High-Pitch Thoracic CT With Simultaneous Assessment of Coronary Arteries

Effect of Heart Rate and Heart Rate Variability on Image Quality and Diagnostic Accuracy

Michael Scharf, MD,* Ricarda Bink, MD,* Matthias S. May, MD,*
Christian Hentschke, MS,† Stephan Achenbach, MD,‡ Michael Uder, MD,*
Michael M. Lell, MD*

Erlangen, Germany

OBJECTIVES The aim of this study was to evaluate the mean heart rate and heart rate variability (HRV) required for diagnostic imaging of the coronary arteries simultaneously with thoracic computed tomography for noncardiac purposes, applying a high-pitch spiral image acquisition protocol for computed tomography angiography (CTA) using a dual-source system.

BACKGROUND For the primary prevention of coronary heart disease, screening methods to identify currently asymptomatic people who are at high risk for developing coronary heart disease are essential. Coronary CTA can rule out coronary artery stenoses with high negative predictive value.

METHODS High-pitch thoracic computed tomography was performed in 111 consecutive patients (mean age 60.2 ± 11.5 years; range 37 to 81 years) using a dual-source system (2 × 128 0.6-mm sections, 38.4-mm collimation width, 0.28-s rotation time). Data acquisition was prospectively electrocardiographically triggered at 60% of the R-R interval using a pitch of 3.2. Image quality was evaluated using a 3-point scale (1 = excellent, 2 = moderate, 3 = poor).

RESULTS Close interobserver agreement for image quality scores of 1,998 evaluated coronary segments was found ($\kappa = 0.93$). Image quality was of diagnostic value in 828 of 1,739 segments (47.6%). In 29 of 111 patients (26%), diagnostic image quality was observed for all segments. Average heart rate and HRV were significantly (p < 0.001) higher in patients with at least 1 nondiagnostic coronary segment compared with those without. All patients with mean heart rates <64 beats/min and HRV <13 beats/min had diagnostic image quality in all coronary segments. Effective radiation dose for thoracic CTA was 1.9 ± 0.66 mSv. The mean scan time was 0.9 ± 0.1 s.

CONCLUSIONS Simultaneous evaluation of coronary arteries in high-pitch dual-source CTA of the thorax for noncardiac purposes is consistently diagnostic in patients with low heart rates and HRV, whereas most patients not receiving beta-blockers had at least 1 segment that was not diagnostic because of heart rate and HRV. Beta blockers are recommended if there are no contraindications and coronary interpretation is anticipated. (J Am Coll Cardiol Img 2011;4:602–9) © 2011 by the American College of Cardiology Foundation

Cardiovascular disease is the leading cause of death in the Western population, accounting for 38.5% of all deaths (1). Fifty percent of men and 64% of women who die after acute coronary events do not experience prior symptoms of chest pain or exertional dyspnea, emphasizing the importance of early detection and treatment of underlying subclinical coronary atherosclerosis (2,3). The identification of currently asymptomatic people who are at high risk for developing coronary heart disease has become an accepted method for the primary prevention of coronary heart disease (4). Cardiovascular prevention algorithms based on traditional risk factors for coronary artery disease often underestimate event risk, especially in women and in young individuals (5). Evidence supporting the use of noninvasive imaging tests to screen for coronary artery disease is gradually accumulating. Adequate image quality provided, coronary computed tomography angiography (CTA) can rule out coronary artery stenoses with high negative predictive value, providing incremental prognostic information in addition to the assessment of conventional risk factors (6,7).

For the assessment of coronary arteries, spiral acquisition with low pitch values (0.2 to 0.4) and retrospective electrocardiographic (ECG) gating is most commonly used, which is associated with substantial oversampling, meaning that the same level is irradiated during several consecutive rotations of the X-ray gantry (8). The mean effective dose for coronary CTA is on the order of 12 mSv, but significant variability among institutions and scanner types, with doses up to 10 to 25 mSv, has been reported (9). Triple-rule-out protocols for the evaluation of coronary and noncoronary disease covering the complete thorax result in even higher dose values (10).

High-pitch dual-source CTA enables the simultaneous visualization of the coronary arteries in patients undergoing thoracic computed tomography (CT) for noncardiac purposes (e.g., pneumonia) within a single cardiac cycle and at a very low radiation dose, which enables screening for coronary artery disease (11,12). Accordingly, the aim of this study was to evaluate maximal threshold values for heart rate and heart rate variability (HRV) required for diagnostic imaging of the coronary arteries in patients undergoing thoracic CT, using a new high-pitch spiral scan mode with prospective ECG triggered dual-source CTA.

