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Non-invasive diagnosis of ischaemic heart failure using 64-slice computed tomography

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Aims We evaluated the accuracy of 64-slice computed tomography (CT) to identify ischaemic aetiology of heart failure (IHF).

Methods and results Ninety-three consecutive patients in sinus rhythm with dilated cardiomyopathy but without suspicion of coronary artery disease (CAD) were enrolled when admitted for angiography. Accuracy of CT to detect significant stenosis (>50% lumen narrowing) was compared with quantitative coronary angiography. IHF was defined as a significant stenosis on left main or proximal left anterior descending artery or two or more vessels. Forty-three out of 1395 segments (3%) were heavily calcified and excluded. CT correctly assessed 103 of 142 (73%) significant stenosis and identified 46 of 50 (92%) patients without and 42 of 43 (98%) patients with CAD, 60 of 62 (97%) patients without and 28 of 31 (90%) patients with IHF. Overall, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of CT for identifying CAD by segment was 96, 73, 99, 92, and 97%, respectively; by patient was 95, 98, 92, 91, and 98%, respectively; and for identifying IHF was 95, 90, 97, 93, and 95%, respectively.

Conclusion Non-invasive 64-slice CT assessment of the extent of CAD may offer a valid alternative to angiography for the diagnosis of IHF.

Keywords Cardiomyopathy • Heart failure • Computed tomography • Angiography

Introduction

Chronic heart failure (HF) is a major and growing problem of public health in the western world.[1] Coronary artery disease (CAD) is believed to be the underlying cause in approximately two-thirds of patients with HF and low ejection fraction (EF) and contributes to the progression of HF.[1–3] The presence and extent of CAD are associated with shorter survival.[4–6] Moreover, revascularization is recommended in patients with severe CAD exhibiting viable myocardium.[7–12] Perfusion defects and segmental wall motion abnormalities suggestive of CAD are commonly present in patients with dilated cardiomyopathy (DCM) on non-invasive imaging.[1,4,13] In clinical practice, patients with HF are considered having an ischaemic aetiology when a history of myocardial infarction or angiographic evidence of CAD is demonstrated.[1–4] Conventional coronary angiography (CCA) remains a cornerstone for the evaluation of patients with newly diagnosed systolic dysfunction and contributes substantially to the diagnosis, prognosis, and management decisions.[1,4,5]

Currently, 64-slice computed tomography (CT) with high temporal and spatial resolution identifies stenotic and non-stenotic coronary artery plaques with an excellent accuracy.[14–19] In the present study, we evaluated the diagnostic accuracy of 64-slice CT to identify ischaemic heart failure (IHF) in patients with left ventricular (LV) systolic dysfunction but without clinical suspicion of CAD compared with CCA.

Methods

Patients

From November 2005 to November 2006, 93 consecutive patients (65 ± 13 years) with a history of symptomatic HF, DCM (LV

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end-diastolic diameter of 63 ± 5 mm), and LV systolic dysfunction (LVEF of 31 ± 7%), admitted for CCA in our institution, were enrolled in the study. Multislice CT was performed before angiogram (median 1 day, range 0–20 days, interquartile 1.25 day). One hundred and nine patients were not enrolled in the study on the basis of our exclusion criteria: known history of CAD or myocardial infarction (64), myocarditis (2), significant valvular heart disease (15), constrictive or hypertrophic cardiomyopathy (8), atrial fibrillation (20), renal insufficiency (serum creatinine > 150 μmol/L), iodine allergy, and pregnancy. The local Ethics Committee approved the study, and informed consent was obtained from all patients.

Conventional coronary angiography

Selective coronary angiogram was performed by conventional technique, using 5F catheters. Intra coronary injection of nitrates (1 mg of isosorbid dinitrate) was systematically used after identifying the stenosis. The 15-segment American Heart Association model of the coronary tree was used.[20] Angiograms were reviewed by an experienced operator blinded to clinical and multislice computed tomography (MSCT) findings. Quantitative coronary angiography (QCA) was performed using the CAAS II algorithm (a second generation system for offline and online QCA).[21] A significant stenosis was defined as a mean diameter reduction >50% in two orthogonal views.

