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Diagnostic Accuracy of Multidetector Computed Tomography Coronary Angiography in Patients With Dilated Cardiomyopathy

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Objectives The purpose of this work was to assess the safety, feasibility, and diagnostic accuracy of multidetector computed tomography (MDCT) in dilated cardiomyopathy (DCM) of unknown etiology.

Background Multidetector computed tomography is an appropriate noninvasive tool for coronary artery disease (CAD) detection, particularly in patients with low probability of the disease, such as patients with DCM of unknown origin.

Methods We studied 61 unknown origin DCM patients (ejection fraction: 33.9 ± 8.6%, group 1) and 139 patients with normal cardiac function with indications for coronary angiography (group 2, control population). All underwent coronary MDCT and angiography. Multidetector computed tomography images were acquired by light speed 16-slice computed tomography. The degree of stenosis was estimated in 15 coronary artery segments according to the American Heart Association model.

Results In group 1, no MDCT-related complications were found, while 10 complications were associated with conventional angiography ($p = 0.001$). Overall feasibility of coronary artery visualization was 97.2% (863 of 888 segments). The most frequent cause of artifacts was interference from a hypertrophic cardiac venous system (10 artifacts, 40%). In group 2, overall feasibility was 96.1% (p = NS vs. group 1). In group 1, all cases with normal (44 cases) or pathological (17 cases) coronary arteries by conventional coronary angiography were correctly detected by MDCT, with, in 1 case, disparity of stenosis severity. In group 1, sensitivity, specificity, and positive and negative predictive values of MDCT for the identification of >50% stenosis were 99%, 96.2%, 81.2%, and 99.8%, respectively. In group 2, sensitivity and negative predictive values were lower than in group 1 (86.1% vs. 99% and 96.4% vs. 99.8%, respectively); specificity (96.4%) and positive predictive value (86.1%) were not significantly different versus group 1.

Conclusions Multidetector computed tomography is feasible, safe, and accurate for identification of idiopathic versus ischemic DCM, and may represent an alternative to coronary angiography. (J Am Coll Cardiol 2007;49:2044–50)

Dilated cardiomyopathy (DCM) is characterized by cardiac enlargement and impaired systolic function of one or both ventricles (1,2). Conventional invasive coronary angiography (ICA) is often performed in patients with DCM to exclude the presence of coronary artery disease (CAD) (3). Although normal angiography is found in more than 50% of DCM cases, detection of coronary lesions is important for accurate prognostication and proper management of patients (4). Even though the risk of ICA is small, serious complications may still occur, and a mortality of 0.1% has been reported (5,6). Furthermore, ICA is inconvenient for the patient, requires technical skills and routine follow-up care, and is an expensive procedure. Therefore, conventional ICA should be limited to patients with high pretest probability of CAD in whom percutaneous coronary intervention or surgical revascularization may be likely (5). However, DCM patients, who have a low-to-intermediate likelihood of CAD, may benefit from a reliable noninvasive coronary imaging technique. The increasing temporal and spatial resolution of the newest generation of multidetector com-

See page 2051

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Table 1 Baseline Characteristics and Echocardiographic Data of Study Patients

	Group 1 (n = 61)	Group 2 (n = 139)	p Value
Age (yrs)	62.2 ± 12	62.2 ± 10.4	NS
Gender (M/F)	47/14	99/40	0.01
BMI (kg/m^2)	28.1 ± 7	28.3 ± 8	NS
Creatinine clearance (ml/min)	71.3 ± 9.1	75.6 ± 9.8	NS
HR 1 h before MDCT (beats/min)	64.2 ± 9.3	76.7 ± 15.5	0.01
Range (beats/min)	52–76	55–98	
HR during MDCT (beats/min)	64.1 ± 9.4	60.5 ± 8.4	NS
Range (beats/min)	51–76	49–72	
Mean calcium score (Agatston score)	148 ± 183	361 ± 396	0.01
EDV (ml)	199.1 ± 89.7	93.5 ± 43.4	0.01
LVEF (%)	33.9 ± 8.6	59.3 ± 8.5	0.01

BMI = body mass index; EDV = end-diastolic volume; HR = heart rate; LVEF = left ventricular ejection fraction; MDCT = multidetector computed tomography; NS = not significant.

puted tomography (MDCT) scanners permits reconstruction with diagnostic image quality of the 3 main coronary arteries and of most side branches and distal vessel segments. Moreover, recent studies with 16-detector MDCT have demonstrated good diagnostic accuracy for significant stenosis detection in evaluable coronary segments, with high global feasibility, sensitivity, and negative predictive value (7–9). Therefore, MDCT may be an appropriate noninvasive tool for CAD detection, particularly in patients with low probability of the disease (7,8,10,11). Therefore, we sought to assess the feasibility, safety, and diagnostic accuracy of MDCT compared with ICA in patients with DCM of unknown etiology. In addition, the results of MDCT in DCM patients were compared with those obtained in patients undergoing this diagnostic modality for other clinical indications.

