IJC Heart & Vasculature 8 (2015) 42–46

Contents lists available at ScienceDirect

IJC Heart & Vasculature

journal homepage: http://www.journals.elsevier.com/ijc-heart-and-vasculature

Diagnostic accuracy of 64 slice multidetector coronary computed tomographic angiography in left ventricular systolic dysfunction☆

Danny Lee [a,*], Dong Li [a], Borut Jug [a,b], Jenny Papazian [a], Matthew Budoff [a,c]

[a] Division of Cardiology, Los Angeles Biomedical Research Institute at Harbor UCLA Medical Center, Torrance, CA, United States
[b] Department of Vascular Diseases, Division of Internal Medicine, University Medical Center, Ljubljana, Slovenia
[c] David Geffen School of Medicine UCLA, Los Angeles, CA, United States

ARTICLE INFO

Article history:
Received 9 April 2015
Accepted 16 April 2015
Available online 22 April 2015

Keywords:
Cardiac CTA
Coronary artery disease
Heart failure

ABSTRACT

Background: Detecting coronary artery disease (CAD) is pivotal in etiologic assessment and management of left ventricular (LV) systolic dysfunction. Only a limited number of studies have specifically addressed the accuracy of coronary computed tomographic angiography (CCTA) in detection/exclusion of CAD in patients with LV systolic dysfunction.

Methods: We included patients who were referred for CCTA and invasive coronary angiography within 6 months of each other because of chest pain, either as part of clinical work-up in two Los Angeles medical centers from September 2006 to May 2010 or as part of the multicenter ACCURACY trial. Sensitivity, specificity, positive and negative predictive value, and likelihood ratios of 64 slice multidetector CCTA against coronary angiography were calculated.

Results: Five hundred and thirty-seven patients were included: 228 (42.5%) were women, mean age was 62 ± 12 years, 82 (15.3%) had LV systolic dysfunction (defined by LVEF <50%). On a patient-based model, the sensitivity of CCTA to detect 50% and 70% coronary lesions was excellent across all LVEF-derived cohorts, ranging from 92% to 100%. The negative predictive value was similarly excellent, ranging from 88% to 100%. CCTA was fairly specific for CAD, with specificity ranging from 83% to 93%, and positive predictive value from 81% to 92%. There was no significant between-group difference for any of the accuracy measures for detecting coronary stenosis at 50% or 70% cutoff.

Conclusion: Sixty-four slice multidetector CCTA is a very sensitive and fairly specific noninvasive diagnostic procedure for detecting coronary stenosis in patients with chest pain regardless of LV systolic function at presentation.

1. Introduction

The most common etiology for heart failure (HF) is coronary artery disease (CAD), to which more than 60% of HF is attributable [1]. A crucial initial step when faced with new onset left ventricular (LV) dysfunction is to determine whether the cause is ischemic or nonischemic, particularly if the original presentation includes symptoms of chest pain or other evidence of ischemia [2]. Detecting CAD is an important step in the diagnosis of ischemic cardiomyopathy (ICM), which is defined as significantly impaired LV function (LVEF <35%–40%) that results from CAD. ICM is a significant independent predictor of mortality in patients with cardiomyopathy [3], particularly when associated with more extensive CAD [4]. In addition to the standard management of heart failure, the management of ICM also includes anti-ischemic medical therapy and coronary revascularization of viable myocardium, which may have a favorable effect on survival as well as LV function [5,6].

Current guidelines recommend that newly diagnosed HF patients with chest pain be considered for assessment for CAD, which may include noninvasive imaging or invasive coronary angiography (ICA) [2]. However, the traditional noninvasive modalities that are commonly used for working up CAD, including echocardiography and nuclear imaging, are frequently nondiagnostic in the setting of heart failure, subsequently requiring referral for ICA [7,8]. In turn, ICA can be costly to patients given its cost and invasiveness, especially for patients in whom the pretest probability of CAD is low. Also, it is not generally indicated in patients who are not eligible for coronary revascularization.

Cardiac computed tomographic angiography (CCTA) has been shown in several large prospective studies to be an effective noninvasive modality for ruling out coronary artery disease (CAD) [9–11]. In

Abbreviations: CAD, coronary artery disease; CCTA, cardiac computed tomographic angiography; EF, ejection fraction; HF, heart failure; ICA, invasive coronary angiography; ICM, ischemic cardiomyopathy; LV, left ventricular.

