Insights Imaging (2012) 3:73–79
DOI 10.1007/s13244-011-0133-0

ORIGINAL ARTICLE

Ultrafast imaging of the entire chest without ECG synchronisation or beta-blockade: to what extent can we analyse the coronary arteries?

Maxime de Malherbe · Alain Duhamel · Nunzia Tacelli · Anne-Lise Hachulla · François Pontana · Jean-Baptiste Faivre · Jacques Remy · Martine Remy-Jardin

Received: 11 June 2011 / Revised: 30 August 2011 / Accepted: 26 September 2011 / Published online: 26 November 2011

Abstract
Objectives To evaluate the accessibility of coronary arteries from chest CT examinations acquired without ECG gating or beta-blockade.
Materials and methods Two hundred forty-two patients (median heart rate: 81.7 bpm) underwent a non-ECG-gated CT examination with high pitch and high temporal resolution. Image analysis was obtained by consensus between two readers.
Results The percentage of accessible segments was 88% at the proximal level (i.e. 4 segments), 75% at the proximal and mid-segment level (i.e. 7 segments), and 61% and 48% when considering 10 and 15 segments, respectively. The mean (± SD) number of accessible segments per patient was 3.5±0.78 and 5.2 ± 1.50 when considering four and seven segments per patient, respectively. The percentage of patients with four segments accessible was 67% (126/242), decreasing to 23% (55/242) with seven segments accessible and 3% (7/242) with ten segments accessible, while the entire coronary artery tree was not accessible for any of the patients. No significant difference was found in the patients' mean hearts with four, seven, or ten accessible segments ($P = 0.4897$).
Conclusion Diagnostic image quality was attainable at the level of proximal segments in 67% of patients, while proximal and mid-coronary segments were accessible in 23% of patients.
Main Messages
- *High-pitch and high-temporal resolution scanning modes make accessible proximal coronary arteries on non ECG-gated chest CT angiograms*
- *It is not necessary to administer beta-blockers to achieve good results.*
- *Tobacco-related cardiovascular disorders could benefit from this scanning mode.*

Keywords Coronary arteries · Dual-source CT · CT angiography · Chest CT · Lung diseases

Introduction

Since the availability of 64-slice MDCT technology, the concept of integrated cardiothoracic imaging has emerged, enabling chest radiologists to gain insight into cardiac function and coronary artery imaging from the same data set as that used for routine assessment of chest organs [1–3], which is particularly useful in situations such as acute pulmonary embolism [4] or chronic obstructive pulmonary diseases (COPD) [5]. The recent introduction of high-pitch acquisition modes on dual-source 64-slice MDCT scanners offers a new option to integrate coronary artery imaging into standard chest CT examinations, currently exclusively reported with a prospectively ECG-synchronised high-pitch acquisition mode [6]. This option would reinforce the diagnostic capabilities of this scanning mode, recently found to provide an excellent overall quality of chest

M. de Malherbe · N. Tacelli · A.-L. Hachulla · F. Pontana · J.-B. Faivre · J. Remy · M. Remy-Jardin
Department of Thoracic Imaging, Hospital Calmette (EA 2694), University of Lille Nord de France, 59000 Lille, France

A. Duhamel
Department of Medical Statistics (EA 2694), University of Lille Nord de France, 59000 Lille, France

M. Remy-Jardin (✉)
Department of Thoracic Imaging, Hospital Calmette, Boulevard Jules Leclercq, 59037 Lille cedex, France
e-mail: martine.remy@chru-lille.fr

examinations even for patients in poor clinical conditions [7]. From a clinical standpoint, high-pitch and high-temporal resolution scanning modes offer the possibility to provide examinations free of motion artefacts, potentially acquired without apnea, at a low radiation dose, all advantageous for respiratory patients. The objective of this study was to investigate the possibility of coronary artery imaging from routine CT angiographic examinations of the chest acquired with high temporal resolution and high-pitch mode despite the absence of ECG synchronisation and pre-examination beta-blockade in a population of respiratory patients.

Materials and methods

Population

Our study group was drawn from a population of 249 consecutive oncology patients gathered in two successive time periods: from May 2008–December 2008 a prototype version of the high temporal resolution-high pitch mode with a first-generation dual-source CT system was used on 123 consecutive patients, forming group 1 (temporal resolution: 83 ms); from September 2009-April 2010 a commercial version of the high temporal resolution-high pitch mode on the second generation of dual-source CT system was used of 126 consecutive patients, forming group 2 (temporal resolution: 75 ms). Patients in group 1 and 2 (1) were all referred from the same pulmonology department for follow-up of thoracic malignancy; (2) had no concurrent abnormalities that could influence coronary artery imaging; and (3) had an upper limit of 100 kg for the patient's body weight (b.w.) to ensure full coverage of both lungs by the tube B system (size of the tube B detector: 26 cm in group 1; 33 cm in group 2). Storage of data sets on external disks enabled their retrospective analysis with a waiver of patients' informed consent in agreement with national regulations.

CT examination

Acquisition parameters

Apart from the rotation time (and the size of the tube B detector), the acquisition parameters were similar for patients in group 1 and 2, including (1) a craniocaudal acquisition at deep inspiration; (2) detector collimation: 2 × 64 × 0.6 mm, slice acquisition 2 × 128 × 0.6 mm by means of a z-flying focal spot; (3) the kilovoltage was set at 100 kV (reference milliamperage: 90 mAs) for patients below 80 kg b.w. and at 120 kV (reference milliamperage: 90 mAs) for patients with a body weight between 80 and 100 kg; (4) the examinations were systematically obtained with automatic adjustment of the milliamperage according to the patient's size (Care Dose 4D; Siemens Medical Solutions, Forchheim, Germany) without administration of beta-blockers or sublingual nitrates.

Injection parameters

In both groups, the injection protocols were similar [nonionic contrast material: iohexol; Omnipaque 350; Amersham Health, Carrigtohill, Ireland; volume: 120 ml (this corresponds to the maximal volume in the injector; the volume administered was often smaller as the injection was manually interrupted whenever necessary at the end of the acquisition); concentration: 350 mg of iodine per millilitre; flow rate: 4 ml/s without saline flush]. The same automatic bolus triggering software program available on the two CT units (Care Bolus; Siemens Medical Solutions, Forchheim, Germany) was systematically applied (ROI within the ascending aorta; threshold: 150 HU).

Reconstruction parameters

Cross-sectional images were reconstructed in both groups from the carina to the heart base with a slice thickness of 0.75 mm in 0.6-mm intervals, a small field of view cropped around the heart, and a soft-tissue convolution kernel (B26f) to generate curved MPRs and MIP images of the coronary arteries (Leonardo workstation; Circulation software; Siemens Medical Solutions, Germany).

Parameters evaluated

Patients' characteristics

For each examination, the patient's heart rate, breath-hold duration, z-axis coverage, and dose-length product (DLP) were systematically recorded. The effective dose was derived from the product of the DLP and a conversion coefficient ($k=0.017$ $mSv.mGy^{-1}$ cm^{-1}) [8]. Although different conversion factors exist and may result in higher dose estimates, this value was selected to allow comparison with recent findings in the literature.

Accessibility of coronary arteries

Image analysis was obtained by consensus between two readers with 2 years and 7 years of experience in cardiac CT at the time of initiation of this study, respectively. The images were reviewed on a workstation (MMWP, Siemens, Forchheim, Germany). The coronary arteries were categorised into 15 segments according to the American Heart Association classification [9]. For each patient, the analysis of the coronary artery tree was undertaken only if the attenuation value within all proximal coronary segments was ≥200 HU. The next step consisted of an individual analysis of each

Table 1 Percentage of accessible segments according to the stratification of the coronary artery tree