Study definitions

DCM was defined as LV end-diastolic diameter >56 mm on M-mode echocardiogram, with LV systolic dysfunction (LVEF <40%) on biplane Simpson's echocardiography. Patients were classified as having CAD if any major coronary artery had >50% diameter stenosis in two orthogonal views.

Because CAD may be associated but not responsible for DCM, we defined IHF as ischaemic cardiomyopathy by the definition used by Felker *et al.*[4] that reclassifies patients with single-vessel disease and without a history of myocardial infarction or revascularization as non-ischaemic unless they have left main or proximal LAD (before the first diagonal branch) or two or more vessel disease.

Multislice computed tomography data

All patients were in sinus rhythm and received intravenous beta-blocker medication immediately before scanning if heart rate exceeded 80 b.p.m. (esmolol hydrochloride, Brevibloc®, Baxter Healthcare, Deerfield, IL, USA). Dosage was titrated in order to lower heart rate below 70 b.p.m. The protocol included a loading dose of 1 mg/kg infused over 2 min followed by a maintenance infusion of 0.2 mg/kg/min for 4 min. However, no patient was excluded due to a higher heart rate. Nitroglycerine was not used before CT acquisition.

All examinations were performed with a 64-slice CT (Sensation 64, Siemens, Erlangen, Germany). The acquisition protocol was described previously.[14] Briefly, data were acquired with a gantry rotation time of 330 ms, a theoretical collimation of 0.4 mm (combining 64 × 0.6 mm slice collimation with the z-sharp double sampling technology) and a table feed of 18 mm/s. The ECG was monitored during the scanning, and 70–90 mL of contrast medium was injected (mean flow rate 4 mL/s) (Iomeprol 400 mg/mL, Bracco, Milan, Italy). Acquisition started automatically in all the patients at a threshold of 100 HU within the region of interest in the descending aorta. The time delay was not recorded but was delayed in most cases. A tube voltage of 120 kV and a current of 600 mA were applied with individual adaptation according to the patient's morphology. The ECG-pulsed current modulation was activated. The estimated effective radiation was 10 ± 5 mSv. Transaxial images were reconstructed retrospectively at diastolic phase from the raw CT data and electrocardiographic tracings with a smooth kernel (B30).

MSCT scans were analysed by consensus of two examiners blinded to the results of CCA and all clinical information. Image quality was classified with a five-point scale as 5 = excellent, 4 = good (minor motion artefact present), 3 = moderate (substantial motion artefacts present, but luminal assessment regarding significant stenosis still possible), 2 = heavily calcified (vessel lumen obscured by calcification), and 1 = blurred (no luminal assessment regarding significant stenosis possible).[14] As previously described,[14] the 15-segment American Heart Association model of the coronary tree was used,[20] each lesion identified was examined using maximum intensity projection and multiplanar reconstruction techniques on parallel plane to the course of the artery using the scanner standard workstation (Leonardo, Siemens). In case of a single lesion per segment, side branches or bifurcations were used as markers for the location. In case of multiple lesions per segment, the worst lesion was recorded. A significant stenosis was defined by visual estimation >50% on maximum intensity projection images for non-calcified lesions and on multiplanar reconstruction images if needed for partially or heavily calcified lesions.