☆ All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

* Corresponding author at: Division of Cardiology, Harbor-UCLA Medical Center, 1124 W Carson St, Torrance, CA 90502, United States. Tel.: +1 310 222 2515; fax: +1 310 782 9652.
E-mail address: danny_lee@alumni.brown.edu (D. Lee).

http://dx.doi.org/10.1016/j.ijcha.2015.04.007

these trials, its sensitivity and NPV were shown to be as high as 99% and 99%, respectively. Thus, CCTA is a promising noninvasive modality to work up heart failure patients for CAD, and has been deemed in CCTA guidelines as an appropriate imaging modality for the detection of CAD in low-to-intermediate pre-test probability patients with reduced LV systolic function [12]. A few studies support a high sensitivity for CAD in LV systolic dysfunction [13–15], but they were performed in relatively small single-center populations. There is also concern that the presence of systolic dysfunction may make CCTA evaluation of CAD less reliable [16,17].

In this study, our aim was to assess the diagnostic performance of CCTA to detect coronary artery stenosis in a large multicenter population of patients across a wide spectrum of LV function, including a significant number with impaired LVEF, using conventional coronary angiography as the gold standard.

2. Methods

2.1. Study population

Our study population consisted of patients from 2 separate sources: (1) the prospectively conducted ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial and (2) a retrospective cohort from a joint database of CCTA diagnostic procedures performed in two Los Angeles medical centers between September 2006 and May 2010. More details regarding the enrollment of patients in the ACCURACY study population have been described elsewhere [9], but briefly, this study was designed to prospectively evaluate adult subjects with chest pain who were being clinically referred for nonemergent ICA and underwent CCTA as part of the study protocol. Individuals were eligible for participation in the ACCURACY study if they were ≥18 years of age, experienced typical or atypical chest pain, and were being referred for nonemergent ICA. Individuals were excluded if they had a known allergy to iodinated contrast; baseline renal insufficiency (creatinine ≥1.7 mg/dl); irregular cardiac rhythm; resting heart rate >100 beats/min; resting systolic blood pressure ≤ 100 mm Hg; contraindication to beta-blocker, calcium-channel blocker, or nitroglycerin; pregnancy; and known history of CAD (prior myocardial infarction, percutaneous transluminal coronary angioplasty or intracoronary stent, or coronary artery bypass surgery). The study was performed at 16 centers in the U.S. For the retrospective cohort, patients were included in the analysis if they had been referred for diagnostic work-up of chest pain and had available CCTA and ICA images with both diagnostic procedures performed no more than 6 months apart. In addition to the exclusion criteria above, patients were excluded from analysis if there was no available data on LVEF. LVEF could be based on either of 4 modalities: CCTA, ICA, nuclear imaging, or echocardiogram. If LVEF from multiple studies were available for a given patient, the lowest one was used for analysis.

In the ACCURACY study, the Institutional Review Board at each participating center had reviewed and approved the study protocol and patient safety monitoring plan before the study commenced. Patients in the retrospective cohort gave informed consent to undergo both diagnostic procedures as part of clinical work-up, and we obtained approval from the Institutional Review Board at each center to review the medical records of these individuals by virtue of maintaining patient records confidentiality.

2.2. CTA protocol and image reconstruction

All CCTA scans were performed with a 64-multidetector row scanner (GE Healthcare, Milwaukee, WI). Accordingly, data were acquired with a collimation of 64 × 0.625 mm and a tube rotation time of 350 ms. The tube current was 300–400 mA at 100–120 kV for patients based on their body size. Individuals presenting with baseline heart rates of >65 beats/min were administered oral beta-blocker therapy as the preferred method for slowing down the heart rate. Intravenous administration was allowed in the protocol, using metoprolol at 5 mg increments to a total possible dose of 25 mg to achieve a resting heart rate of <65 beats/min.