Methods

Study population. Sixty-one consecutive patients admitted to our hospital with DCM of unknown etiology and 139 consecutive patients who were referred for ICA with different clinical indications were enrolled in this study as groups 1 and 2 (from June 2004 to December 2005) (Tables 1 and 2). Exclusion criteria were previous ICA, contraindication to the administration of iodine-based contrast agents, history of CAD, impaired renal function (creatinine clearance <60 ml/min), inability to sustain a 25-s breath hold, body mass index >40 kg/m^2, and cardiac arrhythmias. Based on these exclusion criteria, 28 cases were not enrolled in the study because of inability to sustain a 25-s breath hold (5 cases), cardiac arrhythmias (11 cases), and impaired renal function (12 cases). All patients underwent MDCT within 3.1 ± 0.5 days before ICA. Duration of bed-lying time during MDCT and ICA and complications were assessed in both groups. Bed-lying time for ICA included time for patient preparation and time for the invasive procedure. The study was approved by our institution's scientific and ethical committees, and all participating patients gave written informed consent.

Table 2 Indications for ICA in Patients of Group 2 (n = 139)

Known CAD	51
Chest pain	45
Cardiovascular risk factors	16
Positive stress test	6
Aortic aneurysm	5
Heart valve disease	5
Arrhythmias	4
Hypertension	1
Other	6

CAD = coronary artery disease; ICA = invasive coronary angiography.

Abbreviations and Acronyms

CAD = coronary artery disease
CT = computed tomography
DCM = dilated cardiomyopathy
ICA = invasive coronary angiography
MDCT = multidetector computed tomography

Patient preparation. Most of group 1 patients had a prescan heart rate <65 beats/min due to long-term beta-blocker therapy. Thus, the conventional beta-blocker protocol (intravenous metoprolol about 15 min before MCDT) (12) was used in 2 patients only. In group 2, 51% of patients had a heart rate ≥65 beats/min and were treated with single or multiple intravenous doses of metoprolol (average dose 6.3 ± 1.5 mg) about 15 min before the scan (Table 3). No pretreatment with nitrate was administered.

Scan protocol and image reconstruction. Multidetector computed tomography angiography was performed using a 16-slice computed tomography (CT) scanner (Light Speed Pro, GE Medical Systems, Waukesha, Wisconsin) with a 16 × 0.625-mm collimation, and a gantry rotation time of 400 ms. According to the "electrocardiogram-pulsing technique," the tube current was modulated with a maximum current of 600 mA during a period between 40% and 80% of the R-wave to R-wave interval, and a reduction by 80% during the remaining cardiac cycle. A tube voltage of 120 kV to 140 kV was applied according to the patient's body weight. In group 1 patients, a fixed bolus (130 ml) of Iomeprolo (Iomeron 400 mg/ml, Bracco Diagnostics, Milan, Italy) was injected intravenously at a rate of 4.5 ml/s.

Table 3 Type and Dosage of Beta-Blocker Therapy

	Group 1 (n = 61)	Group 2 (n = 139)	p Value
Metoprolol	0	89 (64%)	
Acute (IV)	2 (3%)	71 (51%)	0.01
Chronic (p.o.)	0	18 (13%)	
Average dose (mg)			
Acute (IV)	1.9 ± 0.9	6.3 ± 1.5	0.01
Chronic (p.o.)	0	78 ± 18	
Carvedilol (chronic)	38 (62%)	1 (0.7%)	0.01
Average dose (mg)	18.3 ± 7.5	25	0.01
Bisoprolol (chronic)	23 (38%)	0	
Average dose (mg)	3.3 ± 2.5	0	

IV = intravenous; MDCT = multidetector computed tomography; p.o. = by mouth.