Statistical analysis

Statistical analysis was performed with StatView 5.0 software (SAS Institute Inc., Cary, NC, USA). Percentages were expressed with a 95% confidence interval. Continuous variables were expressed as mean values ± SD and nominal variables as counts and percentages. The confidence intervals were computed following the method described by Zar[22] for the confidence limits for proportions, implemented in a custom Excel sheet. To be able to detect, with a risk of type I and II of 0.05, a rate of bad segments classification of 5%, 1092 segments (73 patients) were needed.[23] Considering the usual number of patients referred to our institution for HF diagnosis, it appeared that a 1 year study would make it possible to achieve this goal. Comparisons between patients with or without CAD and IHF vs. DCM were made with the two-sample *t*-test for continuous data and two-tailed χ^2 or Fisher's exact test when necessary for nominal variables. Effect of heart rate, LVEF, LV end-diastolic diameter, and body mass index on image quality was assessed by analysis of variance and Student–Newman–Keuls test *post hoc* analysis. The accuracy of MSCT to detect significant stenosis was compared with QCA as the standard of reference. Since severely calcified lesions could not be evaluated, we performed patient-based analysis, either by excluding these segments or considering them as likely stenosis. Because of the possible interdependencies between different vessel segments, the patient statistics were calculated on a vessel-based analysis. A *P*-value <0.05 was regarded as statistically significant.

Results

Baseline characteristics

Multislice CT was performed without complication in all patients. Sixty-one patients (66%) were already under beta-blocker therapy, but additional treatment was needed in 32 (34%) patients before scanning. Esmolol infusion decreased heart rate by 7 ± 4 b.p.m. The mean heart rate during the scan was 73 ± 14 b.p.m. (range 46–115 b.p.m.). The total scan time was 12 ± 2 s. The patient's baseline characteristics are summarized in *Table 1*. Forty-three patients (46%) were considered to have CAD, 50 (54%) had no CAD. Patients with CAD were older and had a higher creatinine and lipids serum levels. Thirty-one

Table 1 Patient characteristics

	CAD+	CAD−	*P*-value	IHF	DCM	*P*-value
Number of patients (%)	43 (46)	50 (54)	—	31 (33)	62 (67)	—
Age (years)	69 ± 11	62 ± 14	0.005	69 ± 11	63 ± 14	0.05
Gender (male/female)	32 (74)/11 (26)	29 (58)/21 (42)	0.1	24 (77)/7 (23)	37 (60)/25 (40)	0.09
Body mass index (kg/m^2)	26 ± 4	26 ± 4	0.84	26 ± 4	26 ± 4	0.97
NYHA class	—	—	0.45	—	—	0.06
I	9 (21)	9 (18)	—	5 (16)	13 (21)	—
II	9 (21)	5 (10)	—	9 (29)	5 (8)	—
III	7 (16)	11 (22)	—	4 (13)	14 (23)	—
IV	18 (42)	25 (50)	—	13 (42)	30 (48)	—
History of angina	17 (40)	19 (38)	0.45	11 (35)	25 (40)	0.82
Risk factors						
Hypertension	25 (58)	24 (48)	0.33	19 (61)	30 (48)	0.24
Diabetes mellitus	9 (21)	9 (18)	0.72	7 (23)	11 (18)	0.58
Smoker	21 (49)	26 (52)	0.76	16 (52)	31 (50)	0.88
Dyslipidaemia	22 (51)	14 (28)	0.02	18 (58)	18 (29)	0.007
Family history of CAD	12 (28)	14 (28)	0.99	10 (32)	16 (26)	0.51
ECG characteristics						
Left bundle branch block	22 (51)	24 (48)	0.76	15 (48)	31 (50)	0.88
Right bundle branch block	1 (2)	3 (6)	0.38	1 (3)	3 (5)	0.72
Q-wave	3 (7)	5 (10)	0.6	2 (6)	6 (10)	0.6
Minor T-wave changes	12 (28)	17 (34)	0.53	9 (29)	20 (32)	0.75
Poor R-wave progression	5 (12)	8 (16)	0.54	5 (16)	8 (13)	0.67
Beta-blocker	32 (74)	29 (58)	0.1	24 (77)	37 (60)	0.09
LVEF (%)	30 ± 8	32 ± 7	0.19	29 ± 8	33 ± 7	0.01
LVEDD	64 ± 6	63 ± 5	0.43	65 ± 6	63 ± 5	0.09
Serum creatinine (μmol/L)	102 ± 25	91 ± 19	0.02	98 ± 22	95 ± 24	0.54
Heart rate (b.p.m.)	71 ± 15	74 ± 13	0.32	71 ± 15	74 ± 13	0.43
Number of diseased vessels						
0	0	50 (100)		0	50 (81)	
1	17 (40)			5 (16)	12 (19)	
2	9 (21)			9 (29)		
3	17 (40)			17 (55)		