Following a scout radiograph of the chest (antero-posterior and lateral), a timing bolus (using 10 to 20 mL contrast) was performed to detect time to optimal contrast opacification in the axial image at a level immediately superior to the ostium of the left main artery. Nitroglycerine 0.4 mg sublingually was administered immediately before contrast injection. During CCTA acquisition, 60–80 mL iodinated contrast (depending on the total scan time) was administered through the antecubital vein at a flow rate of 4 mL/s, followed by a contrast-saline mixture at 4 mL/s and saline flush at 4 mL/s. Images were acquired either by using prospective ECG triggering at 75% of RR interval or by retrospective ECG gating with images constructed at 5% intervals from 5% to 95% of RR interval. Subsequently, data sets were reconstructed and all CCTA images were transferred to 3-dimensional image analysis workstation (GE Advantage Workstation, GE Healthcare, Milwaukee, Wisconsin).

2.3. Noninvasive multidetector CCTA analysis

Multislice computed tomography examinations were evaluated on both patient level and vessel level by ≥2 operators (three in the ACCURACY trial and two in the retrospective cohort). The CCTA readers were permitted to use any or all of the available post-processing image reconstruction algorithms, including 2-dimensional axial and 3-dimensional maximal intensity projection, multiplanar reformat, cross-sectional analysis, and volume rendered technique. CTA were read in a blinded manner, independent of invasive angiography results. The final reads were based on core lab reads (consensus reached between the readers). More detailed information regarding inter-reader variability with the ACCURACY cohort has been published [18].

Coronary arteries were scored using a 15-segment AHA coronary artery classification, as previously described [19]. Coronary artery luminal diameter stenosis was graded as: no stenosis, 1%–29% stenosis, 30%–49% stenosis, 50%–69% stenosis, and ≥70% stenosis by visual assessment of atherosclerotic lesions using multiple projections [20]. For each coronary segment, readers assessed whether coronary segments were evaluable. In the ACCURACY cohort, non-evaluable segments were assigned stenosis severity based on the outcome of the most adjacent proximal and identifiable segment [9]. In the retrospective cohort, uninterpretable segments (due to motion or collimation artifacts, or severe calcifications) were excluded from further analysis.

2.4. Invasive coronary angiography (ICA)

All patients had conventional ICA performed on the basis of clinical presentation and/or imaging findings decided by their cardiologists. ICA was performed according to standard clinical protocols [19]. All images were interpreted by an independent reader blinded to all patients' characteristics and CCTA results. Multiple projections were acquired to discern the maximal coronary artery luminal narrowing, and maximum stenosis in each vessel was recorded. ICA's were quantitatively evaluated for coronary artery stenosis with quantitative coronary angiography software (CAAS, Pie Medical Imaging, Maastricht, the Netherlands). Coronary artery segments were evaluated using a 15-segment AHA coronary tree model and were judged as having significant stenosis at 2 levels (i.e., if ≥50% or ≥70% luminal diameter stenosis was present). Coronary segment narrowing was described as: no lesion, <50% stenosis, 50%–69% stenosis, and ≥70% stenosis.

2.5. Data analysis

Analysis was performed on per-patient basis, and separately for ≥50% and ≥70% luminal narrowing on CCTA and ICA. A positive ICA or CCTA was defined as presence of ≥1 coronary artery segment with obstructive CAD, and a true positive was defined as the presence of ≥1 coronary artery segment considered to have an obstructive stenosis by both CCTA and ICA, irrespective of location. Coronary arteries for data analysis were defined as follows: (1) left main artery; (2) left anterior descending artery including the diagonal branches (Ramus Intermedius arteries were considered to be the first diagonal branch for per vessel analysis); (3) left circumflex artery including the obtuse marginal branches; and (4) right coronary artery inclusive of posterior descending artery and postero-lateral marginal branch.

2.6. Statistical analysis

The initial analysis was performed for the description of demographic characteristics in the full study population. In this step, the patients' LVEF was stratified by four levels: LVEF < 40, 40 ≤ LVEF < 50, 50 ≤ LVEF < 60, and LVEF ≥ 60. These LVEF cutoffs were chosen based on commonly used definitions of reduced/preserved LV systolic function [21,22]. The ANOVA was used to assess the linear trend of parameters in these four groups, and post hoc testing was undertaken using the Dunnett's multiple comparison test. In the second step, the accuracy of MDCT angiography in left ventricular systolic dysfunction was tested by calculating the sensitivity, specificity, accuracy, PPV, and NPV. In the third step, in order to evaluate the agreement of the diagnoses for patients with moderate stenosis (50%–69%) and severe stenosis (blockage greater than 70%) as well, the kappa coefficient was computed. Differences were considered to be statistically significant when P < 0.05. All statistical analyses were performed using SAS 9.3 (SAS Institute, Cary, NC).