	All patients (n=242)	Group 1 (n=116)	Group 2 (n=126)	P value (*)
Proximal segments (i.e. 4 segments)	849/968 (88%)	399/464 (86%)	450/504 (89%)	0.12
Proximal and mid segments (i.e. 7 segments)	1,263/1,694 (75%)	595/812 (73%)	668/882 (76%)	0.24
10 segments	1,485/2,420 (61%)	713/1,160 (61.5%)	772/1,260 (61%)	0.92
Complete coronary tree (i.e. 15 segments)	1,758/3,630 (48%)	863/1,740 (49.6%)	895/1,890 (47%)	0.18

*Refers to comparisons between group 1 and 2 obtained with the chi-square test. No significant difference in the percentage of accessible segments was observed between the two patient groups

coronary segment (whatever its diameter and the potential presence of calcification), rated as accessible if the vessel lumen was completely depicted in the absence of major motion artefacts as further detailed. The degree of movement-associated artefacts was graded with a 4-point scoring system (10): score 1: no motion artefacts; score 2: mild blurring of the segment; score 3: moderate blurring without structure discontinuity; score 4: doubling or discontinuity in the course of the segment preventing evaluation. Scores 1–3 were considered compatible with a diagnostic image quality. The impact of contrast-induced artefacts from the right atrium on the right coronary artery was graded with a 3-point scoring system: score 1: no artefact; score 2: minor artefacts, not precluding analysis of the coronary segment; score 3: marked artefacts, precluding confident analysis of the coronary segment. No attempt was made to provide information on the frequency of coronary artery abnormalities detected in either group of patients.

Four levels of analysis of the coronary tree were defined: (1) analysis of proximal segments (i.e. 4 segments per patient), including segment 1 of the right coronary artery (RCA), segment 5 (left main, LM), segment 6 of the left anterior descending (LAD), and segment 11 of the left circumflex (LCX); (2) analysis of proximal and mid segments of the coronary arteries, namely segments 1–2 (RCA), 5 (left main, LM), 6–7 (LAD), and 11 and 13 (LCX), leading to the analysis of seven segments per patient; (3) analysis of ten segments per patient, including the above-mentioned seven segments and segment 3 (right coronary artery, RCA), segment 4 (right coronary artery, RCA, in case of right predominance; left circumflex artery, LCX, in case of left predominance), and segment 8 (left anterior descending artery, LAD); (4) analysis of the complete coronary arterial tree, i.e. 15 coronary segments per patient.

Statistical analysis

Statistical analysis was performed with commercially available software (SAS Institute, Cary, NC). Results were expressed as means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. Comparative analyses were obtained using the chi-square test for categorical data; when not applicable because of the sample size, Fisher's exact test was used. For numerical variables, we used the unpaired Student's t-test. P values inferior to 0.05 were considered statistically significant.

Results

Population characteristics

From the initial population of 249 patients, 7 patients in group 1 (7/123; 6%) with attenuation values within proximal coronary arteries <200 HU were excluded, leading to a final study group of 242 patients (group 1: n=116; group 2: n=126). A poor level of attenuation within coronary arteries was observed together with a poor level of opacification within the aorta and pulmonary vessels; this limitation was the consequence of poor venous access, itself due to previous chemotherapy treatments. This population included 180 males and 62 females with a mean age of 58 ± 14 years (range: 15–92). The mean heart rate was 82.6±16.6 bpm (range: 50–177) (median value: 81 bpm). The mean body mass index (BMI) was 23.7±4.7 kg/m^2 (range: 12–37.2).

Characteristics of data acquisitions over the entire thorax

CT examinations of the entire thorax were successfully performed in all patients. In the overall study group: (1) the

Table 2 Mean number of accessible segments per coronary artery

	All patients (n=242)	Group 1 (n=116)	Group 2 (n=126)	P value (*)
RCA (segments 1–4)	2.15±1.07	2.18±0.99	2.11±1.14	0.65
LAD (segments 6–10)	2.81±1.06	2.95±1.06	2.67±1.03	0.35
LCX (segments 11–15)	2.18±1.07	2.29±1.12	2.08±1.02	0.166

*Refers to the comparisons between group 1 and 2 obtained with Student's t-test. No significant difference in the mean number of accessible segments per coronary artery was observed between the two patient groups

Table 3 Mean number of accessible segments per patient

	Overall study group (*n*=242)	Group 1 (*n*=116)	Group 2 (*n*=126)	*P* value (*)
Evaluation of 4 segments per patient	3.5±0.78	3.44 ± 0.83	3.6 ± 0.7	0.19
Evaluation of 7 segments per patient	5.2 ± 1.50	5.13 ± 1.56	5.3 ± 1.4	0.37
Evaluation of 10 segments per patient	6.1 ± 2.06	6.15 ± 2.08	6.13 ± 2.04	0.94
Evaluation of 15 segments per patient	7.3±2.77	7.44 ± 2.84	7.10 ± 2.71	0.35

*Refers to the comparisons between group 1 and 2 obtained with Student's t-test. No significant difference in the mean number of accessible segments per patient was observed between the two patient groups

mean z-axis coverage was 299±27.5 mm (range: 252–336); (2) the mean duration of data acquisition was 1.49±0.42 s (range: 0.6–3.02 s); (3) the mean dose-length product (DLP) was 136.9±49.8 mGy.cm (range: 22–418), and the mean effective dose was 2.33 ± 0.85 mSv (0.37-7.11). Although there was no significant difference in the mean z-axis coverage between group 1 and 2, the mean duration of data acquisition was significantly shorter in group 2 (0.99±0.09 vs. 1.77±0.22; $P<0.0001$), and the mean DLP was significantly lower in group 2 (125.0 ± 36.7 vs. 150.02±.58.6; $P<0.0001$). The mean effective dose was 2.55 ±1.0 mSv (range: 0.37-7.11) in group 1 and 2.13 ± 0.62 mSv (range: 0.68-3.93) in group 2 ($P<0.0001$). All chest CT examinations were of diagnostic image quality.

Coronary artery imaging

1 Vessel-per-vessel analysis

The mean (± SD) level of attenuation within proximal coronary segments was 333.3 ± 63.3 HU (range: 200–608.5). The analysis of coronary arteries included: (a) a total of 3,630 coronary artery segments when considering 15 segments per patient, (b) 2,420 segments when considering 10 segments per patient, (c) 1,694 segments when considering 7 segments per patient, and (d) 968 segments when considering 4 segments per patient. As shown in Table 1, 88% of proximal segments and 75% of proximal and mid segments were accessible, while the percentages decreased to 48% when considering the entire coronary artery tree. Among the 1,263 proximal and mid segments rated as accessible, cardiogenic motion artefacts were either absent (score 1: n=10; 0.8%) or rated as minor (score 2: n=362; 28.7%) or moderate (score 3: n= 891; 70.5%). Among the 406 right coronary artery segments rated as accessible, contrast-induced artefacts from the right atrium were either absent (score 1: n=214; 53%) or rated as minor (score 2: n=192; 47%). Table 2 summarises the mean number of accessible segments per coronary artery.

2 Patient-per-patient analysis

Table 3 summarises the mean number of segments analysable in each subdivision of the coronary artery tree. As shown in Table 4, the percentage of patients with four segments accessible was 67%, decreasing to 23% with seven segments accessible and 3% with ten segments, while the entire coronary artery tree was not fully accessible in any of the patients. No significant difference was found in the mean heart rate of patients with four, seven or ten accessible segments (P = 0.4897; Kruskal-Wallis test) or in the percentage of patients with four and seven accessible segments when stratifying the population according to two thresholds of BMI, i.e. 25 kg/m^2 and 30 kg/m^2 ($P>0.05$; chi-square test). Figure 1a, b and c illustrates the overall image quality achievable in our population.

Discussion

To our knowledge, this is the first study investigating the possibility of accessing the coronary arteries during whole-chest CT angiographic examinations obtained without ECG synchronisation or beta-blockade, which strongly differs

Table 4 Percentage of patients with accessible coronary segments, stratified from proximal to distal portions of the coronary tree

	All patients (*n*=242)	Group 1 (*n*=116)	Group 2 (*n*=126)	*P* value (*)
Patients with 4 segments accessible	162 (67%)	73 (63%)	89 (71%)	0.20$^{\chi}$
Patients with 7 segments accessible	55 (23%)	25 (21.5%)	30 (24%)	0.67$^{\chi}$
Patients with 10 segments accessible	7 (3%)	2 (2%)	5 (4%)	0.45*
Patients with 15 segments accessible	0	0	0	NA

NA: not applicable

Comparisons between group 1 and 2 were obtained with chi-square test ($^{\chi}$) or Fisher's exact test (*). No significant difference in the percentage of patients with four, seven, and ten accessible segments was observed between the two patient groups

Fig. 1 A 60-year-old male patient (67 kg, 174 cm, BMI: 22.1 kg/m^2) ▶ with a heart rate of 82 beats per minute. CT images were obtained with a pitch of 3 and temporal resolution of 83 ms (group 1). Curved multiplanar reformations of the right coronary artery (**a**), left anterior descending artery (**b**), and left circumflex artery (**c**) illustrating the good image quality achievable despite the high heart rate (dose-length product: 167 mGy.cm)

from conditions of dedicated cardiac CT examinations. Conversely to the low heart rate (i.e. below 60 bpm) at which successful evaluation of the entire coronary artery tree is generally obtained [10], CT examinations were obtained in patients with a mean heart rate of 82.6 bpm, without administration of sublingual nitrates. Our examinations were obtained with a standard injection protocol previously shown to provide high-quality examinations of the chest [7], whereas dedicated coronary CT angiography is mainly reported with individually tailored contrast-medium injection protocols [11–13]. Moreover, our population was scanned at 100 or 120 kV and 90 reference mAs per tube, while dedicated cardiac CT angiograms are obtained at milliamperage settings ranging from 400 to 560 mAs for similar kilovoltage selection [14–16]. Lastly, our examinations consisted of non-ECG-gated CT examinations, whereas all reported experiences are based on retrospective or prospective ECG-gated acquisitions. Such differences in the scanning protocols for whole chest versus dedicated cardiac CT examinations are fully justified by their respective clinical objectives. Whereas cardiac CT is mainly indicated for triaging patients suspected of having coronary artery disease, chest CT should screen for asymptomatic coronary artery disease on a target zone (i.e. proximal and mid segments [17]) with the same data set as that used for the evaluation of the underlying respiratory disease.

In our scanning conditions, the mean level of attenuation within proximal coronary arteries was 333.3 HU, which is in the range of that reported on coronary CT angiograms obtained with fixed injection parameters on single- and dual-source CT scanners [11, 18, 19]. These results are superior to those reported from whole chest ECG-gated CT examinations [2, 3], suggesting that a high-pitch scanning mode over the entire thorax does not preclude optimal opacification of the coronary arteries. Diagnostic image quality was achievable at the level of 88% of proximal coronary segments, and 75% of proximal and mid segments, decreasing to 61% and 48% when considering 10 and 15 coronary segments, respectively. As expected, these results are substantially lower than those reported from dedicated cardiac CT examinations [6] and should be compared to those reported from whole-chest CT examinations obtained with ECG gating. Investigating two cohorts of patients with a mean heart rate lower than that of the present study group (i.e. 73 and 76 bpm, respectively) with single-source 64-slice MDCT, Delhaye et al. reported higher percentages of accessible segments, ranging from 98% at the proximal level to 65% when considering the entire coronary arterial tree [2, 20]. However, it is interesting to note that the image quality attainable in our patients with a mean heart rate of 82.6 bpm was in the range of that achievable in a comparable population (i.e. mean heart rate: 86 bpm) examined with ECG-gated single-source 64-slice MDCT [3]. Comparing the mean number of accessible segments per patient, the non-ECG-gated high-pitch scanning mode enabled analysis of 3.5 over four proximal segments and 5.2 over seven proximal and mid segments, which supports the comparison with the mean numbers of 3.9 and 5.8 segments, respectively, reported by Pansini et al. with retrospective ECG gating. At the patient level, the proportion of patients with proximal and mid-coronary segments accessible was higher with the non-gated high-pitch scanning mode (i.e. 23%) than with the single-source, retrospectively gated scanning mode (i.e. 11%). Although insufficient for screening for asymptomatic coronary artery disease in each and every respiratory patient, these preliminary results show that motion-free imaging of the coronary arteries is already achievable in approximately one-quarter of respiratory patients. Although traditionally contraindicated in patients with chronic obstructive pulmonary disease (COPD) because of concerns of inducing bronchospasm [21], the use of cardioselective beta-blockers in this large subset of respiratory patients is currently being reconsidered by pulmonologists [22] with new options for cardiothoracic imaging. Moreover, the lower mean radiation dose delivered to patients with our scanning mode (i.e. 2 mSv) compared with the 5.7 mSv in the study from Pansini et al. should be emphasised [3].

We acknowledge the following limitations of this study. Firstly, we undertook coronary artery analysis without taking into consideration some parameters known to negatively influence the results, such as the patient's cardiac rhythm, the diameter of the coronary segments, and the presence of coronary artery disease. Secondly, we excluded seven patients with a poor level of attenuation within coronary arteries, which might have influenced the overall results. However, this inadequate vascular opacification was not limited to the coronary artery tree, but was also seen at the level of central vessels. Explained by the poor venous access in these patients, it was linked to the overall clinical status of our patients and not inherent to the scanning protocol. Thirdly, all studies were evaluated by two radiologists in a joint review manner. A separate data evaluation would have allowed an investigation of the interobserver variability in coronary artery assessment. Thirdly, we limited the patients' weight to 100 kg, which excluded obese patients from our investigation. Lastly, the CT scanning protocols were slightly modified with the technical evolution of the CT system, leading us to successively use a prototype version then a commercial version of the high-pitch mode. However, care was taken to demonstrate the lack of statistically significant difference in the overall results between the two subgroups of patients. Moreover, the limited availability of the second generation of dual-source CT outside tertiary referral centers, thus limiting the clinical impact of this technology, needs to be considered.

In conclusion, these preliminary results demonstrate that diagnostic image quality of the proximal coronary arteries is achievable with high-pitch dual-source CT without ECG synchronisation or beta-blockade.