Data are presented as the number (%) or mean value ± SD. CAD+, patients with coronary artery disease; CAD−, patients without coronary artery disease; IHF, ischaemic heart failure; DCM, dilated cardiomyopathy; NYHA, New York Heart Association; ECG, electrocardiogram; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter.

patients (33%) were considered having an IHF and 62 (67%) a DCM. The patients with IHF were older and had a higher incidence of dyslipidaemia and lower LVEF. Angina, dyspnoea, the remaining risk factors, and ECG characteristics did not differ according to the aetiology. CCA revealed one-vessel disease in 17 patients (18%), two-vessel disease in nine patients (10%), and three-vessel disease in 17 patients (18%). Four patients had significant left main stenosis. No significant stenosis was depicted in 50 patients (54%). Twelve patients presenting one-vessel disease were considered having a DCM with concomitant CAD, since the CAD involved only distal or side branches (seven lesions on the mid-left anterior descending artery, two on the first diagonal branch, two on the mid-right coronary artery, and one on the right posterior descending artery).

Image quality

Image quality was good on average (3.7 ± 1.3) (*Figure 1*). Score 5 ($n = 34$), 4 ($n = 24$), 3 ($n = 9$), 2 ($n = 23$), and 1 ($n = 3$) corresponded to a heart rate of 61 ± 6, 76 ± 11, 77 ± 10, 84 ± 3, 95 ± 5 b.p.m., respectively. According to heart rate, image quality was significantly impaired among patients in score 1 and better among patients in score 5 when compared with patients in score 2, 3, and 4 ($P < 0.0001$). Respiratory artefacts (six patients), heart rate >90 b.p.m. during the scanning (10 patients), and multiple ventricular premature beats (10 patients) impaired image quality to score 2 or 1. No relationship between image quality and body mass index ($P = 0.69$) or LVEF ($P = 0.43$) or LV end-diastolic diameter ($P = 0.32$) was noted.

Lesion-by-lesion analysis

Of 1395 coronary segments, 43 (3%) were heavily calcified and could not be evaluated. Of the remaining 1352 segments, MSCT correctly detected 103/142 (73%) significant stenosis (*Table 2*). Thirty-nine stenosis (27%) were missed or underestimated: 29 lesions were missed because of important calcifications (14), multiple premature ventricular beats (8), or respiratory artefacts (7), and 10 were underestimated. The distribution of missed lesions per vessel was as follows: left main, zero of four (0%); left anterior descending artery (LAD), 15 of 72 (21%); left circumflex artery (LCX), 11 of 31 (35%); right coronary artery (RCA), 13 of 35 (37%). These missed lesions were more frequent on distal side branches 24/39 (62%) and in multilesion patients. Nine lesions were overestimated by MSCT because of motion artefacts (two) and important calcifications (seven) (*Figure 2*). Four of these lesions were on LAD, three on LCX, and two on RCA.

On a per-artery analysis, MSCT had excellent specificity (95–100%) but sensitivity was respectively 100% for left main, 79% for LAD, 65% for LCX, and 63% for RCA. Overall, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of 64-slice CT for identifying significant stenosis was 96, 73, 99, 92, and 97%, respectively.

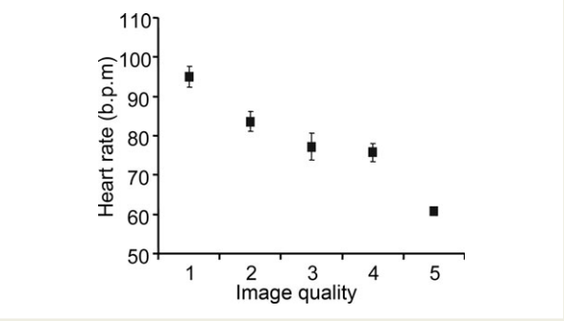

Figure 1 Plot showing comparison between image quality score and heart rate (b.p.m.) during scanning.