3. Results

A total of 537 patients were included in the analysis: 305 with LVEF ≥60%, 150 with LVEF 50%–60%, 55 with LVEF 40%–50%, and 27 with LVEF <40%. 215 of these were from the prospective ACCURACY cohort, while the remaining 322 were part of the retrospective cohort. The mean age of the study population was 62 ± 12 years. Eighty-two (15.3%) patients had left ventricular systolic dysfunction (as defined by LVEF < 50%). In terms of risk factor profile, there were statistically significant differences across groups for hyperlipidemia (highest in 40%–50% cohort), family history (highest in <40% cohort), diabetes mellitus (highest in ≥60% cohort), and current smokers (highest in 50%–60% cohort), although no particular trend was evident (Table 1). There was no significant difference in terms of prevalence of either ≥50 or ≥70% coronary stenosis on ICA.

CCTA correctly identified ≥50% coronary artery stenosis in 50 out of 52 (96.2%) patients with impaired LVEF and 232 out of 237 (97.8%) patients with normal LVEF; it correctly identified ≥70% coronary artery stenosis in 40 (97.6%) out of 41 patients with impaired LVEF and 176 (94.1%) out of 187 patients with normal LVEF. AUC for identification of ≥50% stenosis was 0.92 for patients with LVEF <40%, 0.89 in patients with LVEF 40%–50%, 0.92 in patients with LVEF 50%–60%, and 0.92 in patients with LVEF >60%. AUC for identification of ≥70% stenosis was 0.97 for patients with LVEF <40%, 0.91 in patients with LVEF 40%–50%, 0.93 in patients with LVEF 50%–60%, and 0.90 in patients with LVEF >60% (Table 2).

Overall diagnostic accuracy was good, with excellent sensitivity of 97.6% (95% CI = 95.1–98.8), specificity of 84.9% (95% CI = 79.9–88.8), PPV of 88.4% (95% CI = 84.4–91.5), and NPV of 96.7 (95% CI = 93.4–98.4) to detect 50% stenosis. Accuracy was similarly good for detecting 70% stenosis, with sensitivity of 94.7% (95% CI = 91.0–97.0), specificity of 87.6% (95% CI = 83.4–90.8), PPV of 85.0% (95% CI = 80.1–88.9), and NPV of 95.7 (95% CI = 92.7–97.5). There was no significant difference in sensitivity, specificity, and positive or negative predictive values between LVEF cohorts (*p* for difference: 0.336 for the detection of stenosis >50% and 0.139 for the detection of stenosis >70%, respectively). Diagnostic parameters as stratified by LVEF are displayed in Tables 2–6.

4. Discussion

This is the largest study to date assessing the diagnostic performance of 64-slice multidetector CCTA to detect coronary artery stenosis across a wide spectrum of LVEF, including a significant number of patients with LV dysfunction. Our study demonstrated excellent diagnostic accuracy in heart failure patients, particularly sensitivity and negative predictive value, as is consistent with prior large prospective trials [9–11]. Most significantly, it did not reveal any significant difference between LVEF cohorts for any of the diagnostic parameters, which suggests that CCTA accurately detects obstructive CAD regardless of the presence of systolic dysfunction.

Table 1
Demographic characteristics of study population.