METHODS

Study population. One hundred eleven prospectively registered patients (64 men, 47 women; mean age: 60.2 ± 11.5 years; range 37 to 81 years; mean body mass index: 23.8 ± 4.4 kg/m^2; range 13 to 40 kg/m^2) who underwent clinically indicated thoracic CT were included in this study. Thoracic CT was performed for cancer staging (n = 53), diagnosis of inflammatory lung diseases (n = 25), and suspected pulmonary embolism (n = 33). General exclusion criteria for contrast-enhanced CTA were nephropathy (defined as a serum creatinine level >150 μmol/l) or a known hypersensitivity to iodine-containing contrast agents. The study protocol was approved by the institutional review board, and written informed consent was obtained from all subjects.

Dual-source CT protocol and data reconstruction. All examinations were performed with a dual-source CT system (Definition Flash; Siemens Medical Systems, Forchheim, Germany) using 2 x-ray tubes and 2 detectors arranged at an angular offset of 95°. With a gantry rotation time of 0.28 s, half-scan reconstruction provides a temporal resolution of 75 ms in the center of the field of view. Coronary CTA datasets were acquired using prospective ECG triggered high-pitch spiral acquisition, which is a new type of spiral acquisition developed specifically for dual-source CT. The pitch (table feed per gantry rotation divided by collimated beam width) can be increased substantially, while still allowing image reconstruction because of dual-source geometry (13,14). As a result of the high pitch, overlapping radiation exposure is avoided, thus substantially reducing the radiation dose to the patient.

A caudocranial scan direction was chosen, and all CT imaging data were acquired with a breath hold in deep inspiration to eliminate respiratory motion artifacts. Coronary CTA was performed after determination of the peak enhancement within a "test bolus" protocol: 10 ml of contrast agent (370 mg iodine/ml) (Ultravist, Bayer-Schering Pharma, Berlin, Germany), followed by 60 ml saline solution, both at flow rates of 6 ml/s. The time to peak enhancement (tracked by an ellipsoid region of interest in the descending aorta) was measured using a series of transaxial scans acquired in 2-s increments, with the first image being acquired 15 s after the start of injection. For coronary CTA, 60

ml of contrast agent was injected, followed by a 60-ml flush (80% saline and 20% contrast agent). Image acquisition was started with a delay corresponding to the measured contrast transit time plus 5 s. Patients with suspected pulmonary embolism received a larger contrast agent bolus to maintain good right-sided (pulmonary arteries) and left-sided (coronary arteries) contrast. Attenuation was higher in the aorta, with at least 250 Hounsfield units in the pulmonary arteries. For patients weighing up to 100 kg (n = 107), tube voltage was 100 kV, and tube current was 320 mAs/rotation. For patients weighing more than 100 kg, (n = 4), tube voltage was 120 kV, and tube current was 320 mAs/rotation, because body weight has been shown to influence image noise in low-dose scan protocols (15). Pitch was 3.2 (table feed 43 cm/s).

Image acquisition was prospectively triggered by the patient's ECG and started automatically at the most basal position of the chest to time the data acquisition to arrive at the inferior border of the heart at 60% of the R-peak–to–R-peak interval, with subsequent images being reconstructed progressively later in the data acquisition window (Fig. 1). Consequently, all cross-sectional images depict the coronary arteries during diastole (14). The total duration of data acquisition was depen-

dent on the selected pitch value and the length of thoracic scan volume (range 0.59 to 1.15 s; mean: 0.9 ± 0.1 s). Reconstructed slice thickness was 0.6 mm, the slice increment was 0.3 mm, and a medium-sharp reconstruction kernel was used.