Patient-based analysis

No patient was excluded on the basis of impaired image quality. Multislice CT correctly identified 46 of 50 (92%) patients without and 42 of 43 (98%) patients with significant stenosis on CCA (*Table 3*). All 17 patients with three-vessel disease or left main stenosis were correctly detected by MSCT. Overall, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of 64-slice CT for identifying patients with CAD was 95, 98, 92, 91, and 98%, respectively. Multislice CT correctly identified 60 of 62 (97%) patients without and 28 of 31 (90%) patients with IHF. Therefore, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of 64-slice CT for identifying IHF was 95, 90, 97, 93, and 95%, respectively. If severe calcifications were considered as likely stenosis on CT, that would have not affected the sensitivity with a slight change in specificity (*Table 4*). False positive and negative patients and their characteristics are depicted in *Table 5*.

Table 2 Lesion-by-lesion-based analysis

Coronary segment	*n*	TP	TN	FP	FN	Sensitivity	Specificity	Accuracy	PPV	NPV
Overall	1352	103	1201	9	39	73 (64–80)	99 (99–100)	96 (95–97)	92 (85–96)	97 (96–98)
LM	93	4	89	0	0	100 (40–100)	100 (96–100)	100 (96–100)	100 (40–100)	100 (96–100)
LAD	459	57	383	4	15	79 (68–88)	99 (97–100)	96 (94–97)	93 (84–98)	96 (94–98)
Proximal	93	19	73	1	0	100 (82–100)	99 (93–100)	99 (94–100)	95 (75–100)	100 (95–100)
Mid	92	24	61	3	4	86 (67–96)	95 (87–99)	92 (85–97)	89 (71–98)	94 (85–98)
Distal	92	5	85	0	2	71 (29–96)	100 (96–100)	98 (92–100)	100 (48–100)	98 (92–100)
First diagonal	91	8	76	0	7	53 (27–79)	100 (95–100)	92 (85–97)	100 (63–100)	92 (83–97)
Second diagonal	91	1	88	0	2	33 (1–91)	100 (96–100)	98 (92–100)	100 (2–100)	98 (92–100)
LCX	358	20	324	3	11	65 (45–81)	99 (97–100)	96 (94–98)	87 (66–97)	97 (94–98)
Proximal	91	7	79	2	3	70 (35–93)	98 (91–100)	95 (88–98)	78 (40–97)	96 (90–99)
Distal	89	5	82	1	1	83 (36–100)	99 (93–100)	98 (92–100)	83 (36–100)	99 (93–100)
First obtuse marginal	89	7	78	0	4	64 (31–89)	100 (95–100)	96 (89–99)	100 (59–100)	95 (88–99)
Second obtuse marginal	89	1	85	0	3	25 (1–81)	100 (96–100)	97 (90–99)	100 (2–100)	97 (90–99)
RCA	442	22	405	2	13	63 (45–79)	100 (98–100)	97 (94–98)	92 (73–99)	97 (95–98)
Proximal	89	7	81	0	1	88 (47–100)	100 (96–100)	99 (94–100)	100 (59–100)	99 (93–100)
Mid	86	9	74	1	2	82 (48–98)	99 (93–100)	97 (90–99)	90 (55–100)	97 (91–100)
Distal	89	3	83	1	2	60 (15–95)	99 (94–100)	97 (90–99)	75 (19–99)	98 (92–100)
RPDA	89	2	82	0	5	29 (4–71)	100 (96–100)	94 (87–98)	100 (16–100)	94 (87–98)
PLA	89	1	85	0	3	25 (1–81)	100 (96–100)	97 (90–99)	100 (2–100)	97 (90–99)

TP, true positive; TN, true negative; FP, false positive; FN, false negative; PPV, positive predictive value; NPV, negative predictive value; LM, left main; LAD, left anterior descending artery; LCX, left circumflex; RCA, right coronary artery; RPDA, right posterior descending artery; PLA, posterolateral artery.