	LVEF < 40	40 ≤ LVEF < 50	50 ≤ LVEF < 60	LVEF ≥ 60	*P*-value
	n = 27	*n* = 55	*n* = 150	*n* = 305	
Age, years	61.3 ± 12.1	63.0 ± 10.8	61.4 ± 11.8	61.3 ± 12.5	0.82
Gender					0.58
Female	12 (44.4)	19 (34.5)	68 (45.3)	129 (42.3)	
Male	15 (55.6)	36 (65.5)	82 (54.7)	176 (57.7)	
BMI, kg/m^2	29.4 ± 7.5	29.8 ± 5.3	30.3 ± 5.8	31.1 ± 6.2	0.50
Race/Ethnic, *n* (%)					0.11
Caucasian	12 (46.2)	30 (63.8)	89 (62.7)	187 (67.3)	
African American	5 (19.2)	2 (4.3)	7 (4.9)	15 (5.4)	
Hispanic	6 (23.1)	8 (17.0)	19 (13.4)	24 (8.6)	
Asian	0 (0.0)	1 (2.1)	3 (2.1)	7 (2.5)	
Other	3 (11.5)	6 (12.8)	24 (16.9)	45 (16.2)	
Hyperlipidemia, *n* (%)	10 (43.5)	37 (67.3)	84 (56.8)	146 (50.2)	<0.001
Family history, *n* (%)	14 (60.9)	33 (60.0)	68 (45.9)	157 (53.8)	0.02
Hypertension, *n* (%)	5 (21.7)	17 (30.9)	72 (49.0)	140 (48.3)	0.17
Diabetes mellitus, *n* (%)	6 (26.1)	9 (18.0)	29 (20.1)	88 (30.9)	<0.001
Current smoker, *n* (%)	3 (13.0)	4 (8.0)	24 (16.7)	36 (12.6)	0.006
Prevalence >50% stenosis	15 (55.6)	37 (67.3)	83 (55.3)	156 (51.1)	0.17
Prevalence >70% stenosis	12 (44.4)	29 (52.7)	72 (48.0)	116 (38.0)	0.08

BMI: body mass index.

Table 2
Accuracy of MDCT angiography in left ventricular systolic dysfunction in full population.

	LVEF < 40 ($n = 27$)		40 ≤ LVEF < 50 ($n = 55$)		50 ≤ LVEF < 60 ($n = 150$)		LVEF ≥ 60 ($n = 305$)	
	>50%	>70%	>50%	>70%	>50%	>70%	>50%	>70%
Sensitivity	100%	100%	94.6%	96.6%	100%	97.2%	96.8%	92.2%
Specificity	83.3%	93.3%	83.3%	84.6%	83.6%	89.6%	85.9%	86.8%
PPV	88.2%	92.3%	92.1%	87.5%	88.4%	89.6%	87.8%	81.1%
NPV	100%	100%	88.2%	95.7%	100%	97.2%	96.2%	94.8%
LR+	–	–	5.68	6.28	–	9.35	6.87	6.97
LR−	–	–	0.06	0.04	–	0.03	0.04	0.09
AUC	0.92	0.97	0.89	0.91	0.92	0.93	0.92	0.9

PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR−: negative likelihood ratio; AUC: area under curve.

Table 4
Accuracy of MDCT angiography (40 ≤ LVEF < 50, $n = 55$).

	Stenosis > 50%		Stenosis >70%	
		95%CI		95%CI
Sensitivity	94.6%	0.82, 0.99	96.6%	0.82,0.99
Specificity	83.3%	0.59, 0.96	84.6%	0.65,0.96
PPV	92.1%	0.79, 0.98	87.5%	0.71,0.96
NPV	88.2%	0.64, 0.99	95.7%	0.78,0.99
LR+	5.68	2.01, 15.9	6.28	2.54,15.49
LR−	0.06	0.02, 0.25	0.04	0.05,0.28
AUC	0.89	0.79, 0.99	0.91	0.83,0.98

PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR−: negative likelihood ratio; AUC: area under curve.

The excellent diagnostic accuracy of CCTA in heart failure patients further supports its role as a promising noninvasive modality for the workup of CAD in heart failure patients. Its high sensitivity and negative predictive value in heart failure patients make it very effective for detecting and ruling out CAD, while its relatively high specificity and positive predictive value give it a distinctive advantage over ischemia-driven functional tests, which are relatively sensitive but at best moderately specific in detecting high-grade coronary stenosis [7,8]. CCTA has also been shown in other studies to be highly accurate on a per-vessel basis, thus also allowing it to characterize the extent of CAD and provide additional prognostic information not given by functional tests [4,9]. Therefore, while conventional ICA remains the gold standard for working up patients with a high pretest probability of having CAD given the option to simultaneously revascularize stenotic lesions, CCTA may be useful in the context of patients with low-to-intermediate pretest probability of having CAD, especially if traditional noninvasive imaging such as echocardiogram is nondiagnostic.

Before CCTA can be considered as part of the workup of HF patients, its risks must be weighed against its benefits. The administration of nephrotoxic contrast is necessary in both CCTA and invasive angiography, although it is a significant risk compared to echocardiogram or nuclear imaging and must be considered when choosing between imaging modalities. The exposure to radiation has traditionally been significantly greater in CCTA than ICA, although a growing proportion of CCTA studies are performed with prospective ECG-gating, which reduces effective radiation doses by 80% [23] and compares favorably to radioisotope stress perfusion imaging [24] as well as conventional ICA [25]. Most of the CCTA's in our study were performed with retrospectively gated helical data acquisition, as the prospective ECG-gated technique was introduced fairly recently; however, the image quality of these gating methods appears to be comparable [26].

