Sixty-Four–Slice Multidetector Computed Tomography

An Accurate Imaging Modality for the Evaluation of Coronary Arteries in Dilated Cardiomyopathy of Unknown Etiology

Daniele Andreini, MD; Gianluca Pontone, MD; Antonio L. Bartorelli, MD; Piergiuseppe Agostoni, MD, PhD; Saima Mushtaq, MD; Erika Bertella, MD; Daniela Trabattoni, MD; Gaia Cattadori, MD; Sarah Cortinovis, MD; Andrea Annoni, MD; Alice Castelli, MD; Giovanni Ballerini, MD; Mauro Pepi, MD

Background—The goal of this study was to assess the safety, feasibility, and diagnostic accuracy of 64-slice multidetector computed tomography (MDCT) for the evaluation of coronary arteries in dilated cardiomyopathy (DCM) of unknown etiology. Sixteen-slice MDCT is useful in patients affected by DCM. However, technical limitations, such as cardiac arrhythmias, an inability of patients to sustain a long breath-hold, and the need of a high dose of contrast agent may limit its accuracy and widespread use.

Methods and Results—Invasive coronary angiography (ICA) and MDCT coronary angiography were performed on 132 consecutive patients (82 men; age 63±11 years) affected by DCM (ejection fraction, 34±10%) of unknown etiology. In 2 patients (1.5%), MDCT was not feasible because of atrial fibrillation. Of the remaining 130 patients, 88 exhibited normal and 42 exhibited diseased coronary arteries in both MDCT and ICA. All patients with coronary artery disease except for 1 were correctly classified by MDCT as 1-vessel (11 cases), 2-vessel (13 cases), and 3-vessel (18 cases) disease. In the segment-based analyses, the overall feasibility for MDCT was 98.5% (1902 of 1930 segments). Segment-based and patient-based analyses for the detection of luminal stenosis of >50% and >70% were performed. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MDCT for the detection of >50% stenosis were 98.1%, 99.9%, 98.7%, 99.8%, and 99.7%, respectively. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MDCT for the detection of >70% stenosis were 99.5%, 98.6%, 94.1%, 99.9%, and 99.4%, respectively.

Conclusions—Excellent feasibility and diagnostic accuracy, combined with low invasiveness, make 64-slice MDCT an ideal imaging modality for the anatomic evaluation of coronary circulation in patients with DCM of unknown etiology. **(*Circ Cardiovasc Imaging*. 2009;2:199-205.)**

Key Words: CT ■ congestive heart failure ■ coronary circulation

Heart failure (HF) is a major growing public health problem involving 5 million patients in the United States, with more than 550 000 patients diagnosed for the first time each year, and at least 10 million patients in Europe.[1,2] Coronary artery disease (CAD) is the underlying cause in two-thirds of HF cases and contributes to the progression of the disease. At present, clinical guidelines recommend invasive coronary angiography (ICA) for patients with HF and angina (class I, level B) and patients with HF and chest pain or suspected CAD (class IIa, level C).[3] Currently, ICA is recommended to patients with a high pretest probability of CAD, mostly because of its invasiveness and the risk of complications. Furthermore, ICA is inconvenient for the patient and expensive for the community, and it requires technical skills and routine follow-up care.[4,5] Thus, patients with dilated cardiomyopathy (DCM) with a low to intermediate likelihood of CAD may benefit from a reliable noninvasive coronary imaging technique, whereas ICA may be reserved for those with proven CAD and in whom coronary revascularization may be indicated.

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The 16-slice multidetector computed tomography (MDCT) scanners have demonstrated good diagnostic accuracy for the detection of significant coronary stenosis in patients with known or suspected CAD with high global feasibility, sensitivity, and negative predictive value (NPV).[6–8] Therefore, MDCT may be an appropriate noninvasive tool for CAD detection, particularly in patients with low probability of the

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From the Centro Cardiologico Monzino (D.A., G.P., A.L.B., P.A., M.S., E.B., D.T., G.C., S.C., A.A., G.B., M.P.), IRCCS, Institute of Cardiology, University of Milan, Italy; and the Department of Radiology (A.C.), San Paolo Hospital, University of Milan, Italy.

Correspondence to Daniele Andreini, MD, Via Parea 4, 20138 Milan, Italy. E-mail daniele.andreini@ccfm.it

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Table 1. Baseline Characteristics of Study Patients

No.	130
Age, y	63±11
Sex, male/female	81/49
BMI, kg/m^2	27.4±8
Cardiac risk factors	
Hypertension, n (%)	51 (39)
Hypercholesterolemia, n (%)	42 (32)
Diabetes mellitus, n (%)	14 (10)
Current smoking, n (%)	17 (13)
Family history of CAD, n (%)	29 (22)
Serum creatinine, mg/dL	1±0.2
HR 1 h before MDCT, bpm	65±11
Range, bpm	42–81
HR during MDCT, bpm	63±11
Range (bpm)	42–78
EDV, mL	194±73
LVEF, (%)	34±10

BMI indicates body mass index; HR, heart rate; EDV, end diastolic volume; LVEF, left ventricular ejection fraction.