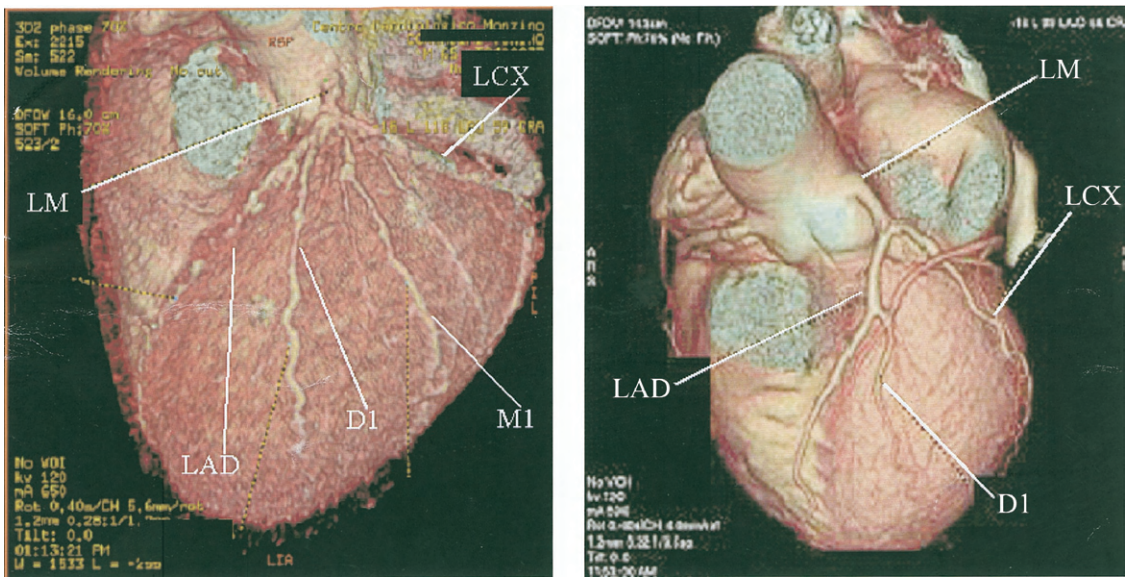

Figure 1 **Volume Rendering Reconstruction of Coronary Tree**

Ischemic form of dilated cardiomyopathy **(left)** and idiopathic form of dilated cardiomyopathy **(right)** are shown.
D1 = first diagonal branch; LAD = left anterior descending artery; LCX = left circumflex artery; LM = left main; M1 = first marginal branch.

The conventional double-bolus protocol (intravenous injection of 30 ml of saline solution at 2 ml/s immediately after contrast agent administration) was not used in these patients. In group 2, a variable dose (110 ml ± 11 ml) of Iomeprolo (Iomeron 400 mg/ml, Bracco Diagnostics) was injected intravenously at a rate of 4.5 ml/s during the scan, and a saline solution (30 ml at 2.0 ml/s) was injected intravenously immediately after contrast agent administration (double-bolus protocol) to reduce hyperattenuation in the superior vena cava and right heart (13,14). Multidetector CT data were acquired by the fluoroscopic bolus-tracking technique, started as soon as the signal density level in the ascending aorta reached a threshold of 100 HU. Image data sets were analyzed using volume rendering, multiplanar reconstruction, and vessel analysis software packages (CardioQ3 package, GE Medical Systems). For the "segment" and "burst reconstruction" algorithms, the temporal resolutions were 200 ms and 100 ms, respectively. The z-axis spatial resolution was 0.3 mm. Coronary calcium score was assessed with a dedicated software application (Smart Score, GE Medical Systems). The overall Agatston score was recorded in each patient.

MDCT image analysis. According to the 15-segment American Heart Association classification, the MDCT data sets were evaluated for the presence of significant coronary artery stenosis within the left main artery; proximal, middle, and distal segments of the left anterior descending artery; first and second diagonal branches; proximal, middle, and distal segments of the left circumflex artery; first and second marginal branches; proximal, middle, and distal segments of the right coronary artery; and posterior descending artery (15). Arteries with a diameter ≤1.5 mm were excluded from the analysis, while segments in which image quality did not allow evaluation of patency were classified as not evaluable. The causes of impaired image quality (unfeasibility) were classified as presence of coronary wall calcification, motion artifacts related to nonrespect of breath-hold or chest movement, misalignment of slices related to variation of heart rate or to premature ventricular beats, presence of cardioverter/pacemaker leads, contrast-enhanced cardiac veins, intramyocardial tract of coronary vessel, and insufficient contrast enhancement. Any diameter narrowing of contrast-enhanced coronary lumen >50%, which could be identified in at least 2 independent planes, was defined as significant stenosis. Analysis was performed by 2 experienced readers without knowledge of the patients ICA findings. We classified as ischemic DCM forms with detection of at least significant double-vessel CAD or with significant disease of the left main artery or proximal left anterior descending artery (16) (Fig. 1).

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

Statistical analysis. The global feasibility of the MDCT scan was evaluated. An estimation of accuracy (sensitivity, specificity, positive predictive value, and negative predictive value) was calculated on a segment model. These diagnostic parameters were expressed with a 95% confidence interval. Differences between the 2 groups were tested by the Student *t* test for unpaired data and the discrepancies in terms of accuracy of MDCT scan by the 2-tailed Fisher exact test. The interobserver variability for the detection of significant coronary artery stenosis on MDCT and ICA images was tested with a k test (17). Disagreements were resolved by consensus. Statistical analyses were performed using SPSS 13.0 software (SPSS, Inc., Chicago, Illinois).

Results

The mean time needed for MDCT investigation was similar in groups 1 and 2 (9.1 ± 4.3 min and 9 ± 4.2 min) and significantly lower than that required for ICA (35.1 ± 8.9 min and 36.2 ± 9 min, $p < 0.001$). Mean breath-holding scan time was 13.4 ± 3.2 s. Evaluation of the safety of the 2 diagnostic modalities in group 1 revealed no complications related to MDCT, and 10 (16.3% of patients) complications associated with ICA ($p = 0.002$), including 6 (9.8% of patients) cases of acute heart failure ($p = 0.028$) and 4 (6.5% of patients) minor vascular complications ($p = 0.12$). No MDCT-related complications were observed in group 2 patients, in whom minor vascular complications after ICA occurred in 8 (5.7% of patients) cases.