CT image evaluation. The image datasets were analyzed using an offline workstation (Multi-Modality Workplace, Siemens Medical Systems). Image quality was independently evaluated by 2 observers (M.S. and M.M.L., with 4 and 10 years of experience in cardiovascular radiology, respectively) in random order, blinded to all clinical data and each other's findings. Analysis was performed on a per segment basis, using the 18-segment model of the Society of Cardiovascular Computed Tomography (Table 2) (16). Because of normal anatomic variation, not all coronary segments were present in all patients. According to a semiquantitative 3-point grading scale, image quality of coronary artery segments was classified as excellent (score of 1 = no image quality–deteriorating artifact related to motion or arterial wall calcification), moderate (score of 2 = artifacts but with possible evaluation and good confidence), or poor (score of 3 = no evaluation possible because of artifacts). All diagnostic coronary artery segments (i.e., scores 1 and 2) were visually assessed for the presence of significant
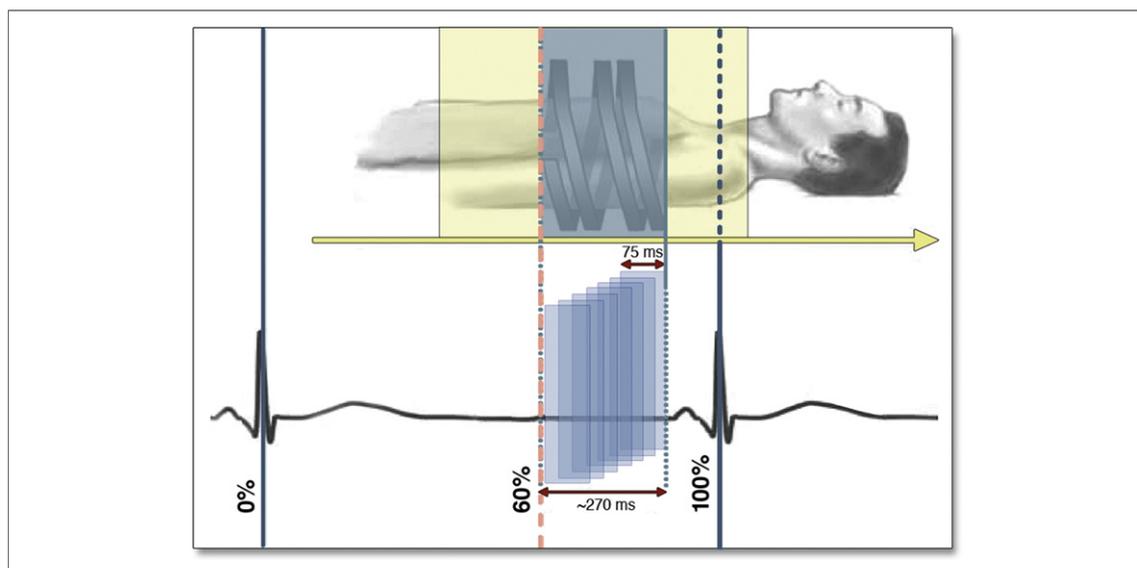
Figure 1. Simultaneous Image Acquisition of Coronary Arteries With High-Pitch Electrocardiographically Triggered CTA of the Thorax

A high pitch value (3.2) is used, so that the x-ray tubes and detectors rotate around the patient without overlap. Imaging of the complete volume of the heart is performed in approximately 270 ms. Images are reconstructed with a temporal resolution of 75 ms. Level for image acquisition at 60% of the R-peak–to–R-peak interval was selected manually at the inferior border of the heart (**dashed line**). While the data window of the most basal image started at 60% of the R-peak–to–R-peak interval (0% to 100%), subsequent images were reconstructed progressively later in the cardiac cycle. Scan range covering the heart (**dark shadowed field**) was obtained during diastole. Whole thoracic scan range is indicated by the **light shadowed field**. CTA = computed tomography angiography.

stenoses, defined as a luminal diameter narrowing of more than 50%. The vessel diameters were measured on reconstructions perpendicularly oriented to the vessel course. Each vessel was analyzed on at least 2 imaging planes, 1 parallel and 1 perpendicular to the course of the vessel. In the case of disagreement in data analysis between the observers, consensus was reached in a joint reading to determine the final image quality score per segment.

Radiation dose estimates of coronary CTA. Radiation dose was determined on the basis of the dose-length product documented in the CT scan protocol, separately for the test bolus acquisition and the coronary CTA acquisition. Effective dose from coronary CTA was estimated on the basis of the dose-length product, using a conversion coefficient ($k = 0.014$ mSv $\cdot$ mGy^{-1} $\cdot$ cm^{-1}) for the chest in adults (11). This value is averaged between male and female models.