There are several limitations of our findings. First, the study population was sampled from two heterogeneous cohorts with a large portion of data acquired retrospectively, thus implying a substantial risk of referral, spectrum, and ascertainment bias (non-random selection of patients being referred for invasive coronary angiography upon CCTA yielding to higher-than-expected prevalence of CAD). This approach was taken in order to improve the power of our study and to widen the applicability of our results to a "real life" population. A different analysis utilizing the same database of patients showed no significant difference in diagnostic performance of CCTA within the two cohorts, thus suggesting that bias was in fact minimal [27]. Second, the patients in our study population were all referred for the workup of chest pain symptoms. The current guidelines recommend consideration of noninvasive workup of CAD in heart failure patients without chest pain, and it is not clear how well our results would apply to these patients. Third, the presence of CAD in a patient with heart failure does not necessarily imply causality of ischemic cardiomyopathy, and should be assessed in the context of the rest of the patient's clinical and imaging findings, such as evidence of prior myocardial infarct. This is a limitation of invasive catheterization as well as CCTA, although CCTA can also demonstrate other structural evidence of myocardial infarct [28–30].

In conclusion, 64-multidetector CCTA is very sensitive and fairly specific for detecting coronary stenosis in patients with chest pain regardless of left ventricular systolic function at presentation. In our study, CCTA was able to detect all patients with CAD and impaired LVEF, with a sensitivity and negative predictive value of 100% in this cohort. Thus, CCTA is an excellent filter for patients with reduced ejection fraction to identify those with ischemic cardiomyopathy who may benefit from medical anti-ischemic optimization or revascularization.

Authors with the respective contribution

Danny Lee, MD—analysis and interpretation of data, drafting, and final approval of the manuscript.

Dong Li, MD, PhD—analysis and interpretation of data, drafting, and final approval of the manuscript.

Borut Jug, MD, PhD—conception and design, analysis and interpretation of data, drafting, and final approval of the manuscript.

Jenny Papazian, MD—conception and design, analysis and interpretation of data, drafting, and final approval of the manuscript.

Table 3
Accuracy of MDCT angiography (LVEF < 40, $n = 27$).

	Stenosis > 50%		Stenosis >70%	
		95%CI		95%CI
Sensitivity	100%	0.78, 1.0	100%	0.74, 1.0
Specificity	83.3%	0.52, 0.98	93.3%	0.68, 0.99
PPV	88.2%	0.64, 0.99	92.3%	0.64, 0.99
NPV	100%	0.69, 1.0	100%	0.77, 1.0
LR+	–	–	–	–
LR−	–	–	–	–
AUC	0.92	0.81, 1.0	0.97	0.90, 1.0

PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR−: negative likelihood ratio; AUC: area under curve.

Table 5
Accuracy of MDCT angiography (50 ≤ LVEF < 60, $n = 150$).

	Stenosis > 50%		Stenosis >70%	
		95%CI		95% CI
Sensitivity	100%	0.96, 1.0	97.2%	0.90, 0.99
Specificity	83.6%	0.73, 0.92	89.6%	0.81, 0.95
PPV	88.0%	0.80, 0.94	89.6%	0.81, 0.95
NPV	100%	0.94, 1.0	97.2%	0.90, 0.99
LR+	–	–	9.35	4.84, 18.04
LR−	–	–	0.03	0.008, 0.12
AUC	0.92	0.87, 0.96	0.93	0.89, 0.97

PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR−: negative likelihood ratio; AUC: area under curve.

Table 6
Accuracy of MDCT angiography (LVEF ≥ 60, $n = 305$).

	Stenosis > 50%		Stenosis >70%	
		95%CI		95%CI
Sensitivity	96.8%	0.93, 0.99	92.2%	0.86, 0.96
Specificity	85.9%	0.79, 0.91	86.8%	0.81, 0.91
PPV	87.8%	0.82, 0.92	81.1%	0.73, 0.87
NPV	96.2%	0.91, 0.99	94.8%	0.90, 0.98
LR+	6.87	4.62, 10.22	6.97	4.82, 10.09
LR−	0.04	0.02, 0.09	0.09	0.05, 0.17
AUC	0.92	0.88, 0.94	0.90	0.86, 0.93

PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR−: negative likelihood ratio; AUC: area under curve.