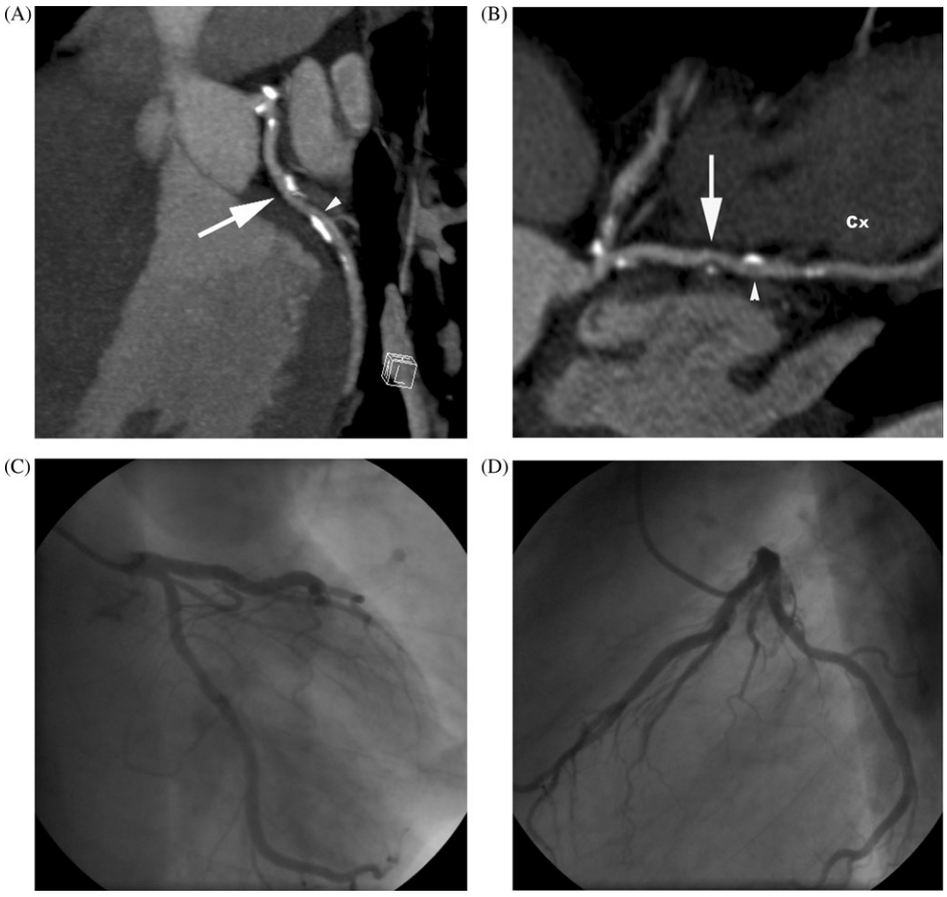

Figure 2 Sixty-four slice computed tomography in a 56-year-old man admitted for dilated cardiomyopathy [(*A*) and (*B*)]. Maximum intensity projection image demonstrates two calcified lesions on the proximal left circumflex artery (*A*). Curved multiplanar reconstruction image of the left circumflex artery demonstrates a significant stenosis (>50%) (arrow) and a non-stenotic-calcified plaque (arrowhead). On coronary angiography, both lesions were not significant [(*C*) and (*D*)].

Table 3 Patient-based analysis with calcified lesions excluded

Classification	*n*	TP	TN	FP	FN	Sensitivity	Specificity	Accuracy	PPV	NPV
CAD+	93	42	46	4	1	98 (88–100)	92 (81–98)	95 (88–98)	91 (79–98)	98 (89–100)
IHF	93	28	60	2	3	90 (74–98)	97 (89–100)	95 (88–98)	93 (78–99)	95 (87–99)

TP, true positive; TN, true negative; FP, false positive; FN, false negative; PPV, positive predictive value; NPV, negative predictive value; CAD+, patients with coronary artery disease; IHF, ischaemic heart failure.