Statistical analysis. All computations were performed using SPSS version 17.0 (SPSS, Inc., Chicago, Illinois) and R environment for statistical computing (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables are expressed as mean $\pm$ SD and categorical variables as frequencies or percentages. Throughout the analysis, a 2-sided p value <0.05 was considered statistically significant. Interobserver agreement on image quality of the coronary artery segments was evaluated using Cohen's kappa statistics.

Heart rate was defined as mean heart rate during examination. HRV is the difference between minimal and maximal heart rate during examination. Differences in heart rate and HRV between patients with diagnostic image quality in all artery segments and patients with at least 1 segment with nondiagnostic image quality were assessed using Mann-Whitney *U* tests. Optimal cutoff values for patients' heart rates and HRV were identified by optimizing the mean of sensitivity and specificity in view of distinguishing 2 "true" groups of patients with more and less than 3 artery segments of image quality score 3, respectively (17). The identified cutoff values were used to subdivide the study sample into 4 groups: low heart rate with low HRV, low heart rate with high HRV, high heart rate with low HRV, and high heart rate with high HRV.

Additionally the influence of heart rate and HRV on the risk for poor image quality per artery segment was modeled by a hierarchical generalized mixed-effects model with artery segments nested in

patients (18). Odds ratios (OR) were calculated as effect sizes.

Sample size to identify optimal cutoff values was calculated for a power level of >80% and an alpha error level of 0.05 to detect a difference of 0.25 from $\pi_0 = 0.5$, which would reflect randomly distributed group membership of "true" image quality groups as defined above. For this purpose, a sample size of n $\approx$ 111 was necessary.

RESULTS

Patients' physical characteristics and scan parameters are presented in Table 1. There was no image quality loss for the evaluation of the initial pathology due to the simultaneous assessment of coronary arteries.

Close interobserver agreement was found for image quality scores. Mean image quality per segment was 2.28 $\pm$ 0.30 for reader 1 and 2.31 $\pm$ 0.30 for reader 2. Identical scores were given in 1,919 of 1,998 segments (96%). Cohen's kappa was 0.93, indicating substantial agreement.

A total of 1,739 coronary artery segments were present (mean: 15.7 coronary artery segments per patient; Table 2). Of those, 491 (28.2%) had image quality scores of 1 in the consensus reading, 337 segments (19.4%) had scores of 2, and 911 segments (52.4%) were rated as unevaluable (score 3). Overall, the mean image quality score per segment was 2.29 $\pm$ 0.30. The mean per patient image quality score (reflecting the worst segment for each patient) was 2.7 $\pm$ 0.6. In 29 patients (26%), all

Table 1. Patient Physical Characteristics and Scan Parameters

Variable	Mean $\pm$ SD	Range
Physical characteristics		
Body weight (kg)	73 $\pm$ 14	38–118
Height (cm)	173 $\pm$ 8	156–190
Heart rate during image acquisition (beats/min)	76 $\pm$ 19	42–125
HRV during image acquisition (beats/min)	23 $\pm$ 23	4–97
Scan parameters		
Scan range length for thoracic CTA (mm)	370 $\pm$ 64	—
Duration of data acquisition (s)	0.9 $\pm$ 0.3	—
DLP for test bolus acquisition (mGy $\cdot$ cm)	18.7 $\pm$ 6.3	—
Effective dose for test bolus (mSv)	0.26 $\pm$ 0.09	—
DLP for thoracic CTA (mGy $\cdot$ cm)	138.5 $\pm$ 47.1	78–299
Effective dose for thoracic CTA (mSv)	1.90 $\pm$ 0.66	1.1–4.2
DLP for thoracic CTA. 100-kV group (mGy $\cdot$ cm)	126 $\pm$ 26	—
Effective dose for thoracic CTA, 100-kV group (mSv)	1.8 $\pm$ 0.4	—
DLP for thoracic CTA, 120-kV group (mGy $\cdot$ cm)	179 $\pm$ 73	—
Effective dose for thoracic CTA, 120-kV group (mSv)	2.5 $\pm$ 1.0	—

CTA = computed tomography angiography; DLP = dose-length product; HRV = heart rate variability.