References

1. White CS, Kuo D, Kelemen M, Jain V, Musk A, Zaidi E, Read K, Sliker C, Prasad R (2005) Chest pain evaluation in the emergency department: can MDCT provide a comprehensive evaluation? AJR 185:533–540
2. Delhaye D, Remy-Jardin M, Rozel C, Dusson C, Wurtz A, Delannoy-Deken V, Duhamel A, Remy J (2007) Coronary artery imaging during preoperative CT staging: preliminary experience with 64-slice multidetector CT in 99 patients. Eur Radiol 17:591–602
3. Pansini V, Remy-Jardin M, Tacelli N, Faivre JB, Flohr T, Deken V, Duhamel A, Remy J (2008) Screening for coronary artery disease in respiratory patients: comparison of single- and dual-source CT in patients with a heart rate above 70 bpm. Eur Radiol 18:2108–2119
4. Fremont B, Pacouret G, Jacobi D, Puglisi R, Charbonnier B, de Labriolle A (2008) Prognostic value of echocardiographic right ventricular end-diastolic diameter ratio in patients with acute pulmonary embolism. Chest 133:358–362
5. Gerhardsson de Verdier M (2008) The big three concept: a way to tackle the health care crisis? Proc Am Thorac Soc 5:800–805
6. Goetti R, Baumüller S, Feuchtner G, Stolzmann P, Karlo C, Alkhadi H, Leschka S (2010) High-pitch dual-source CT angiography of the thoracic and abdominal aorta: is simultaneous coronary artery assessment possible? AJR 194:938–944
7. Tacelli N, Remy-Jardin M, Flohr T, Faivre JB, Delannoy V, Duhamel A, Remy J (2010) Dual-source chest CT angiography with high temporal resolution and high pitch modes: evaluation of image quality in 140 patients. Eur Radiol 20:1188–1196
8. Huda W, Odgen KM, Khorasani MR (2008) Converting dose-length product to effective dose at CT. Radiology 248:995–1003
9. Austen WG, Edwards JE, Frye RL et al (1975) Reporting system on patients evaluated for coronary artery disease: report of the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. Circulation 51(suppl 4):5–40
10. Matt D, Scheffel H, Leschka S et al (2007) Dual-source CT coronary angiography: image quality, mean heart rate, and heart rate variability. AJR 189:567–573
11. Seifarth H, Puesken M, Kalafut JF et al (2009) Introduction of an individually optimize protocol for the injection of contrast medium for coronary CT angiography. Eur Radiol 19:2373–2382
12. Husmann L, Herzog BA, Burkhard N et al (2009) Low-dose coronary CT angiography with prospective ECG triggering: validation of a contrast material protocol adapted to body mass index. AJR 193:802–806
13. Bamberg F, Sommer WH, Schenzle JC et al (2010) Systolic acquisition of coronary dual-source computed tomography angiography: feasibility in an unselected patient population. Eur Radiol 20:1331–1336
14. Scheffel H, Alkadhi H, Plass A et al (2006) Accuracy of dual-source CT coronary angiography: first experience in a high pre-test probability population without heart rate control. Eur Radiol 16:2739–2747
15. Johnson TR, Nikolaou K, Becker A et al (2006) Dual-source CT cardiac imaging:initial experience. Eur Radiol 16:1409–1415

16. Achenbach S, Ropers D, Kuettner A et al (2006) Contrast-enhanced coronary artery visualization by dual-source computed tomography–initial experience. Eur J Radiol 57:331–335
17. Choi EK, Choi SI, Rivera JJ, Nasir K, Chang SA, Chun EJ, Kim HK, Choi DJ, Blumenthal RS, Chang HJ (2008) Coronary computed tomography angiography as a screening tool for the detection of occult coronary artery disease in asymptomatic individuals. J Am Coll Cardiol 52:357–365
18. Burgstahler C, Reimann A, Brodoefel H et al (2009) Quantitative parameters to compare image quality of noninvasive coronary angiography with 16-slice, 64-slice and dual-source computed tomography. Eur Radiol 19:584–590
19. Halpern EJ, Levin DC, Zhang S, Takakuwa KM (2009) Comparison of image quality and arterial enhancement with a dedicated coronary CTA protocol versus a triple rule-out coronary CTA protocol. Acad Radiol 16:1039–1048
20. Delhaye D, Remy-Jardin M, Salem R, Teisseire A, Khalil C, Delannoy-Deken V, Duhamel A, Remy J (2007) Coronary imaging quality in routine ECG-gated multidetector CT examinations of the entire thorax: preliminary experience with a 64-slice CT system in 133 patients. Eur Radiol 17:902–910
21. Egred M, Shaw S, Mohammad B, Waitt P, Radrigues E (2005) Under-use of beta-blockers in patients with ischemic heart disease and concomitant chronic obstructive pulmonary disease. QJM 98:493–497
22. Cazzola M, Matera MG (2008) Beta-blockers are safe in patients with chronic obstructive pulmonary disease, but only with caution. Am J Respir Crit Care Med 178:661–662