disease.[9–12] Recently, 16-slice MDCT has been shown to be useful in excluding CAD in DCM patients due to its high sensitivity and NPV.[13] However, widespread use of 16-slice MDCT may have several limitations. The dose of contrast agent required (130 mL) may increase the risk of contrast-induced nephropathy in patients with HF. Moreover, previous clinical experience has shown that proper coronary imaging may not be feasible in a sizable number of patients because of cardiac arrhythmias or an inability to maintain a 25-second breath-hold. Finally, the specificity and positive predictive value (PPV) were good but less than optimal. Therefore, the aim of the present study was to evaluate the feasibility and accuracy of coronary imaging by new-generation 64-slice MDCT for patients with DCM of unknown etiology and to compare this noninvasive imaging modality with ICA.

Methods

Study Population

One hundred thirty-two consecutive patients admitted to our institute from September 2006 to April 2008 with DCM of unknown etiology, in whom ICA was requested, were included in the present study (Table 1). Exclusion criteria included previous ICA, a reported allergic reaction to iodine-based contrast agents, a history of CAD, impaired renal function shown by creatinine clearance <60 mL/min, an inability to sustain a 15-second breath-hold, a body mass index >40, and cardiac arrhythmias. Based on these criteria, only 2 patients were excluded because of atrial fibrillation. Accordingly, 130 patients met the study inclusion criteria. All patients underwent MDCT within 3.1±0.5 days before ICA. The duration of bed-lying time during MDCT and ICA, as well as complications, were assessed. The time for ICA included patient preparation and performance of the invasive procedure. The study was approved by our institution's scientific and ethics committees, and all participating patients gave written informed consent.

Patient Preparation

Most patients had a prescan heart rate of <65 bpm as the result of long-term β-blocker therapy. Thus, the conventional β-blocker protocol of intravenous metoprolol approximately 15 minutes before MDCT[14] was used in only 18 patients (Table 2). Pretreatment with nitrate was not performed.

Table 2. Type and Dosage of β-Blocker Therapy

Type	Dosage
Metoprolol	
Acute*	18 (14%)
Chronic†	0
Average dose, mg	
Acute*	6 mg (2.5–10)
Chronic†	0
Carvedilol, chronic	45 (35%)
Average dose, mg	19.3±8.2
Bisoprolol, chronic	51 (39%)
Average dose, mg	3.5±2.6
Nebivolol, chronic	32 (25%)
Average dose, mg	3.6±2.8

*Intravenous; †per os.

Scan Protocol and Image Reconstruction

Scanning was performed by a 64-slice MDCT scanner (VCT, GE Medical System, Milwaukee, Wis) with 64×0.625 mm collimation, a 350-ms gantry rotation time, an effective tube current of 700 mA, and 120-kV tube voltage. The "smart prep" scanning was performed to obtain a 4-chamber projection. A bolus of 80 mL high concentration contrast medium (Iomeron, 400 mg/mL, Bracco, Milan, Italy) was administered intravenously at 5 mL/s, followed by 50 mL of saline at the same infusion rate. The scan was initiated according to the bolus-tracking technique. In brief, patients were asked to take a deep breath after the filling of the right cardiac chambers and reaching a predefined threshold of 200 Hounsfield units in the left atrium. Dose modulation was attained by ECG gating for a maximum gantry delivery of between 40% and 80% during the R-R interval and the least delivery during the remainder of the cardiac cycle. The effective radiation dose for MDCT was calculated as the product of the dose-length product (DLP) times a conversion coefficient for the chest (k=0.017 mSv/mGy cm).[15] The overall Agatston score was recorded for each patient.

MDCT Image Analysis

The MDCT data sets were evaluated for the presence of significant coronary artery stenosis within the left main coronary artery; proximal, mid, and distal segments of the left anterior descending coronary artery; first and second diagonal branches; proximal, mid, and distal segments of the left circumflex coronary artery; first and second marginal branches; proximal, mid, and distal segments of the right coronary artery; and the posterior descending artery according to the 15-segment American Heart Association classification.[16] Arteries with a diameter ≤1.5 mm were excluded from the analysis, whereas segments in which image quality did not allow for the evaluation of patency were classified as not evaluable. The causes of impaired image quality (unfeasibility) were classified as the presence of coronary wall calcification, motion artifacts related to noncompliance with breath-holding or chest movement, the misalignment of slices related to variation in the heart rate or to premature ventricular beats, the presence of cardioverter/pacemaker leads, contrast-enhanced cardiac veins, the intramyocardial tract of the coronary vessel, or insufficient contrast enhancement. Any narrowing of the contrast-enhanced coronary lumen >50% that could be identified in at least 2 independent planes was defined as significant stenosis. The analysis was performed by 2 experienced readers (D.A. and G.P.) without knowledge of the ICA findings in the patients. The diagnosis of left ventricular dysfunction associated with severe CAD was made