Matthew Budoff, MD—conception and design, analysis and interpretation of data, drafting, and final approval of the manuscript.

Disclosure of funding

Matthew J. Budoff is on the speaker's bureau for GE. No other author has any financial disclosures in relationship to this study.

Acknowledgments

The authors would like to thank Harpreet Bhatia and Ronald Karlsberg, MD, for providing additional data for analysis, as well as Mohit Gupta, MD, for assisting with compiling and organizing the data.

References

[1] He J, Ogden LG, Bazzano LA, Vupputuri S, Loria C, Whelton PK. Risk factors for congestive heart failure in US men and women: NHANES I epidemiologic follow-up study. Arch Intern Med 2001;161:996–1002.
[2] Hunt SA, Abraham WT, Chin MH, Feldman AM, Francis GS, Ganiats TG, et al. 2009 focused update incorporated into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the International Society for Heart and Lung Transplantation. Circulation 2009;119:e391–479.
[3] Bart BA, Shaw LK, McCants Jr CB, Fortin DF, Lee KL, Califf RM, et al. Clinical determinants of mortality in patients with angiographically diagnosed ischemic or nonischemic cardiomyopathy. J Am Coll Cardiol 1997;30:1002–8.
[4] Felker GM, Shaw LK, O'Connor CM. A standardized definition of ischemic cardiomyopathy for use in clinical research. J Am Coll Cardiol 2002;39:210–8.
[5] Allman KC, Shaw LJ, Hachamovitch R, Udelson JE. Myocardial viability testing and impact of revascularization on prognosis in patients with coronary artery disease and left ventricular dysfunction: a meta-analysis. J Am Coll Cardiol 2002;39:1151–8.
[6] Passamani E, Davis KB, Gillespie MJ, Killip T. A randomized trial of coronary artery bypass surgery. Survival of patients with a low ejection fraction. N Engl J Med 1985;312:1665–71.
[7] Yamaguchi S, Tsuiki K, Hayasaka M, Yasui S. Segmental wall motion abnormalities in dilated cardiomyopathy: hemodynamic characteristics and comparison with thallium-201 myocardial scintigraphy. Am Heart J 1987;113:1123–8.
[8] Bax JJ, Boogers MM, Schuijf JD. Nuclear imaging in heart failure. Cardiol Clin 2009;27:265–7.
[9] Budoff MJ, Dowe D, Jollis JG, Gitter M, Sutherland J, Halamert E, et al. Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. J Am Coll Cardiol 2008;52:1724–32.
[10] Meijboom WB, Meijs MF, Schuijf JD, Cramer MJ, Mollet NR, van Mieghem CA, et al. Diagnostic accuracy of 64-slice computed tomography coronary angiography: a prospective, multicenter, multivendor study. J Am Coll Cardiol 2008;52:2135–44.
[11] Miller JM, Rochitte CE, Dewey M, Arbab-Zadeh A, Niinuma H, Gottlieb I, et al. Diagnostic performance of coronary angiography by 64-row CT. N Engl J Med 2008;359:2324–36.
[12] Taylor AJ, Cerqueira M, Hodgson JM, Mark D, Min J, O'Gara P, et al. ACCF/SCCT/ACR/AHA/ASE/ASNC/NASCI/SCAI/SCMR 2010 appropriate use criteria for cardiac computed tomography. Circulation 2010;122:e525–55.
[13] Ghostine S, Caussin C, Habis M, Habib Y, Clément C, Sigal-Cinqualbre A, et al. Non-invasive diagnosis of ischaemic heart failure using 64-slice computed tomography. Eur Heart J 2008;29:2133–40.
[14] Andreini D, Pontone G, Bartorelli AL, Agostoni P, Mushtaq S, Bertella E, et al. Sixty-four-slice multidetector computed tomography: an accurate imaging modality for the evaluation of coronary arteries in dilated cardiomyopathy of unknown etiology. Circ Cardiovasc Imaging 2009;2:199–205.
[15] Srichai MB, Fisch M, Hecht E, Slater J, Rachofsky E, