 mm) and maximum intensity projections (MIP, 5 mm), as well as curved multiplanar reformats off any of the three datasets. Both readers inspected all coronary artery segments (modified 17-segment classification of the American Heart Association⁸) and determined image quality as follows:

1. **Overall image quality** was assessed using a five-point ranking scale as previously described^{9–11}. A score of 1 (*excellent*) was given in the absence of motion artifacts and a clear delineation of the coronary vessels; a score of 2 (*good*) was given if minor artifacts and mild blurring of the coronary vessels was noted; a score of 3 (*fair*), moderate artifacts and moderate blurring without structure discontinuity of the coronary vessels; a score of 4 (*poor*), severe artifacts, doubling or discontinuity in the course of the coronary vessels; and a score of 5 (*unreadable*), dataset not evaluable and vessel structures not differentiable from surrounding tissues. Examples of image quality are shown in Figure 1 and Figure 2. A score of 3 or better was considered acceptable in terms of image quality for routine clinical diagnostic purposes, while a score of 4 or 5 was considered unacceptable.
2. **Contrast-to-Noise Ratio:** To determine the contrast-to-noise ratio (CNR), 3–4 mm² circular regions of interest (ROI) were placed in the lumen of the coronary arteries and the connective tissue adjacent to the vessel. The mean CT attenuation was measured at three locations: mid right coronary artery (RCA), mid left anterior descending coronary artery (LAD), and prox left circumflex coronary artery (LCX). Image noise was measured by placing a 200 mm² circular ROI in the contrast enhanced lumen of the aortic root at the level of the performed coronary measurements and determining the standard deviation of CT attenuation. The CNR was then calculated by dividing the difference in Hounsfield unit (HU) between the

contrast in the coronary lumen and surrounding tissue by the image noise as described previously¹.

3. **Non-evaluable Segments:** Each coronary artery segment was graded as either evaluable or non-evaluable for the assessment of coronary stenosis. Non-evaluable was defined as the inability to definitely exclude the presence of a significant stenosis corresponding to a luminal narrowing >50%. In addition, the readers determined whether the cause for non-evaluability was due to calcification (presence of coronary calcification with blooming artifacts), motion (moderate to severe blurring limiting the evaluability for stenosis), stair step artifact (discontinuity in the course of the coronary vessels), poor contrast-to-noise (qualitative), or presence of coronary stent. When there was more than one etiology, the readers selected the cause contributing to non-evaluability the most.

Predictors of Image Quality

Clinical Characteristics—The following clinical covariates were prospectively collected: age, gender, body mass index (BMI=weight [kg]/ height squared [meters²]), baseline heart rate (HR, bpm), heart rate during scanning (bpm), hypertension (systolic blood pressure >140 mm Hg or diastolic blood pressure >90 mm Hg or current antihypertensive treatment), diabetes (fasting plasma glucose ≥126 mg/dL or treatment with a hypoglycemic agent), hyperlipemia (defined as total cholesterol of ≥200 mg/dL or treatment with a lipid lowering medication), smoking status, family history of CAD (first-degree relative [female <65 years or male <55 years] with a documented history of myocardial infarction or sudden cardiac death), and history of CAD (prior stent placement or documented history of myocardial infarction).

CT Protocol—The following cardiac CT related protocol variables were prospectively collected: use and dosage of beta-blockage in the CT suite, prior use of beta-blockage use in the ED or current or beta-blocker medication, use of nitroglycerin prior to scanning, tube current (mAs), delay time (seconds), amount of contrast material injected (mL), scan time (seconds), and door-to-door time (minutes).

Statistical Analysis

Descriptive characteristics for all variables were expressed as mean±SD for continuous and percentages for categorical variables.

Inter- and intra-observer assessment of reproducibility of image quality was performed in a subset of 25 patients using Cohen's Kappa (K) to determine the degree of agreement with K: < 0.4 (weak), K: 0.4–0.7 (good/moderate) and K: >0.70 (excellent) agreement.

Clinical and protocol-related characteristics between patients with acceptable image quality (Score: 1 to 3) and patients with poor image quality or unreadable exams (Score: 4 and 5) were compared using a two-tailed student's t-test for continuous predictors or Fisher's Exact test for categorical predictors. We performed multivariate logistic regression analysis to determine independent clinical and protocol-related predictors of poor image quality or unreadable exams. All variables with p-value <0.2 in univariate analysis were included in the model and odd ratios (OR) with 95% confidence intervals (CI) for each of these covariates were derived. Similarly, derive crude and independent predictors for subjects with 1 non-evaluable segment.

All analyses were performed using SAS (Version 9.1, SAS Institute Inc., Cary, NC, USA) and a p-value <0.05 was considered to indicate statistical significance.

RESULTS

The patient characteristics of the study cohort 378 consecutive patients who underwent coronary CT scanning prior to hospital admission (143 women, mean age: 52.9 ± 12 years) are detailed in Table 1.

The average door-to-door time in the CT suite for each subject was 15.9 ± 7 min including an average scan time of 14.1 ± 2 seconds. The mean baseline HR was 76.5 ± 16 bpm. Overall, 236 subjects (62%) received pre-scan intravenous beta-blockade and 91 (24%) received oral beta-blocker in the ED or prior to admission. The mean HR during scanning was 65.1 ± 11 bpm and same between patients who received and who did not receive beta blocker (65.2 ± 11 vs. 64.3 ± 12 ; $p=0.27$). Administration of beta blocker significantly decreased the heart rate (13.4 ± 16 bpm, $p<0.001$). Nitroglycerin was administered in 302 subjects (80%) prior to the scan. Following an average delay time of 20.4 ± 3 s, 85.4 ± 12 mL of contrast agent was injected.

Overall Image Quality

Among 378 subjects, 346 (91%) had acceptable and 33 (9%) had poor image quality or unreadable studies ($n=25$ [7%] and $n=8$ [2%], respectively). Among subjects with acceptable image quality, 149 (43%) had excellent, 121 (35%) good, and 76 (22%) fair image quality

Contrast-to-Noise-Ratio—Overall, CNR was 12.8 ± 5 and similar between RCA (12.4 ± 5), LAD (12.7 ± 5), and LCX (13.4 ± 6 , $p=0.90$). Poor image quality or unreadable exams had significantly lower CNR, both overall (14.5 ± 5 vs. 10.1 ± 4 , $p=0.001$) and in a per-artery comparison (14.6 ± 5 vs. 9.0 ± 4 , $p=0.0002$; 14.3 ± 5 vs. 10.0 ± 5 , $p=0.006$; and 14.8 ± 6 vs. 11.2 ± 6 , $p=0.04$, for RCA, LAD, and LCX, respectively). Average CNR was strongly correlated with categories of image quality ($r=0.58$, $p<0.0001$).

Clinical Predictors—In univariate analysis, subjects with poor image quality or unreadable exams were significantly older ($p=0.02$), more likely to have diabetes mellitus ($p=0.002$), hypertension ($p<0.001$), and a history of CAD ($p=0.04$) (Table 2). In contrast, the percentage of poor image quality or unreadable exams did not differ according to gender, BMI, hyperlipidemia, smoking status, family history of CAD, and baseline heart rate. In multivariable analysis, only diabetes and hypertension remained significantly associated with poor image quality or unreadable exams (OR: 2.94 [95%-CI: 1.2–7.1], $p=0.02$ and OR: 2.62 [95%-CI: 1.1–6.3], $p=0.03$).

Protocol-related Predictors—In univariate analysis, poor or unreadable image quality was associated with higher HR during the scan ($p=0.004$), higher tube current ($p=0.04$), and longer scan time ($p=0.04$) (Table 2). Poor or unreadable image quality was not associated with the use of beta-blocker ($p=1.00$), nitroglycerin ($p=0.09$), amount of contrast material ($p=0.08$), or the delay of data acquisition ($p=0.17$). In multivariable analysis, only HR during the scan remained an independent predictor for poor image quality or unreadable exams (OR: 1.43 per 10 bpm, [95%-CI: 1.07–1.90], $p=0.02$). After exclusion of patients with HR >65 bpm, the association between HR during the scan and poor or unreadable image quality was no longer significant ($p=0.23$).

Non-evaluable Coronary Segments

Overall, 4.1% (257/6253) of coronary segments in 61 subjects were determined to be non-evaluable. Causes for non-evaluability were the presence of severe calcification and motion in 35% ($n=91$), calcification in 24% ($n=62$), motion in 11% ($n=29$), “stair-step” or miss-

registration artifacts in 12% (n=31), qualitatively poor contrast-to-noise and calcification in 6% (n=15) and exclusively poor contrast-to-noise in 7% (n=19), and coronary stent placement in 4% (n=10); Figure 3.

Clinical Predictors—In univariate analysis, age ($p<0.001$), diabetes ($p<0.001$), hypertension ($p<0.001$), hyperlipemia ($p<0.001$), and history of CAD ($p<0.001$) were significantly associated with CT exams with 1 non-evaluable segment, whereas gender, BMI, smoking and baseline HR were not (Table 3). The strong association between major cardiovascular risk factors and the presence of non-evaluable segments persisted in multivariable adjusted analysis (Figure 4). Specifically, older patients (OR: 1.08 annually, 95%-CI: 1.05–1.12, $p<0.001$), patients with a higher baseline heart rate (OR: 1.35 per 10 bpm, 95%-CI: 1.11– 1.67, $p=0.003$), and subjects with diabetes, hypertension, and history of CAD were more likely to have exams with 1 non-evaluable segment (OR: 4.43, 95%-CI: 1.93–10.17, $p<0.001$; OR: 2.27, 95%-CI: 1.01–4.73 $p=0.03$; and OR: 5.12, 95%-CI: 2.0–13.06, $p<0.001$, respectively).

Protocol-related Predictors—There was no statistically significant difference of CT protocol related variables between patients with and without non-evaluable segments (Table 3).

Inter- and intra-observer agreement for the classification of overall image quality and non-evaluable segments was excellent ($K=0.91$ and $K=0.93$, respectively).

DISCUSSION

In this study of consecutive patients with acute chest pain in the ED, we demonstrate that 91% of cardiac CT exams have acceptable overall diagnostic image quality and that 96% of coronary segments were evaluable for the presence of significant stenosis. Higher heart rate and major cardiovascular risk factors were independent predictors of unacceptable image quality or non-evaluable coronary segments.

Overall Image quality

With the advent of 64-slice technology, improvements in image quality have led to better diagnostic accuracy with moderate heart rates or coronary calcification^{12–14}. While these studies indicated the feasibility of coronary CT for accurate non-invasive assessment of CAD, these data were primarily derived from patients who were scheduled for elective coronary angiography. Image quality assessment may be different and is largely unknown in the group of patients who presents acutely with chest pain to the ED. Our findings that sufficient diagnostic image quality was obtained in >90% of patients confirm the feasibility of coronary CT in the ED setting. In fact, only 2% (8/378) exams were classified as unreadable. Our findings are consistent with a recent meta-analysis on the use of coronary CT in patients with acute chest pain where Vanhoenacker et al. pooled of nine studies (total of 566 patients) and found that 3% of exams were classified as non-evaluable¹⁵.

We found that diabetes mellitus, hypertension, and higher heart rate during the scan (OR: 2.94, OR: 2.62, and OR: 1.43 per 10 bpm; respectively) were independent predictors for insufficient overall image quality. These findings are in line with previous research performed in patients undergoing invasive angiography. A possible explanation may be that diabetic and hypertensive patients have a higher calcified plaque burden^{16, 17}. Higher heart rates are associated with a decline in image quality due to the limited temporal resolution of the 64-slice CT scanners^{1, 9, 18}. Thus, the presence of coronary calcification and higher heart rates during the scan may be the major contributor to image quality degradation¹⁹.

Moreover, our results indicate that heart rate control remains critical to achieve an acceptable overall image quality with standard 64-slice CT technology. This finding is further accentuated by the observation that exclusion of patients with HR >65 bpm resulted in attenuation of the association between heart rate and poor/unreadable image quality ($p=0.23$).

Notably, there is now growing evidence that newer CT scanners with improved temporal resolution enable acquisition of high image quality datasets independent of heart rate ²⁰. Thus, the implementation of these CT scanners in the acute care setting may result in further improvements in image quality.

Consistent with our subjective assessment of image quality, we found an excellent CNR in the majority of the studied subjects. Measured CNR was higher in subjects with sufficient as compared to subjects with insufficient image quality and strongly correlated with overall degree of image quality ($p=0.001$ and $p<0.001$, respectively). Thus, our results confirm previous research demonstrating that higher intra-coronary attenuation is associated with higher reader confidence for the detection of CAD ^{20, 21}.

Per Segment Evaluability

On a per-segment basis, our results show that 96% of coronary segments are evaluable for the detection or exclusion of coronary stenosis. Also, we found that age and major cardiovascular risk factors increase the likelihood for exams with at least one non-evaluable coronary segment. Coronary calcification and motion, especially the combination was of the two (35%), was the major cause for non-evaluability. This observation that calcification is the predominant limiting factor affecting evaluability confirms earlier work from others ^{2, 4, 22} and our group ¹⁹. Thus, further research is warranted to prospectively investigate whether a non-contrast enhanced calcium scan may help in excluding subjects with high likelihood of non-evaluable coronary segments.

We also found that patients with a history of CAD are at increased risk for non-evaluable segments but not for insufficient overall image quality. This may be because our analysis included patients with history of stent placement ($n=10$). All of these segments were classified as non-evaluable although there are a number of studies suggesting that stent imaging of proximal and large-sized stents may be feasible ^{23, 24}.

Overall, appropriate selection of subjects based on these findings may further decrease the number of non-evaluable segments. Thus, special consideration should be given to older subjects (OR: 1.08, indicating an 8% increased risk per year of age) and subjects with diabetes (OR: 4.43 indicating an almost five-fold increased risk), hypertension (OR: 2.27, indicating an two-fold increased risk), and history of CAD (OR: 5.12, indicating an fivefold increased risk). In those patients the risk for heavily calcified, non-evaluable segments in which a coronary stenosis cannot be excluded is high. Further research will be necessary to fully establish the value of cardiac CT in the emergency room setting.

Limitations

This study was designed as a prospective observational study to assess the clinical utility of CT for predicting acute coronary syndrome. We did not specifically design the study to compare various CT protocol-related parameters and variables for image quality analysis. Also, we used a dedicated coronary CT protocol and did not study the value of a larger coverage including the pulmonary and aortic vasculature ("triple rule-out"). Further research using newer scanner generations will be necessary to evaluate the image quality and clinical impact of such imaging procedures.

Our analysis was restricted to subjective evaluation of image quality both for the overall image quality and for evaluability on a per-segment basis. Additionally, assessment of image quality was performed in a joint reading by experience readers.

The use of cardiac CT needs to be evaluated in the context of associated radiation exposure (~10 to 15 mSv). Thus, further developments such as prospective ECG triggering will greatly facilitate acceptance in clinical practice.

We acknowledge that due to our study protocol our population may slightly differ from patients with acute chest pain clinically referred for coronary CT. As per recommendation of the local institutional review board we restricted enrollment to patients with serum creatinine 1.3 mg/dL and creatinine clearance >50mL/min. Thus, our patients may represent a slightly healthier cohort than in clinical practice.

Conclusion

Over 90% of patients presenting with acute chest pain to the ED have diagnostic image quality and 96% of coronary segments are evaluable to detect or exclude the presence of significant coronary stenosis. However, diabetic patients with hypertension and sustained higher HR have a higher likelihood for insufficient image quality whereas older patients and those with major cardiovascular risk factors have increase risk for non-evaluable coronary segments. These patients may need special consideration for patient preparation and optimization of CT scanning protocols.

Acknowledgments

Sources of Funding

The study was supported by Grant No. R01 HL080053 from the National Institutes of Health, Bethesda, Maryland; General Electric Healthcare, Waukesha, Wisconsin; and Siemens Medical Solutions, Forchheim, Germany.

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Figure 1.

Acceptable Image Quality Score of 1 to 3. Maximum intensity projection (MIP) images of the right coronary artery in a scan graded with a score of 1 for excellent (Figure 1A), score of 2 for good with mild blurring (Figure 1B), and score of 3 for fair image quality with moderate blurring and increased image noise (Figure 1C).

Figure 2. Poor or Unreadable Image Quality Score of 4 and 5. Maximum intensity projection (MIP) images of the right coronary artery in a scan graded with a score of 4 for poor image quality (Figure 2A) and a score of 5 for unreadable (Figure 2B).

Figure 3.

Frequency of causes of non-evaluable coronary artery segments. Calcification and motion was the most frequent cause rendering a segment non-evaluable (35%). CAC: coronary artery calcification, CNR: contrast-to-noise ratio.

Figure 4.

Forrest plot showing clinical predictors of non-evaluable coronary segments (Odds Ratio with 95%-confidence intervals). Older patients (OR: 1.08 annually, 95%-CI: 1.05–1.12, $p < 0.001$), patients with a higher baseline heart rate (OR: 1.35 per 10 bpm, 95%-CI: 1.11–1.67, $p = 0.003$), and subjects with diabetes, hypertension, and history of CAD were more likely to have exams with 1 non-evaluable segment (OR: 4.43, 95%-CI: 1.93–10.17, $p < 0.001$; OR: 2.27, 95%-CI: 1.01–4.73 $p = 0.03$; and OR: 5.12, 95%-CI: 2.0–13.06, $p < 0.001$, respectively). CAD: coronary artery disease; OR: odds ratio; CI: confidence interval.

Table 1

Patient characteristics, overall coronary computed tomography (CT) image quality, and per-segment evaluability among 378 consecutive subjects who presented with acute chest pain but inconclusive evaluation in the emergency department. In all patients coronary CT was performed prior to hospital admission.

Age, years	52.9±12
Gender (female)	143 (38%)
Body mass index (kg/m ²)	29.0±6
Diabetes mellitus	43 (11%)
Hypertension	154 (41%)
Hyperlipidemia	145 (38%)
Smoking history	98 (26%)
Family history CAD	91 (24%)
History of CAD	30 (8%)

CAD denotes coronary artery disease.

Table 2

Overall Image Quality: Patient characteristics and coronary CT protocol-related variables between patients with acceptable image quality (image quality score 1 to 3, n=345) and patients with poor image quality and unreadable exams (image quality score 4 and 5, n=33).

Per Patient Basis			
	Acceptable Image Quality	Poor Image Quality or Unreadable Exams	P-value
<i>Patient Characteristics</i>			
Age, years	52.3±11	58.9±15	0.02
Gender (female)	218 (63%)	17 (52%)	0.19
Body mass index (kg/m ²)	29.0±6	29.9±8	0.51
Diabetes mellitus	33 (10%)	10 (30%)	0.002
Hypertension	130 (38%)	24 (73%)	<0.0001
Hyperlipidemia	129 (37%)	16 (48%)	0.26
Smoking	88 (26%)	10 (30%)	0.54
Family history of CAD	83 (24%)	8 (24%)	1.00
History of CAD	24 (7%)	6 (18%)	0.04
Baseline HR (bpm)	76.2±16	79.5±16	0.25
<i>CT Protocol Characteristics</i>			
HR during scan (bpm)	64.4±11	73.2±15	0.004
Use of Beta-Blocker	216 (63%)	20 (61%)	1.00
Nitroglycerin administration	281 (81%)	21 (64%)	0.09
Tube Current (mAs)	885±44	902±49	0.04
Scan time (sec)	14.1±2	13.6±1	0.04
Contrast Volume (mL)	85.8±13	81.8±10	0.08
Delay (sec)	20.4±3	19.7±3	0.17

HR: heart rate in beats per minute; CAD: coronary artery disease.

Table 3

Per Segment Evaluability: Patient characteristics and coronary computed tomography (CT) protocol variables between patients with all coronary segments evaluable (n=61) and patients with 1 non-evaluable coronary segment (n=317).

Per-Segment Evaluability			
	All Segments Evaluable	1 Segment Non- evaluable	P-value
<i>Clinical Characteristics</i>			
Age, years	51.1±11	62.1±12	<0.0001
Gender (female)	194 (61%)	41 (67%)	0.39
Body mass index (kg/m ²)	28.9±6	29.8±7	0.26
Diabetes	24 (8%)	19 (31%)	<0.0001
Hypertension	108 (34%)	46 (75%)	<0.0001
Hyperlipidemia	107 (34%)	38 (62%)	<0.0001
Smoking	80 (25%)	18 (30%)	0.52
Family history of CAD	73 (23%)	18 (30%)	0.32
History of CAD	13 (4%)	17 (28%)	<0.0001
Baseline HR (bpm)	76.1±16	79.0±17	0.19
<i>Protocol Characteristics</i>			
HR during scan (bpm)	64.8±12	66.6±10	0.28
Use of Beta-Blockage	198 (62%)	38 (62%)	1.00
Nitroglycerine administration	259 (81%)	43 (70%)	0.07
Tube Current (mAs)	887±44	885±45	0.80
Scan time (sec)	14.1±2	14.0±2	0.77
Amount Contrast Material (mL)	85.6±13	84.6±12	0.58
Delay (sec)	20.2±3	20.9±3	0.10

HR: heart rate in beats per minute; CAD: coronary artery disease.