At the time of MDCT scan, the mean heart rate was similar in the 2 groups (Table 1). Agatston calcium score was significantly lower in group 1 than in group 2 (Table 1). The overall MDCT feasibility was 97.2% in group 1 and 96.1% in group 2 (p = NS). In group 1, we evaluated 895 of 915 coronary artery segments. Twenty segments were excluded from analysis because of diameter ≤1.5 mm. Reliable imaging was not possible in 25 of the 895 segments (2.8%). Causes of impaired image quality of coronary artery segments are summarized in Table 4. In group 1, the most deleterious factors for image quality and interpretation were hypertrophic cardiac veins (10 artifacts, 40%) (Fig. 2), misalignment due to heart rate variations (7 artifacts, 28%), extensive coronary wall calcification (5 artifacts, 20%), and motion artifacts (3 artifacts, 12%). Of the 2,085 coronary artery segments scanned in group 2, 45 were excluded from analysis because of diameter ≤1.5 mm, and 80 (3.9%) were judged unevaluable. The major causes of unfeasibility were misalignment of slices related to heart rate variations (32 artifacts, 40%), followed by the presence of extensive vessel wall calcification (30 artifacts, 37.5%), motion artifacts (10 artifacts, 12.5%), and hypertrophic cardiac veins (8 artifacts, 10%) (Table 4).

Interobserver agreement was excellent (k = 0.87) for MDCT detection of significant coronary artery stenosis.

On the basis of ICA, 17 (28%) patients of group 1 had significant CAD (1-vessel disease: 4 patients; 2-vessel disease: 4 patients; 3-vessel disease: 9 patients). In this group, all cases with normal (44 cases, 72%) or pathological coronary arteries were correctly detected by MDCT, even though in 1 case a mild disparity in terms of severity of stenosis was observed. In group 2, 98 (70.5%) patients showed significant CAD (1-vessel disease: 38 patients; 2-vessel disease: 39 patients; 3-vessel disease: 21 patients). The k value for ICA detection of significant coronary artery stenosis was 0.88. Table 5 reports sensitivity and specificity of MDCT as compared with ICA on a segment-based evaluation in the 2 groups of patients. In group 1, sensitivity was 100% in all segments with the exception of the second marginal branch of the left circumflex artery (90.9%). Thus, the overall sensitivity was 99%. The overall specificity in this group was 96.2%, with values ranging from 92% for distal left anterior descending artery to 100% for distal left circumflex and posterior descending arteries. In group 2, overall sensitivity was significantly lower than in group 1 (86.1% vs. 99%, $p < 0.001$), with the lower sensitivity in 2 segments (first diagonal and left main artery) (Table 5); overall the negative predictive value was also significantly lower than in group 1 (96.4% vs. 99.8%, $p < 0.001$), whereas overall specificity was similar between groups (96.4% vs. 96.2%, p = NS). When assessing individual segments, a significantly higher specificity value was found in group 2 as compared with group 1 for distal left anterior descending artery only (92% vs. 100%, $p = 0.01$). Finally, the positive predictive value was similar in groups 1 (81.2%) and 2 (86.1%, p = NS).

Table 4 Causes of Nondiagnostic MDCT Imaging in the 15 Coronary Artery Segments of the 2 Study Groups

	Group 1 (No. of Segments = 25)				Group 2 (No. of Segments = 80)			
	CVS	HR	Ca++	MA	CVS	HR	Ca++	MA
LM	0	0	1	0	0	0	2	0
LAD								
Proximal	0	0	1	1	0	0	5	2
Middle	0	1	0	1	0	4	5	1
Distal	0	0	0	0	0	3	0	0
D1	0	0	0	0	0	1	4	0
D2	0	0	1	0	0	0	3	1
LCX								
Proximal	0	0	0	0	0	0	2	1
Middle	2	0	0	1	2	0	3	2
Distal	2	1	0	0	2	2	1	0
M1	1	0	0	0	1	0	0	0
M2	1	1	0	0	0	0	0	0
RCA								
Proximal	0	0	1	0	0	2	3	2
Middle	0	2	0	0	0	10	1	1
Distal	0	1	1	0	0	9	1	0
PD	4	1	0	0	3	1	0	0
Total	10	7	5	3	8	32	30	10

Ca++ = calcification; CVS = cardiac venous system; D1 = first diagonal branch; D2 = second diagonal branch; HR = heart rate; LAD = left anterior descending artery; LCX = left circumflex artery; LM = left main artery; M1 = first marginal branches; M2 = second marinal branch; MA = motion artifact; MDCT = multidetector computed tomography; PD = posterior descending artery; RCA = right coronary artery.