Discussion

Our data demonstrate that 64-slice CT provides a high diagnostic accuracy to detect significant CAD in patients with HF and LV systolic dysfunction. CT identifies IHF with an excellent specificity (97%), providing clinically important findings with therapeutic and prognostic implications. Moreover, compared with CCA, CT correctly assessed the extent of CAD. Heavy calcifications and tachycardia remain current limitations.

Use of computed tomography for differentiation of ischaemic from non-ischaemic cardiomyopathy

Coronary artery-calcified plaque as measured by cardiac CT has a high sensitivity and negative predictive value for detecting obstructive CAD but markedly limited specificity, because calcified plaque may be present in non-obstructive lesions, and a positive calcium scan indicates atherosclerosis but most often no significant

Table 4 Patient-based analysis with calcified lesions considered as stenosis

Classification	n	TP	TN	FP	FN	Sensitivity	Specificity	Accuracy	PPV	NPV
CAD+	93	43	44	5	1	98 (88–100)	90 (78–97)	94 (86–98)	90 (77–97)	98 (88–100)
IHF	93	28	59	3	3	90 (74–98)	95 (87–99)	94 (86–98)	90 (74–98)	95 (87–99)

TP, true positive; TN, true negative; FP, false positive; FN, false negative; PPV, positive predictive value; NPV, negative predictive value; CAD+, patients with coronary artery disease; IHF, ischaemic heart failure.

Table 5 False-positive and -negative patients with calcified lesions excluded

		n	Localization	Aetiology
CAD+	FP	Patient 1	Mid-RCA	Premature heart beat
		Patient 2	Mid-LAD	Calcification
		Patient 3	Mid-LAD	Calcification
		Patient 4	Distal LCX	Calcification
	FN	Patient 5	Distal RCA	Calcification
IHF	FP	Patient 6	Prox LCX	Calcification
		Patient 7	Distal RCA	Premature heart beat
	FN	Patient 8	First diagonal, prox LCX	HR > 90 b.p.m.
		Patient 9	First diagonal	HR > 90 b.p.m.
		Patient 10	Mid and distal LAD, first diagonal, mid-RCA, first obtuse marginal	HR > 90 b.p.m.

CAD+, patients with coronary artery disease; IHF, ischaemic heart failure; FP, false positive; FN, false negative; RCA, right coronary artery; LAD, left anterior descending artery; LCX, left circumflex artery.

stenosis.[24–26] Contrast-enhanced cardiovascular magnetic resonance could identify reversible myocardial dysfunction[27] and HF related to CAD but could fail in patients with large areas of hibernating myocardium without necrosis.[28] Despite the potential attractiveness of non-invasive testing, CCA is usually required in patients with symptomatic HF for accurate identification of CAD, prognostic information with the extent of CAD, and therapeutic management of bypassable arteries.[4,5]

Clinical implications

We found as in previous studies that symptoms, risk factors, and ECG findings are not reliable to differentiate IHF and DCM.[5,29] Our data demonstrate the high diagnostic accuracy (95%) of 64-slice CT to detect patients with or without CAD. In patients with CAD, sensitivity and negative predictive value reached 98% with an excellent specificity of 92%, which exceeded the performance of other non-invasive tests. The definition of ischaemic cardiomyopathy of Felker *et al.*[4] is more accurate because it relies on the extent of CAD. In our study, 64-slice CT detected IHF with an excellent specificity 97% (60 of 62), but sensitivity decreased to 90% (28 of 31). All patients with three-vessel or left main disease (17 of 17) were correctly identified. Moreover, CCA could have been avoided in 65% of the cases (60 of 93 patients) with a negative predictive value of 95%.

Factors affecting image quality

Lower heart rates were associated with improved image quality as in previous studies,[14,16,18,19] independently of LVEF, LV end-diastolic diameter, or body mass index. The management of heart rate in these high-risk patients of HF required a short half-life beta-blocker agent (esmolol hydrochloride) for safety reasons. The small reduction observed in heart rate (7 ± 4 b.p.m.) could be explained by the insufficient dose in this setting.

Influence of lesion detection

Sixty-four slice CT offers high diagnostic accuracy (96%) to detect significant stenosis but sensitivity was moderate (73%). False-negative lesions were primarily due to calcified lesions or multiple premature ventricular beats. Although lowering heart rate could reduce the frequency of premature ventricular beats, severe calcifications remain a current limitation despite the increased spatial resolution of 64-slice CT. Calcified plaques create blooming artefacts especially on MIP images.[14,16–19] MPR produces images containing all available Hounsfield unit values reducing the partial volume effect (averaging different densities within a single voxel) providing a better delineation of the coronary lumen. In our study, specificity (99%) for identification of significant stenosis was higher than sensitivity (73%). This could be explained by the high incidence of false-negative lesions due to calcified plaque, since they were not considered as likely stenosis in our interpretation, and the localization of missed lesions primarily on side branches.

The higher rate of false-negative/false-positive lesion (14/7) due to calcifications in our study contrasts with reported data in previous studies by Leber *et al.* (2/10), Raff *et al.* (2/16), and Leschka *et al.* (8/24).[17–19] This discrepancy between our results could be explained by the fewer segments excluded from lesion evaluation owing to massive calcifications: 43 (3%) in our study vs. 87 (10%) for Leber *et al.* and 130 (12%) for Raff *et al.*[17,19] Note that false-negative lesions were localized on distal side branches in 62% (24/39) and primarily on RCA and LCX which are more sensitive to cardiac motion especially in patients with a higher heart rate. Finally, false-negative lesions were more frequent

in multilesion patients in whom calcified plaques assessment remains challenging.[14]

Comparison with previous studies

Our data are consistent with previous findings of 16-slice CT.[30,31] Cornily *et al.*[30] demonstrated the excellent sensitivity and negative predictive value of CT to detect ischaemic cardiomyopathy when restricted to patients with a low calcium score (Agatston < 1000) with a per-vessel analysis. Moreover, the cardiac venous system was assessable in all patients providing helpful data for resynchronization therapy.[30] Andreini *et al.*[31] confirmed in 61 patients with DCM the feasibility, safety, and accurate identification of ischaemic cardiomyopathy.

Currently, 64-slice CT with higher temporal and spatial resolution requires shorter duration of acquisition (12 over 25 s with 16-slice CT), is less sensitive to motion artefacts and heart rate, and offers a reliable non-invasive tool to detect CAD. Moreover, CT imaging of myocardial perfusion and viability are promising concepts to detect acute and healed myocardial infarction[32,33] and would be a valuable tool if stress tests could be combined[34] to predict the physiological implication and functional assessment of stenosis in the diagnosis of ischaemic cardiomyopathy.

Limitations

This is a single-centre experience and all our patients were symptomatic and referred for angiography for the evaluation of HF. This could have influenced CT results but most clinicians still use CCA as the standard for differentiating IHF from DCM.[4,5] The prevalence of non-ischaemic aetiology is higher in our population than in the general population since we excluded patients with a history of CAD. Our high negative predictive value is consistent with previous studies of CT[14,17–19] but would be lower in a general population. In our study, we used only the anatomical grading of stenosis (< and >50%) to define CAD as in clinical practice; however, the functional assessment of stenosis severity does not necessarily imply an ischaemic aetiology of a cardiomyopathy since stress tests have limited performance.[13,35] Moreover, obstructive CAD as assessed by angiography may be a concomitant disease rather than the aetiology of cardiomyopathy. Conversely, myocardial infarctions can complicate non-significant coronary stenosis due to spasm or plaque rupture.[28] Nitrates were not used before scanning as for CCA to avoid the additive lower blood pressure effect with beta-blocker therapy.

In summary, 64-slice CT is an excellent tool for classifying patients with HF and LV systolic dysfunction in relation to the presence or absence of CAD. A normal CT in this setting may avoid invasive diagnostic procedures. Non-invasive CT assessment of the extent of CAD is a reliable alternative to angiography for the diagnosis of IHF in patients with controlled HR and sinus rhythm.

Conflict of interest: none declared.

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