**Table 2.** Image Quality Scores of the Coronary Artery Segments

Characteristic	Right Coronary Artery					Left Main Coronary Artery	Left Anterior Descending Coronary Artery					Left Circumflex Artery						
Segment number	1	2	3	4	16	5	6	7	8	9	10	11	12	13	14	15	17	18
Number of segments evaluated (%)	98	99	97	94	94	99	100	99	95	95	68	100	96	95	77	55	51	52
Score 1*	33 (37)	14 (15)	21 (23)	25 (28)	24 (26)	70 (78)	40 (44)	28 (31)	22 (24)	30 (34)	16 (18)	40 (44)	27 (30)	16 (18)	16 (18)	4.5 (5)	13 (15)	2.7 (3)
Score 2*	24 (27)	25 (28)	18 (20)	19 (21)	14 (16)	20 (22)	33 (37)	31 (35)	19 (21)	11 (12)	8 (9)	22 (25)	17 (19)	14 (16)	9 (10)	4.5 (5)	9 (10)	3.6 (4)
Score 3*	41 (45)	60 (67)	58 (65)	50 (55)	56 (62)	9 (10)	27 (30)	40 (44)	54 (60)	54 (60)	44 (49)	38 (42)	52 (58)	65 (72)	52 (58)	46 (51)	29 (32)	46 (51)

Percentages of 18 different coronary artery segments evaluated in 111 patients. *Scores of evaluated segments are indicated as percentages and n (%). Segments not evaluated were either missing because of normal anatomic variation or were excluded from analysis because of coronary artery bypass.

segments had diagnostic image quality (score 1 or 2), whereas image quality was not of diagnostic value in 82 patients (74%). Nondiagnostic image quality was most often found in the left circumflex coronary artery (LCX) (62.8% [332 of 529 segments]) in the following distribution: proximal LCX (42 of 111), obtuse marginal branch 1 (58 of 107), mid LCX (72 of 106), obtuse marginal branch 2 (58 of 86), posterolateral branch (51 of 58), and posterior descending artery (51 of 61). Unevaluable segments were less often found in the left main coronary artery (9.0% [10 of 110]). Distribution of right coronary artery (RCA) (nondiagnostic 55.0% [294 of 535 segments]) was as follows: proximal RCA (45 of 109 patients), mid RCA (67 of 110), distal RCA (65 of 108), posterior descending artery (55 of 104), and posterolateral branch (62 of 104).

Patients with nondiagnostic segments (n = 82) had a significantly (p < 0.005) higher mean heart rate and HRV (heart rate 83 ± 17 beats/min, HRV 27 ± 25 beats/min) than those with diagnostic images of all coronary artery segments (n = 29) (heart rate 57 ± 9 beats/min, HRV 12 ± 8 beats/min) (Figs. 2A to 2D). Mean heart rate and
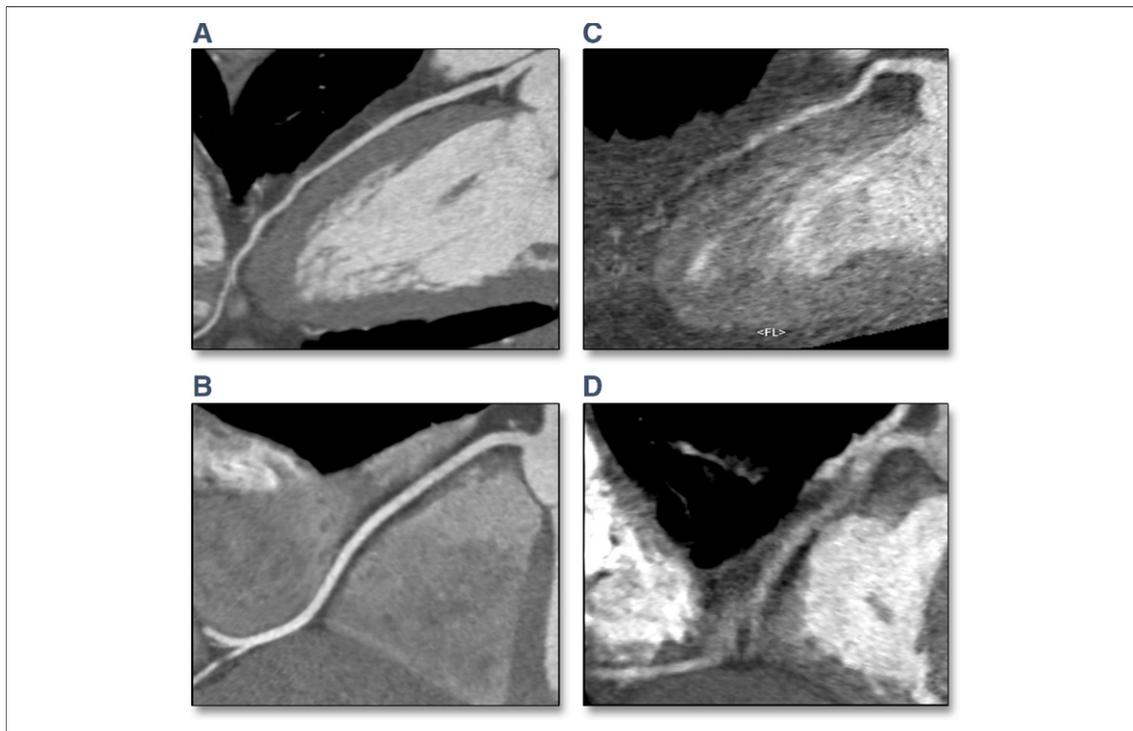
Figure 2. Comparison of Image Quality of Coronary Arteries Related to Heart Rate and HRV, Using High-Pitch Dual-Source CT of the Thorax

Curved multiplanar reformations of thoracic computed tomography (CT) angiograms of the left anterior descending (LAD) coronary artery **(A)** and the right coronary artery (RCA) **(B)** in a 50-year-old man with a heart rate of 58 beats/min and heart rate variability (HRV) of 11 beats/min show excellent image quality. Nondiagnostic image quality in all segments of the LAD coronary artery **(C)** and RCA **(D)** is demonstrated in a 53-year-old man with heart rate of 70 beats/min and HRV of 27 beats/min.

HRV in the whole group were 76 ± 19 beats/min and 23 ± 23 beats/min, respectively. The identified cutoff value with optimal specificity (0.89; 95% confidence interval [CI]: 0.67 to 0.96) and sensitivity (0.83; 95% CI: 0.74 to 0.90) for discrimination between diagnostic and nondiagnostic image quality by heart rate during scanning was <64 beats/min. For HRV, the optimal cutoff value was <13 beats/min (specificity 0.89; 95% CI: 0.67 to 0.96; sensitivity 0.57; 95% CI: 0.46 to 0.67) (Fig. 3).

When the data on patients were distributed into 4 groups separated by these thresholds, all coronary artery segments were evaluated with diagnostic image quality in patients with low heart rates (<64 beats/min) and low HRV (<13 beats/min) (Figs. 4A and 4B, Table 3). In contrast, CT investigations with nondiagnostic visualization of the coronary arteries most frequently occurred in patients with both high heart rates (≥64 beats/min) and high HRV (≥13 beats/min). The risk for getting a nondiagnostic image quality score increased every 10 beats/min of heart rate significantly (p < 0.001), with an OR of 2.04 (95% CI: 1.69 to 2.46) and with an OR of 1.08 (95% CI: 1.04 to 1.13) for every beat per minute in HRV (p < 0.001). Furthermore, we found a negative interaction effect between both (OR: 0.99; 95% CI: 0.987 to 0.998; p = 0.005) indicating a less important HRV with increasing heart rate.

Coronary CTA showed the presence of significant (>50%) stenoses in 7 of 29 patients with diagnostic image quality (1 to 4 segments per patient affected). The affected segment was the proximal left anterior descending coronary artery in 5 cases, the LCX coronary artery in 4 cases, the RCA in 3 cases, and a large diagonal branch in 2 cases. Evaluation of diagnostic segments in patients with at least 1 nondiagnostic segment showed stenoses in 18 of 82 patients.

DISCUSSION

High-pitch dual-source CTA enables diagnostic visualization of coronary arteries in patients undergoing thoracic CT for noncardiac purposes, provided heart rate and HRV are adequately controlled. In our study, all coronary artery segments were of diagnostic value in patients with average heart rates <64 beats/min and HRV <13 beats/min, whereas higher heart rates or HRV reduced the simultaneous assessment of coronary artery disease. Therefore, to optimize coronary image quality, the use of beta-blockers must be considered
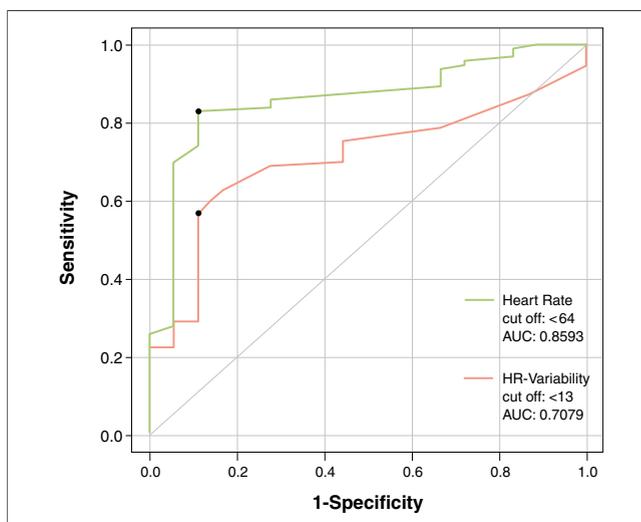
Figure 3. ROC Curves for Optimal Cutoff Points of HR and HRV Discriminating Between Diagnostic and Nondiagnostic Image Quality

Receiver-operator characteristic (ROC) curve for heart rate (HR) **(green line)**: the cutoff value **(black dot in green line)** with optimal specificity (0.89; 95% confidence interval [CI]: 0.67 to 0.96) and sensitivity (0.83; 95% CI: 0.74 to 0.90) for discrimination between diagnostic and nondiagnostic image quality was <64 beats/min. ROC curve for heart rate variability (HRV) **(pink line)**: the optimal cutoff value **(black dot in pink line)** was <13 beats/min (specificity 0.89; 95% CI: 0.67 to 0.96; sensitivity 0.57; 95% CI: 0.46 to 0.67). Values for specificity are indicated as 1 − specificity. AUC = area under the curve.

in most patients. Even if coronary artery scans are not completely diagnostic in patients with higher heart rates or HRV, diagnostic segments with coronary artery stenoses can be depicted. This is
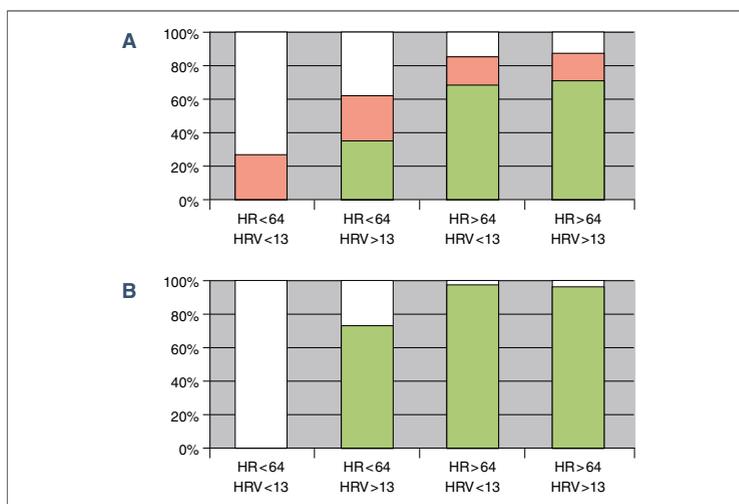
Figure 4. Evaluable Coronary Arteries per Segment and per Patient, Differentiated by Mean HR (> or <64 beats/min) and HRV (> or <13 beats/min)

(A) Percentages of segments with excellent image quality (score = 1; **white boxes**), moderate image quality (score = 2; **pink boxes**), and nondiagnostic image quality (score = 3; **green boxes**). **(B)** Patients with all segments of diagnostic image quality (**white boxes**) and patients with at least 1 segment of nondiagnostic image quality (**green boxes**).

Table 3. Image Quality per Segment and per Patient in Groups Separated by HR and HRV

Finding	Low HR, Low HRV	Low HR, High HRV	High HR, Low HRV	High HR, High HRV
Heart rate parameter				
Mean ± SD HR (beats/min)	55 ± 5	56 ± 7	84 ± 13	87 ± 16
Mean ± SD HRV (beats/min)	8.5 ± 1.9	34.1 ± 23.4	8.2 ± 2.6	22.6 ± 22.5
Image quality per segment				
Excellent (score 1)	73.9 (257/348)	38.3 (59/154)	14.9 (73/490)	13.8 (103/748)
Moderate (score 2)	26.1 (91/348)	27.3 (42/154)	17.5 (86/490)	16.1 (120/748)
Poor (score 3)	—	34.4 (53/154)	67.6 (331/490)	70.1 (525/748)
Image quality per patient				
All segments have diagnostic image quality	100 (23/23)	27.3 (3/11)	3.2 (1/31)	4.3 (2/46)
Not all segments have diagnostic image quality	—	72.7 (8/11)	96.8 (30/31)	95.7 (44/46)

Values for image quality per segment and per patient are indicated as percentages and numbers (n/N). Low heart rate (HR) is defined as <64 beats/min, low heart rate variability (HRV) as <13 beats/min, HR as ≥64 beats/min, and high HRV as ≥13 beats/min. HRV is defined as the difference between minimal and maximal HR during examination.

especially important for patients with contraindications to the use of beta-blockers or whose heart rates are not lowered sufficiently despite the use of beta-blockers. The identified cutoff rates in our study should be prospectively tested for general recommendations.

Our findings agree with previous studies, showing that lower mean heart rates due to the use of beta-blockers significantly improve image quality for coronary visualization on high-pitch dual-source CTA (11,19). The explanation for the influence of mean heart rate is that diastole, as the phase of the cardiac cycle with the slowest motion velocity of the coronary arteries, shortens both absolutely and in relation to the R-peak–to–R-peak interval as heart rate increases. Consequently, timing of the start of image acquisition is inconsistent, and the diastolic resting period becomes too short for complete visualization of the proximal and distal coronary artery segments. In addition, to apply high-pitch spiral acquisition, heart rate must be regular, because inconstant heart rates would lead to inaccurate positioning of the data acquisition window, with data being acquired either too early in the cardiac cycle (if heart rate decreases) or too late (if heart rate increases) (20).

In the context of imaging asymptomatic subjects for risk stratification, this new scan mode is extremely attractive because of the very low associated dose and high image quality. Essential challenges to image quality and accurate detection of vessel stenosis are motion and blooming artifacts (8). While cardiac motion is mainly a concern at elevated or irregular heartbeat, blooming artifacts are caused by severe calcification, which can lead to obscuration of the entire vessel lumen (21). It has been shown that dual-source CT improves the accuracy and specificity of noninvasive coronary angiography with regard to the diagnosis of significant stenoses in patients with heart rates ≤ 65 beats/min compared with conventional CTA (6). The high negative predictive value in combination with a high rate of evaluable coronary segments permits significant coronary artery stenoses to be reliably excluded (6).

In the new-generation dual-source CT systems, a high-pitch data acquisition mode allows high-pitch values of 1.5 to 3.4 by filling the sampling gaps with the data acquired with the second detector system. It thus is possible to perform image acquisition of the entire heart within a single cardiac cycle (19). Compared with conventional prospective ECG triggered CT, this technique eliminates the risk for step-motion artifacts (22). Radiation dose in cardiac CT is also closely related to the pitch value. The pitch values for spiral coronary CTA are typically substantially lower than 1 (e.g., 0.2 to 0.4), which indicates that the table is advanced by much less than 1 detector width during each scanner rotation (20). Thus, the same region of the chest is exposed during several consecutive rotations, which increases radiation dose up to 10 to 25 mSv (9). Radiation exposure in dual-source CTA is substantially lower than in retrospective ECG gated thoracic CTA, because of the high pitch and therefore the decrease in overlapping projection data (23). Radiation exposure is also closely related to the scan protocol. The 100-kV protocol resulted in significantly (p < 0.001) lower estimated radiation dose values for the thorax compared to scans with 120 kV.

Study limitations. Dual-source CT was not primarily performed for the evaluation of coronary arteries. Therefore, our data are limited, because the diagnostic performance of coronary CTA was not verified with invasive coronary angiography. Furthermore, our study did not include a randomized

comparison with other scan modes concerning radiation exposure and image quality. We did not analyze the influence of the calcium score on image quality, and the assessment of image quality was subjective. Radiation doses were estimated and not measured, but this approach has been suggested by the American Association of Physicists in Medicine as being reasonably valid (24).

CONCLUSIONS

High-pitch dual-source CTA of the thorax for noncardiac purposes enables simultaneous diagnostic evaluation of the coronary arteries in patients with mean heart rates < 64 beats/min and HRV < 13 beats/min. Especially in the context of imaging young patients or asymptomatic subjects for risk stratification, this new scan mode is extremely attractive because of the very low associated dose, but the use of beta-blockers to optimize image quality must be considered.

Reprint requests and correspondence: Dr. Michael Scharf, Department of Radiology, University of Erlangen, Maximiliansplatz 1, 91054 Erlangen, Germany. *E-mail:* michaelscharf1@gmx.de.

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