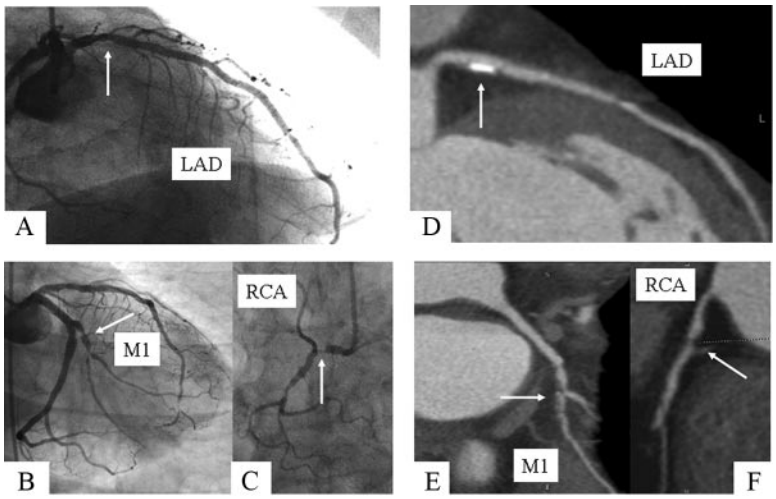

Figure 1. Dilated cardiomyopathy associated with severe CAD. Head-to-head comparison of invasive coronary angiography (left panel) compared with MDCT multiplanar reconstruction (right panel). White arrows show significant stenosis on the proximal segments of left anterior descending artery (LAD), first marginal branch (M1), and right coronary artery (RCA).

when significant double-vessel CAD or significant disease of the left main or proximal left anterior descending coronary arteries was detected[17] (Figure 1 and Figure 2).

Invasive Coronary Angiography

Conventional ICA was performed after intracoronary injection of 0.2 mg of isosorbide dinitrate by a standard technique using 6F catheters. The coronary arteries were divided into segments according to the American Heart Association classification used for MDCT analysis.[15] The angiograms were analyzed using quantitative coronary angiography software (QuantCor, QCA, Pie Medical Imaging) and end-diastolic frames by 2 interventional cardiologists (A.B. and D.T.), who were blinded to the MDCT results. The severity of coronary stenosis was quantified in 2 orthogonal views and classified as significant if the lumen diameter reduction was >50%.

Statistical Analysis

Continuous variables were presented as mean±SD. The overall feasibility of the MDCT scan was evaluated. An estimation of accuracy (sensitivity, specificity, PPV, and NPV) was calculated on a segment-based model and on a patient-based model, based on a 50% and also on a 70% threshold against the standard of ICA findings. On a patient-based analysis, patients with at least 1 detected stenosis >50% and with at least 1 detected stenosis >70% in a native coronary arteries were classified as positive. We also performed a segment-based analysis, using both 50% and 70% threshold, including all segments for analysis with nonevaluable segments censored as positive.[9] The 95% confidence intervals for all diagnostic accuracy parameters were calculated using the conventional binomial estimator method. The intraobserver and interobserver variabilities for the detection of significant coronary artery stenosis in MDCT and ICA images were evaluated by κ statistic[18] between 2 observers. Disagreements were resolved by consensus. Statistical analyses were performed using SPSS 13.0 software (SPSS Inc, Chicago, Ill). A paired *t* test was used to compare the procedure time. A McNemar test was used to compare the complication rates. A value of $P<0.05$ was considered statistically significant.

Results

In the whole study population, the time needed for investigation with MDCT and ICA was 8.9±4.4 minutes and 33.2±9.5 minutes, respectively ($P<0.001$). However, the time needed for postprocessing analysis of the MDCT was 22±12 minutes. For MDCT, the mean breath-holding scan time was 8.4±2.7 seconds, and the mean effective radiation dose during MDCT was 19.4 mSv. The Agatston calcium score was 153±191. Evaluation of the safety of the 2 diagnostic modalities revealed no complications related to MDCT and 9 complications (7% of patients) associated with ICA ($P=0.002$), including 4 cases of acute HF and 5 minor

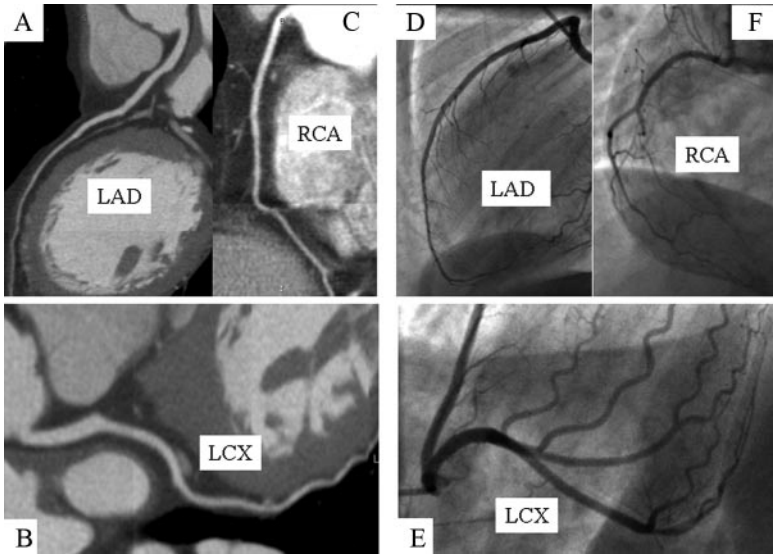

Figure 2. Idiopathic form of dilated cardiomyopathy. Head-to-head comparison of MDCT multiplanar reconstruction (left panel) compared with invasive coronary angiography (right panel). LAD indicates left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery.