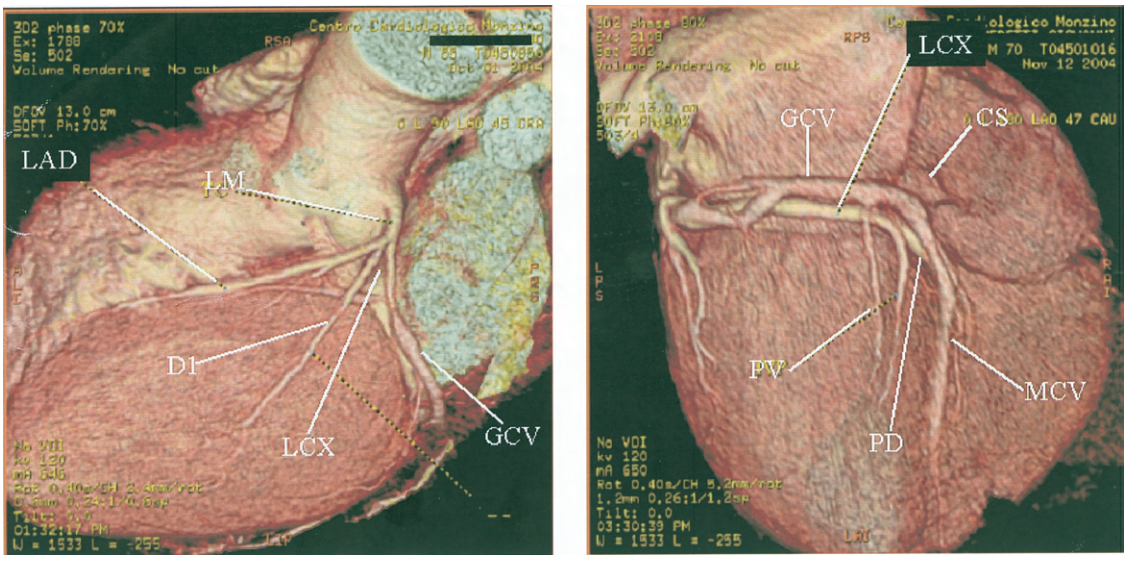

Figure 2 **Examples of Artifacts Due to Hypertrophic Cardiac Venous System Interference**

Volume rendering reconstruction of coronary tree: great cardiac vein (GCV) and its branches hide proximal **(left)** and middle-distal segment **(right)** of LCX. Middle cardiac vein (MCV) hides posterior descending artery **(right)**. CS = coronary sinus; PD = posterior descending artery; PV = posterior vein; other abbreviations as in Figure 1.

Discussion

Previous studies have demonstrated the ability of MDCT to visualize the clinically relevant coronary arteries and to detect significant stenoses in patients with already proven or suspected CAD (7,9). To date, however, no studies have been published comparing MDCT with ICA for the detection of coronary artery stenoses in a consecutive series of patients with DCM of unknown etiology. The major finding of this study is that 16-row MDCT is feasible, safe, and accurate for detecting CAD with high sensitivity and specificity in patients with DCM. The distinction between ischemic and nonischemic DCM and, more importantly, the evaluation of CAD extent have major clinical implications in patients with DCM (4).

Table 5 **Diagnostic Accuracy of MDCT Imaging in the 15 Coronary Artery Segments of the 2 Study Groups**

	Group 1 (No. of Segments = 870) Sensitivity/Specificity	Group 2 (No. of Segments = 1,960) Sensitivity/Specificity	p Value
LM	100%/93%	67%/97%	NS/NS
LAD			
Proximal	100%/98%	97%/91%	NS/NS
Middle	100%/96%	96%/92%	NS/NS
Distal	100%/92%	100%/100%	NS/0.02
D1	100%/97%	62%/92%	NS/NS
D2	100%/94%	100%/100%	NS/NS
CFX			
Proximal	100%/98%	100%/98%	
Middle	100%/95%	100%/94%	NS/NS
Distal	100%/100%	71%/98%	0.05/NS
M1	100%/97%	75%/100%	NS/NS
M2	91%/97%	88%/100%	NS/NS
RCA			
Proximal	100%/96%	80%/94%	0.05/NS
Middle	100%/96%	92%/92%	NS/NS
Distal	100%/96%	73%/98%	NS/NS
PDA	100%/100%	75%/100%	NS/NS
Total	99%/96%	86%/96%	0.001/NS

CFX = circumflex artery; NS = not significant; PD = posterior descending artery; other abbreviations as in Table 4.

Indeed, ischemic etiology is a significant independent predictor of worse long-term outcome, may change the therapeutic strategies, and may affect the response to drug treatment (17). This has led to the recommendation for ICA, because its results substantially contribute to diagnosis, prognosis, and management decision in DCM patients (18). The appeal of MDCT compared with ICA, particularly in this subset of patients, consists in its rapid execution and noninvasive characteristics. Indeed, this exam avoids patient discomfort, catheter-associated complications, and the risk of worsening heart failure due to the selective injection of contrast media in the coronary arteries and prolonged bed-lying time. No complications related to MDCT examination occurred in patients with DCM, while minor vascular complications (4 cases) or acute episodes of heart failure (6 cases) occurred when they underwent ICA. Invasiveness and different duration of the 2 diagnostic examinations (9.1 ± 4.3 min vs. 35.1 ± 8.9 min) may explain these findings, which underline the importance of using a noninvasive and rapid imaging modality in chronic heart failure patients with severely depressed left ventricular function. Despite the stability of the hemodynamic condition, which was an inclusion criteria in our series, the relative high percentage of acute heart failure during ICA may be explained by the severity of left ventricular dysfunction (mean ejection fraction 33.9%).

Feasibility of MDCT. Overall MDCT feasibility in patients with DCM was high (97%), and it was similar to that of the control group. Previous studies have demonstrated a highly significant inverse relationship between heart rate and diagnostic image quality, the latter being best for heart rates <65 beats/min (19). Different medical interventions were used in the 2 study populations to lower heart rate. Most of the DCM patients had a heart rate already at the desired level because of the long-term carvedilol or bisoprolol treatment. Intravenous metoprolol was needed in only 2 cases, thus reducing the risk of further depression of left ventricular systolic function and other complications that require strict observation and increase the patient's length of stay. Conversely, 64% of group 2 patients had a heart rate at rest >65 beats/min and were treated with intravenous metoprolol. Pharmacologic heart rate control was associated with high overall feasibility of the MDCT scan, with a low rate of artifacts due to misalignment of slices (7 artifacts of 895 segments in group 1). The major source of artifacts in DCM is venous coronary system interference with the arterial coronary tree, particularly in the left circumflex and posterior descending arteries.

Diagnostic accuracy of MDCT. In a direct comparison with ICA, the diagnostic accuracy of MDCT in the detection of normal (44 cases) or diseased (17 cases) coronary arteries was very high, and all patients were correctly classified as having idiopathic or ischemic DCM. Moreover, the very high sensitivity and negative predictive value was evenly distributed among all examined segments. In one case only the severity of the coronary lesion was overestimated by MDCT. These findings are in agreement with the very high diagnostic accuracy of MDCT already observed in patients with a low-to-intermediate likelihood of CAD (19–22). A recent multicenter study performed by Garcia et al. (23) in 238 patients demonstrated that 16-row scanner MDCT may be particularly useful in excluding CAD in selected patients, such as DCM patients, due to its high sensitivity and negative predictive value. Interestingly, in agreement with recent reports, we found a good sensitivity and high specificity also in group 2 that included patients undergoing MDCT for various indications with a high prevalence of CAD (24–28). However, in these patients the overall sensitivity (86.1%) and negative predictive value (96.4%) were lower than that observed in group 1 (99% and 99.8%, respectively), even though the specificity remained high. The higher sensitivity and negative predictive value in DCM patients may be explained by a low pretest likelihood of CAD and a more accurate imaging of the coronary artery tree. It is likely that the reduction of cardiac and coronary motion due to the severe systolic dysfunction and the increased left ventricular end-diastolic volume of DCM patients played a positive role in image quality and diagnostic accuracy. Another factor that may have increased the correct assessment was the low prevalence of coronary wall calcification, a major cause of false-positive findings (29). Indeed, the major source of the few artifacts observed in DCM patients was the contrast-enhanced venous system that interfered with the evaluation of the arterial coronary tree, particularly along the course of the left circumflex and posterior descending arteries.

Study implications. The application of MDCT may have a clinical impact on the diagnostic approach and management of patients with DCM. Indeed, angiographic quantification of CAD is the most definitive method for assessing the presence of significant stenoses and the extent of CAD. In addition, the newer definition of ischemic DCM reclassifies patients with single-vessel disease as nonischemic unless there is evidence of left main or proximal left anterior artery disease or a history of myocardial infarction or revascularization (17). Indeed, patients with single-vessel disease who are classified as nonischemic have heart failure "out of proportion" to their extent of CAD and, interestingly, have a prognosis similar to those without any angiographic evidence of CAD (4). In our series, all cases were correctly classified as idiopathic or ischemic DCM based on the new standardized definition of the disease. Thus, given its high negative predictive value, MDCT could be used instead of ICA to exclude the presence of significant CAD in these patients. Moreover, MDCT reduces the risk and complications associated with ICA, and, thanks to its feasibility, rapidity, lower cost, and possible utilization as an outpatient examination may be preferable to ICA in DCM patients. Additionally, MDCT may also assist in identifying DCM patients in whom ICA is indicated because a revascularization procedure is likely needed.

Study limitations. There are some limitations to the present study. First, the patients of group 1 had a relatively low pretest probability of CAD since cases with known CAD were excluded. Second, the results of this study reflect the experience

of a single center in a relatively small number of patients. Third, MDCT results obtained in DCM patients were not compared with other imaging modalities, such as stress echocardiography, perfusion scintigraphy, or magnetic resonance imaging. However, this does not greatly affect our conclusions because visualization of the coronary arteries is indicated in most patients with left ventricular systolic dysfunction, regardless of the results of other noninvasive diagnostic tests. Fourth, our data were obtained with a 16-detector CT scanner. The current introduction of new 64-detector CT scanners may overcome some limitations of the previous technology, reducing execution time and enhancing feasibility, and may further confirm our results (30). Finally, as opposed to ICA, the MDCT images were evaluated visually because validated quantification algorithms are still unavailable.

Conclusions

This study indicates that MDCT is a feasible, safe, and accurate method to rule out significant coronary artery stenoses in patients with DCM, and, thus, it may be suggested as a diagnostic tool to differentiate ischemic from nonischemic etiology of the disease. It may, therefore, represent a clinically valuable alternative to ICA in the diagnostic workup of these patients with the advantage of avoiding catheter-associated risk, cost, and discomfort.

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EDITORIAL COMMENT

Visualizing the Coronaries in Patients Presenting With Heart Failure of Unknown Etiology*

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While earlier in the past century hypertension and rheumatic heart disease were the most common causes of congestive heart failure in the U.S. (1,2), by the 1970s coronary artery disease (CAD) had taken the lead as the most common cause of chronic left ventricular (LV) dysfunction and congestive heart failure (1,2). More recently, the obesity pandemics and the increasing prevalence of diabetes mellitus in the industrialized world have underscored the current guidelines (3) that clinical cardiologists should investigate the presence and extent of CAD in most patients presenting with heart failure. This diagnostic separation can be difficult using clinical and noninvasive techniques and has therapeutic implications, as many patients with obstructive coronary disease and depressed LV function benefit from revascularization.

See page 2044

Presently, to definitively rule out CAD, the performance of invasive coronary angiography with or without hemodynamic measurements from the left and right cardiac chambers is recommended. The paper by Andreini et al. (4) in this issue of the *Journal* examines the feasibility of a different strategy to assess the presence of CAD in patients with congestive heart failure. They compared coronary angiography by multidetector computed tomographic (CT) angiography (MDCTA) with conventional invasive angiography in 61 patients with severe global LV dysfunction and heart failure of unknown etiology. In addition, they evaluated the performance of MDCTA against angiography in a group of 139 patients with normal LV function referred to MDCTA for nonheart failure reasons. They found that MDCTA correctly differentiated dilated cardiomyopathy patients with versus those without CAD. The importance of their findings to patients presenting with heart failure cannot be underestimated. In a matter of seconds (12 s to 18 s for 16-slice MDCTA and 6 s to 12 s for 64-slice MDCTA), cardiologists are now able to exclude CAD as the main etiology or as a contributing pathophysiologic factor in patients presenting with heart failure. Moreover, MDCT coronary angiography can identify, with a reasonable degree of accuracy, the presence and location of coronary stenoses versus nonobstructive soft or calcified atherosclerotic plaques (5). Importantly also, this technology is rapidly advancing towards enhanced temporal resolution using dual source CT technology (6), reduced radiation by prospective gating, and greater coverage by devices equipped with 256 detectors (7) that allow obtaining a full cardiac image within 3 s to 5 s in a nonhelical mode (8).

The diagnostic performance of 16-slice MDCTA in the study by Andreini et al. (4) is superior to recently published meta-analyses of single-center studies and a multicenter clinical trial utilizing this technology in comparison with invasive coronary angiography (9,10). The discrepancies are likely secondary to the typical biases of small single-center diagnostic studies relative to larger multicenter trials such as patient mix (in this case a small number of dilated cardiomyopathy patients with primary cardiomyopathies [n = 44] and an even smaller group of patients with advanced coronariopathies), concentrated expertise in data acquisition and data analysis among other factors that tend to increase the range of abnormalities and favor stronger correlations. In the larger control group, patient selection may have been less dichotomous in terms of underlying pathology with diagnostic performances that more closely resemble those reported for larger single-center trials (9,10). The possibility that coronary angiography performed by newer 32- or 64-slice MDCT scanners would be even more accurate is suggested by previous meta-analyses comparing <16- versus >16-slice MDCTA (9), but definitive answers are still unavailable.

While the potential advantages of evaluating CAD by MDCTA versus coronary angiography in terms of convenience, avoidance of invasive catheterization, and the ability to provide assessment of both stenotic as well as nonobstructive plaques are clear, several disadvantages, however, deserve discussion. First, the major limitation of CT is that quantities of iodinated contrast agent application similar to those needed for angiography are required. Accordingly this approach does not offer an advantage for those individuals at increased risk for dye-related side effects or toxicity. Secondly, if LV hemodynamic measurements are needed, invasive catheterization will not be precluded. Finally, if CAD requires invasive intervention, the diagnostic and

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JACC Vol. 49, No. 20, 2007
May 22, 2007:2051–2

therapeutic procedures can be combined saving the patient an additional CT test that also entails radiation and iodinated contrast administration. In this regard, if the CT shows significant CAD that requires short-term intervention, the additional radiation and contrast load may represent an additive safety concern. The latter cases are, however, the exception rather than the rule in the workup of patients with dilated cardiomyopathy of unknown etiology. Future studies addressing clinical presentation and other potential ancillary triage mechanisms could further refine the utilization of MDCTA in the workup of these patients.

It is also important to note that MDCTA offers substantially more data than coronary angiography. Computed tomographic imaging provides exquisite and high resolution assessment of cardiac structure and function, including precise tissue analysis. Thus, as we move towards the use of this imaging modality for coronary anatomy, the type and extent of clinical information may also expand significantly.

Finally, as we place the findings of this study in relation to other recent trials focusing on the utilization of MDCTA to exclude or assess the presence and severity of CAD in patients referred for aortic and mitral valve replacement (11), patients with left bundle branch block (12), and those who underwent cardiac transplantation (13), we might speculate that this modality may find a special niche in specific groups of patients who currently undergo invasive angiography but could in the future be better evaluated noninvasively. The combination of coronary angiography with quantitative assessment of global and regional myocardial function, transmural scar stent (14,15), and perfusion (16) in the future could further enhance the attractiveness of MDCTA in the care of patients with advanced heart disease and congestive heart failure. In the meantime, additional prospective studies testing the utility of MDCTA in patients with heart failure and cardiomyopathies of unknown etiology are needed before we can solidify a recommendation that this is the preferred modality of workup for these patients. The study by Andreini et al. (4) is an important first step in that direction.

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Multidetector CT an attractive alternative to invasive angiography to diagnose ischemic etiology in dilated cardiomyopathy

May 14, 2007 | Shelley Wood

Washington, DC - Using multidetector (multislice) computed tomography (MDCT) to screen for coronary causes of dilated cardiomyopathy is feasible, safe, and offers an attractive substitute for standard coronary angiography to differentiate between ischemic and idiopathic, authors of a new study say [**1**].

Dr Daniele Andreini (University of Milan, Italy) and colleagues report their findings in the May 22, 2007 issue of the *Journal of the American College of Cardiology*. To **heart*wire***, Andreini explained: "The appeal of MDCT compared with conventional coronary angiography, particularly in this subset of patients, is that it is rapid and noninvasive, thus avoiding catheter-associated risk and patient discomfort."

Their study examined technical considerations, safety, and diagnostic accuracy of 16-slice MDCT in 61 subjects with dilated cardiomyopathy of unknown etiology who also underwent conventional angiography. An additional 139 patients with normal heart function but suspected coronary artery disease (CAD) also received both imaging tests.

Among patients with dilated cardiomyopathy, MDCT successfully identified all normal (n=44) and abnormal/diseased (n=17) coronary artery segments, as confirmed by standard coronary angiography. Sensitivity, specificity, and positive and negative predictive values for the identification of stenosis >50% were high among dilated cardiomyopathy patients. Values were also high for MDCT imaging among patients with normal heart function, but both sensitivity and negative predictive values were significantly lower among these patients than among those with dilated cardiomyopathy.

This makes sense, the authors suggest: "The higher sensitivity and negative predictive value in dilated cardiomyopathy patients may be explained by a low pretest likelihood of CAD and a more accurate imaging of the coronary artery tree," they write. "It is likely that the reduction of cardiac and coronary motion due to the severe systolic dysfunction and the increased left ventricular end-diastolic volume of dilated cardiomyopathy patients played a positive role in image quality and diagnostic accuracy."

Diagnostic accuracy of MDCT or the identification of >50% stenosis

Value	Dilated cardiomyopathy patients (%)	Suspected CAD patients (%)	p
Sensitivity	99	86.1	<0.001
Specificity	96.2	96.4	NS
Positive predictive value	81.2	86.1	NS
Negative predictive value	99.8	96.4	<0.001

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In terms of safety, no complications occurred during MDCT in either group, whereas 16% of the dilated cardiomyopathy patients and 6% of suspected CAD patients experienced a complication (acute heart failure or minor vascular complication) during invasive coronary angiography.

An attractive alternative

MDCT's high negative predictive value makes it a reasonable substitute for standard coronary angiography in this group of patients, Andreini et al conclude. "Thanks to its feasibility, rapidity, lower cost, and possible utilization as an outpatient examination, [MDCT] may be preferable to invasive coronary angiography in [dilated cardiomyopathy] patients," they write.

In an accompanying editorial, **Drs João AC Lima** (Johns Hopkins University, Baltimore, MD) and **Joshua Hare** (University of Miami, FL) hail the authors' findings, saying, "The importance of their findings to patients presenting with heart failure cannot be underestimated" [**2**].

In "a matter of seconds . . . cardiologists are now able to exclude CAD as the main etiology or as a contributing pathophysiologic factor in patients presenting with heart failure," Lima and Hare note. MDCT can also distinguish with reasonable accuracy between coronary stenoses and nonobstructive soft or calcified plaques and, with technological advancements such as dual-source CT to improve temporal resolution, prospective gating to reduce radiation, and greater coverage using 256 detectors, results may get even better, they add.

Contrast, radiation still drawbacks

Despite some clear advantages, there are also important drawbacks to MDCT, the editorialists write. For one, in this study MDCT offered no savings in terms of reduced dose of contrast dye, and so it would still be problematic for patients sensitive to dye-related toxicity. Furthermore, if revascularization is warranted or if left ventricular hemodynamic measurements are required, patients would still require catheterization, thereby negating the advantages of a noninvasive test.

Responding to **heart*wire***, Andreini pointed out that dilated cardiomyopathy patients with CAD are in the minority. "Based on our study data and selection criteria . . .patients affected by coronary artery disease are few—17 out of 64, or 28%, in our study. Therefore, if 17 patients had a double dose of contrast medium and radiation exposure, 44, or 72%, could avoid an invasive conventional coronary angiography thanks to MDCT detection of normal coronary vessels," Andreini said.

While doses of contrast medium were slightly higher for MDCT vs invasive coronary angiography in this study (130 mL vs 100 mL), this was with a 16-slice scanner. "A 64-slice CT actually in use in our laboratory permits—thanks to its higher temporal resolution—a significant reduction of contrast dose," Andreini noted.

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