Table 3. Diagnostic Accuracy of MDCT Imaging in the 15 Coronary Artery Segments of the 130 Patients (Segments for Analysis Only; n=1902)

Segment	TP	TN	FP	FN	Sensitivity, %	Specificity, %	NPV	PPV	Accuracy
LM (n=129)	10	119	0	0	100	100	100	100	100
LAD									
Proximal (n=129)	31	98	0	0	100	100	100	100	100
Mid (n=128)	10	118	0	0	100	100	100	100	100
Distal (n=130)	6	123	0	1	85.7 (79–92)	100	100	99.2 (97–100)	99.2 (98–100)
D1 (n=128)	9	118	0	1	90 (85–95)	100	100	99.2 (97–100)	99.2 (98–100)
D2 (n=122)	2	119	1	0	100	99.2 (98–100)	100	66.7 (13–100)	99.2 (98–100)
LCx									
Proximal (n=129)	11	118	0	0	100	100	100	100	100
Mid (n=127)	9	118	0	0	100	100	100	100	100
Distal (n=125)	3	122	0	0	100	100	100	100	100
M1 (n=129)	5	124	0	0	100	100	100	100	100
M2 (n=122)	3	119	0	0	100	100	100	100	100
RCA									
Proximal (n=124)	15	108	1	0	100	98.3 (97–100)	98.3 (82–100)	100	99.2 (98–100)
Mid (n=127)	14	113	0	0	100	100	100	100	100
Distal (n=127)	2	125	0	0	100	100	100	100	100
PDA (n=126)	4	121	0	1	88.8 (73–87)	100	100	99.2 (97–100)	99.2 (98–100)
Total (n=1902)	134	1763	2	3	98.1 (97–99)	99.9 (99–100)	98.7 (97–100)	99.8 (99–100)	99.7 (99–100)

TP indicates true positive; TN, true negative; FP, false positive; FN, false negative; LM indicates left main coronary artery; LAD, left anterior descending coronary artery; D1, first diagonal branch; D2, second diagonal branch; LCx, left circumflex coronary artery; M1, first marginal branch; M2, second marginal branch; RCA, right coronary artery; PDA, posterior descending artery; PPV, positive predictive value; NPV, negative predictive value.

vascular complications. At the time of the MDCT scan, the mean heart rate was 63±11 bpm (Table 1). The overall MDCT feasibility was 98.5%. We evaluated 1922 of 1950 coronary artery segments. Twenty segments were excluded from analysis because their diameters were ≤1.5 mm. Twenty-eight (1.5%) of 1930 segments were not reliably visualized. The most deleterious factor for image quality and interpretation was misalignment of slices caused by heart rate variations (15 artifacts, 54%), followed by extensive coronary wall calcification (6 artifacts, 22%), motion artifacts related to inability to sustain a 15-second breath-hold or chest movement (4 artifacts 14%), and premature ventricular beats (3 artifacts, 10%). The intraobserver and interobserver agreements, calculated between 2 observers, were excellent (k=0.88 and k=0.85, respectively) for significant coronary artery stenosis detection by MDCT, and it was similar for ICA (k=0.89 and k=0.85, respectively).

On the basis of ICA, DCM associated with severe CAD was diagnosed in 42 (32%) patients, whereas idiopathic DCM was found in 88 (68%) patients. All cases of the idiopathic or ischemic form of DCM were correctly classified by MDCT. Moreover, MDCT allowed for the correct detection of all cases of significant stenosis of the left main coronary artery, proximal and mid segments of the left anterior descending, left circumflex, and right coronary arteries that were diagnosed by ICA. Furthermore, MDCT correctly identified all cases of 1-vessel disease (11 patients), 2-vessel disease (13 patients), and 3-vessel disease (18 patients) as recognized by ICA, with the exception of 1 patient who was classified as having 2-vessel disease by MDCT but was found to have 3-vessel disease by ICA. Table 3 reports the diagnostic accuracy parameters of MDCT imaging compared with ICA in a segment-based evaluation of the 15 coronary artery segments in the whole population of patients, using a 50% threshold, including segments for analysis only (n=1902, 28 segments judged as not assessable were excluded from this analysis of diagnostic accuracy). Table 4 shows the diagnostic accuracy parameters for segment-based evaluation using a 50% stenosis threshold, including all segments for analysis with nonevaluable segments censored as positive (n=1930). In the segment-based analysis, the sensitivity for detecting >70% stenosis was 99.5% (99.2% to 99.8%); specificity, 98.6% (96.7% to 100%); NPV, 94.1% (90.4% to 97.8%); PPV, 99.9% (99.7% to 100%); and accuracy, 99.4% (99.1% to 99.8%). After censoring all nonevaluable segments as positive, the sensitivity for detecting >70% luminal stenosis was 99.5% (99.2% to 99.8%); specificity, 88.3% (83.4% to 93.3%); NPV, 94.1% (90.4% to 97.8%); PPV, 98.9% (98.4% to 99.4%); and accuracy, 98.5% (98.1% to 99.1%).

In the patient-based analysis, the sensitivity for the detecting >50% stenosis was 100%; specificity, 98.7% (96.2% to 100%); NPV, 100%; PPV, 98.2% (94.6% to 100%); and accuracy, 99.2% (97.7% to 100%). In the patient-based analysis, the sensitivity for the detecting >70% stenosis was 98% (95.7% to 100%); specificity, 98.7% (96.2% to 100%); NPV, 98.7% (96.2% to 100%); PPV, 98.2% (94.3% to 100%); and accuracy, 98.5% (96.3% to 100%).

Discussion

Several studies previously demonstrated the ability of MDCT to visualize the clinically relevant coronary arteries and

Table 4. Diagnostic Accuracy of MDCT Imaging in the 15 Coronary Artery Segments of the 130 Patients (All Segments for Analysis With Nonevaluable Segments "Positive"; n=1930)

Segment	TP	TN	FP	FN	Sensitivity, %	Specificity, %	NPV	PPV	Accuracy
LM (n=130)	10	119	1	0	100	99.1 (97–100)	90.0 (74–100)	100	99.2 (98–100)
LAD									
Proximal (n=130)	32	98	0	0	100	100	100	100	100
Mid (n=130)	10	118	2	0	100	98.3 (96–100)	90.4 (78–100)	100	98.5 (96–100)
Distal (n=130)	6	123	0	1	85.7 (79–92)	100	100	99.2 (97–100)	99.2 (98–100)
D1 (n=129)	10	118	0	1	91 (86–96)	100	100	99.2 (98–100)	99.2 (98–100)
D2 (n=122)	2	119	1	0	100	99.2 (98–100)	66.7 (13–100)	100	99.2 (98–100)
LCx									
Proximal (n=130)	11	118	1	0	100	99.2 (97–100)	91.7 (76–100)	100	99.2 (98–100)
Mid (n=130)	11	118	1	0	100	99.2 (97–100)	91.7 (76–100)	100	99.2 (98–100)
Distal (n=127)	3	122	2	0	100	60 (17–100)	98.4 (96–100)	100	98.5 (96–100)
M1 (n=130)	6	124	0	0	100	100	100	100	100
M2 (n=122)	1	121	0	0	100	100	100	100	100
RCA									
Proximal (n=130)	19	108	3	0	100	97.6 (95–100)	86.4 (72–100)	100	97.7 (95–100)
Mid (n=130)	14	113	3	0	100	97.4 (94–100)	82.3 (64–100)	100	97.7 (95–100)
Distal (n=130)	4	125	1	0	100	99.1 (97–100)	80 (45–100)	100	99.2 (98–100)
PDA (n=130)	4	121	4	1	80 (73–87)	50 (15–84)	96.8 (94–100)	99.2 (97–100)	96.1 (93–99)
Total (n=1930)	143	1765	19	3	99.8 (99–100)	89.7 (85–94)	98.2 (96–100)	98.9 (98–99)	98.8 (98–99)

TP indicates true positive; TN, true negative; FP, false positive; FN, false negative; LM indicates left main coronary artery; LAD, left anterior descending coronary artery; D1, first diagonal branch; D2, second diagonal branch; LCx, left circumflex coronary artery; M1, first marginal branch; M2, second marginal branch; RCA, right coronary artery; PDA, posterior descending artery; PPV, positive predictive value; NPV, negative predictive value.

identify significant stenosis in patients with known or suspected CAD. To our knowledge, only 1 study, performed with a 16-slice scanner, evaluated the diagnostic ability of MDCT for the identification of coronary stenosis in patients affected by DCM of unknown etiology.[13] The previous study demonstrated that MDCT has high feasibility, sensitivity, and NPV for the identification of significant coronary stenosis, allowing for a correct distinction between ischemic and nonischemic forms of DCM, but it also identified the main drawbacks of the 16-slice technique, namely, the high number of unfeasible or unreliable studies due to cardiac arrhythmias and an inability to sustain a 25-second breath-hold, the high dose of contrast agent needed (130 mL) and its associated increased risk of contrast-induced nephropathy, particularly in patients with DCM, and, finally, the specificity and PPV that, although good, were not excellent (96% and 81%, respectively).

In the present study, 64-slice MDCT demonstrated that it is possible to overcome the limitations of the previous generation scanners. Indeed, only 2 of 132 patients had to be excluded from the study because of atrial fibrillation, but, thanks to the shorter scanning time (from 25 to 15 seconds), we were able to perform the scan on patients presenting with all types of isolated premature beats. For the same reason, patients unable to sustain the typical breath-hold period needed with 16-slice scanners were not excluded, and the contrast agent dose was reduced by almost 45% (from 130 to 80 mL).

The 64-slice MDCT allowed for a marked reduction in the rate of false-positive coronary stenosis compared with 16-slice MDCT, which showed a PPV of 81%. There were only 2 false-positive findings of stenosis in the entire population of 130 patients, leading to specificity and PPV of 99.9% and 98.7%, respectively, in the segment-based analyses. Sixty-four–slice MDCT not only correctly discriminated idiopathic forms of DCM from the forms of DCM associated with severe CAD, as was the case with the 16-slice MDCT,[13] but also more precisely quantified the extent and severity of CAD. Indeed, all 10 patients with significant stenosis of the left main coronary artery and proximal and mid segments of the 3 main coronary arteries were identified and correctly assessed by MDCT as 1-vessel, 2-vessel, and 3-vessel disease. The only exception was 1 patient in whom MDCT evidenced 3-vessel disease and ICA demonstrated 2-vessel disease. This diagnostic ability is clinically relevant because ischemic etiology, lesion extent, and left main coronary artery involvement are significant independent predictors of a worse long-term outcome.[19]

MDCT Feasibility

The overall MDCT feasibility in the entire population was found to be very good (98.5% in the segment-based analyses). This result can be explained by the careful preparation of the patients; in particular, most of the patients received long-term orally administered β-blocker treatment, which significantly diminishes the tendency for a high heart rate in patients with DCM. The analysis of potential artifacts highlights the absence of interference between the cardiac venous system and the coronary artery tree, which was the primary cause of artifacts with the 16-slice MDCT. These results can

be attributed to the increased temporal resolution of 64-slice MDCT that allows for a better differentiation of the arterial and venous phases.

Diagnostic Accuracy of MDCT

Patients with DCM may be considered ideal candidates for MDCT evaluation. Indeed, the pharmacologically induced low heart rate and reduced coronary motion due to systolic dysfunction have a positive effect on image quality. Furthermore, the low to intermediate pretest probability of CAD in these patients contributes to the high accuracy reported for MDCT.[9,13] This may explain why the diagnostic accuracy for both patient-based and segment-based analyses, which was already high with 16-slice MDCT, was close to 100% with 64-slice MDCT.

Clinical Implications

Beyond confirming the safety of MDCT in patients with DCM, the present study demonstrates that 64-slice MDCT allows for an accurate differentiation of idiopathic forms of DCM from the forms of DCM associated with severe CAD and the precise quantification of the angiographic extent of CAD. Furthermore, these results can be obtained using contrast agent doses equivalent to those used for ICA (80 mL). Finally, the cost-effectiveness[20] (estimated cost of 160 Euro for MDCT versus 550 Euro for ICA and 126 Euro for rest-stress Tc99 study), rapidity of execution, and possibility of conducting outpatient examinations are all advantages in favor of MDCT compared with ICA. However, the mean effective radiation dose of 64-slice MDCT is still high (19 mSv) in comparison with the radiation dose of ICA (6 to 8 mSv in our institute) and rest-stress Tc99 study (12 to 20 mSv).[21]

Study Limitations

The main limitation of this study is that our results reflect the experience of a single center where 2 cardiac radiologists are fully dedicated to 64-slice MDCT. Therefore, reproducibility of these data in different clinical environments must be assessed. Moreover, we included in the study a highly selected population of patients with DCM, admitted to our Heart Failure Unit with a recent diagnosis of DCM of unknown etiology in patients without history of CAD and in stable clinical conditions, leading to a low frequency of cardiac arrhythmias and renal dysfunction. Finally, it is difficult to determine the intrinsic pathology underlying the left ventricular dysfunction even in the presence of significant CAD. Thus, the detection of stenosis of the epicardial coronary arteries by MDCT or ICA does not necessarily indicate that CAD is the underlying cause of left ventricular dysfunction in patients with DCM, as the fortuitous association of nonischemic DCM with CAD. Therefore we classified the patients with DCM with significant double-vessel CAD or significant disease of the left main or proximal left anterior descending coronary arteries as "DCM patients with severe CAD" instead to "ischemic forms of DCM." However, these observations do not detract much from our study results, since the detection of CAD in patients with severe left ventricular dysfunction has an important diagnostic and prognostic value.

Conclusions

The possibility of examining almost all patients affected by DCM and extremely high diagnostic accuracy, combined with the safety of the examination and the significant reduction in contrast agent compared with scanners of the previous generation, make 64-slice MDCT an ideal imaging modality for coronary artery evaluation and etiology assessment in patients with DCM.

Disclosures

None.

References

1. Hunt SA, Abraham WT, Chin MH, Feldman AM, Francis GS, Ganiats TG, Jessup M, Konstam MA, Mancini DM, Michl K, Oates JA, Rahko PS, Silver MA, Stevenson LW, Yancy CW, Antman EM, Smith SC Jr, Adams CD, Anderson JL, Faxon DP, Fuster V, Halperin JL, Hiratzka LF, Jacobs AK, Nishimura R, Ornato JP, Page RL, Riegel B; American College of Cardiology; American Heart Association Task Force on Practice Guidelines; American College of Chest Physicians; International Society for Heart and Lung Transplantation; Heart Rhythm Society. ACC/AHA 2005 Guideline Update for the Diagnosis and Management of Chronic Heart Failure in the Adult: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Update the 2001 Guidelines for the Evaluation and Management of Heart Failure): developed in collaboration with the American College of Chest Physicians and the International Society for Heart and Lung Transplantation: endorsed by the Heart Rhythm Society. *Circulation.* 2005;112:e154–e235.
2. Swedberg K, Cleland J, Dargie H, Drexler H, Follath F, Komajda M, Tavazzi L, Smiseth OA, Gavazzi A, Haverich A, Hoes A, Jaarsma T, Korewicki J, Lévy S, Linde C, López-Sendón JL, Nieminen MS, Piérard L, Remme WJ; Grupo de Trabajo de Diagnóstico y Tratamiento de la Insuficiencia Cardíaca Crónica de la Sociedad Europea de Cardiología; Comité de la ESC para la elaboración de las Guías de Práctica Clínica, et al. Grupo de Trabajo de Diagnóstico y Tratamiento de la Insuficiencia Cardíaca Crónica de la Sociedad Europea de Cardiología; Comité de la ESC para la elaboración de las Guías de Práctica Clínica. Guidelines for the Diagnosis and Treatment of Chronic Heart Failure: executive summary (update 2005) *Rev Esp Cardiol.* 2005;58:1062–1092.
3. Bachinski LL, Roberts R. New theories: causes of dilated cardiomyopathy. *Cardiol Clin.* 1998;16:603.
4. Scanlon P, Faxon D, Audet AM, Carabello B, Dehmer GJ, Eagle KA, Legako RD, Leon DF, Murray JA, Nissen SE, Pepine CJ, Watson RM, Ritchie JL, Gibbons RJ, Cheitlin MD, Gardner TJ, Garson A Jr, Russell RO Jr, Ryan TJ, Smith SC Jr; Society for Cardiac Angiography and Interventions. ACC/AHA guidelines for coronary angiography: a report of the American College of Cardiology/Amerian Heart Association Task Force on practice guidelines (Committee on Coronary Angiography). *J Am Coll Cardiol.* 1999;33:1756–1824.
5. Bashore TM, Bates ER, Berger PB, Clark DA, Cusma JT, Dehmer GJ, Kern MJ, Laskey WK, O'Laughlin MP, Oesterle S, Popma JJ, O'Rourke RA, Abrams J, Bates ER, Brodie BR, Douglas PS, Gregoratos G, Hlatky MA, Hochman JS, Kaul S, Tracy CM, Waters DD, Winters WL Jr; American College of Cardiology. Task Force on Clinical Expert Consensus Documents. American College of Cardiology/Society for Cardiac Angiography and Interventions Clinical Expert Consensus Document on cardiac catheterization laboratory standards: a report of the American College of Cardiology Task Force on Clinical Expert Consensus Documents. *J Am Coll Cardiol.* 2001;37: 2170–2214.
6. Hoffman MH, Shi H, Schmitz BL, Schmid FT, Lieberknecht M, Schulze R, Ludwig B, Kroschel U, Jahnke N, Haerer W, Brambs HJ, Aschoff AJ. Noninvasive coronary angiography with multislice computed tomography. *JAMA.* 2005;293:2471–2478.
7. Achenbach S, Ropers D, Pohle F-K, Raaz D, von Erffa J, Yilmaz A, Muschiol G, Daniel WG. Detection of coronary artery stenosis using multi-detector CT with 16×0.75 collimation and 375 ms rotation. *Eur Heart J.* 2005;26:1978–1986.
8. Kuettner A, Beck T, Drosch T, Kettering K, Heuschmid M, Burgstahler C, Claussen CD, Kopp AF, Schroeder S. Diagnostic accuracy of noninvasive coronary imaging using 16-detector slice spiral computed

tomography with 188 ms temporal resolution. *J Am Coll Cardiol*. 2005; 45:123–127.
9. Garcia MJ, Lessick J, Hoffmann MHK; CATSCAN Study Investigators. Accuracy of 16-row multidetector computed tomography for the assessment of coronary artery stenosis. *JAMA*. 2006;296:403–411.
10. Pontone G, Andreini D, Quaglia C, Ballerini G, Nobili E, Pepi M. Accuracy of multidetector spiral computed tomography in detecting significant coronary stenosis in patient populations with differing pre-test probabilities of disease. *Clin Radiol*. 2007;62:978–985.
11. Ghostine S, Caussin C, Daoud B, Habis M, Perrier E, Pesenti-Rossi D, Sigal-Cinqualbre A, Angel CY, Lancelin B, Capderou A, Paul JF. Non-invasive detection of coronary artery disease in patients with left bundle branch block using 64-slice computed tomography. *J Am Coll Cardiol*. 2006;48:1929–1934.
12. Meijboom WB, Mollet NR, Van Mieghem CA, Kluin J, Weustink AC, Pugliese F, Vourvouri E, Cademartiri F, Bogers AJ, Krestin GP, de Feyter PJ. Pre-operative computed tomography coronary angiography to detect significant coronary artery disease in patients referred for cardiac valve surgery. *J Am Coll Cardiol*. 2006;48:1658–1665.
13. Andreini D, Pontone G, Pepi M, Andreini D, Ballerini G, Bartorelli AL, Magini A, Quaglia C, Nobili E, Agostoni P. Diagnostic accuracy of multidetector computed tomography coronary angiography in patients with dilated cardiomyopathy. *J Am Coll Cardiol*. 2007;49:2044–2050.
14. Shim SS, Kim Y, Lim SM. Improvement of image quality with beta-blocker premedication on ECG-gated 16-MDCT coronary angiography. *Am J Roentgenol*. 2005;184:649–654.
15. Einstein AJ, Moser KW, Thompson RC, Cerqueira MD, Henzlova MJ. Radiation dose to patients from cardiac diagnostic imaging. *Circulation*. 2007;116:1290–1305.
16. Austen WG, Edwards JE, Frye RL, Gensini GG, Gott VL, Griffith LS, McGoon DC, Murphy ML, Roe BB. A reporting system on patients evaluated for coronary artery disease: Report of the Ad Hoc Committee for grading of coronary artery disease, Council of Cardiovascular Surgery, American Heart Association. *Circulation*. 1975;51:35–40.
17. Felker GM, Shaw L, O'Connor CM. A standardized definition of ischemic cardiomyopathy for use in clinical research. *J Am Coll Cardiol*. 2002;39:210–218.
18. Fleisch JL. Statistical Methods for Rates and Proportions, II Ed. New York: John Wiley & Sons; 1981.
19. Williams JF, Bristow MR, Fowler MB, Francis GS, Garson A, Gersh BJ, Hammer DF, Hlatky MA, Leier CV, Packer M, Pitt B, Ullyot DJ, Wexler LF, Winters WL, Task Force Members: Ritchie JL, Cheitlin MD, Eagle KA, Gardner TJ, Garson A, Gibbons RJ, Lewis RP, O'Rourke RA, Ryan TJ. Guidelines for the evaluation and management of heart failure: report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Evaluation and Management of Heart Failure). *Circulation*. 1995;92:2764–2784.
20. Mowatt G, Cummins E, Waugh N, Walker S, Cook J, Jia X, Hillis GS, Fraser C. Systematic review of the clinical effectiveness and cost-effectiveness of 64-slice or higher computed tomography angiography as an alternative to invasive coronary angiography in the investigation of coronary artery disease. *Health Technol Assess*. 2008;12:iii–iv, ix-143.
21. Marcassa C, Bax JJ, Bengel F, Hesse B, Petersen CL, Reyes E, Underwood R, on behalf of the European Council of Nuclear Cardiology (ECNC), the European Society of Cardiology Working Group 5 (Nuclear Cardiology and Cardiac CT), and the European Association of Nuclear Medicine Cardiovascular Committee. Clinical value, cost-effectiveness, and safety of myocardial perfusion scintigraphy: a position statement. *Eur Heart J*. 2008;29:557–563.

CLINICAL PERSPECTIVE

The goal of this study was to assess the safety, feasibility, and diagnostic accuracy of 64-slice multidetector computed tomography (MDCT) for the evaluation of coronary arteries in dilated cardiomyopathy of unknown etiology. Invasive coronary angiography and MDCT coronary angiography were performed on 132 consecutive patients (82 men; age, 63±11 years) affected by dilated cardiomyopathy (ejection fraction, 34±10%) of unknown etiology. All patients with coronary artery disease except for 1 were correctly classified by MDCT as having 1-vessel (11 cases), 2-vessel (13 cases), and 3-vessel (18 cases) disease. In the segment-based analyses, the overall feasibility for MDCT was 98.5%. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MDCT for the detection of >50% or >70% stenosis were very high. Beyond confirming the safety of MDCT in patients with dilated cardiomyopathy, the present study demonstrates that 64-slice MDCT allows precise quantification of the angiographic extent of coronary artery disease. Furthermore, these results can be obtained using contrast agent doses equivalent to those used for invasive coronary angiography (80 mL). Excellent feasibility and diagnostic accuracy, combined with low invasiveness, make 64-slice MDCT an ideal imaging modality for the anatomic evaluation of coronary circulation in patients with dilated cardiomyopathy of unknown etiology.

Sixty-Four–Slice Multidetector Computed Tomography: An Accurate Imaging Modality for the Evaluation of Coronary Arteries in Dilated Cardiomyopathy of Unknown Etiology

Daniele Andreini, Gianluca Pontone, Antonio L. Bartorelli, Piergiuseppe Agostoni, Saima Mushtaq, Erika Bertella, Daniela Trabattoni, Gaia Cattadori, Sarah Cortinovis, Andrea Annoni, Alice Castelli, Giovanni Ballerini and Mauro Pepi

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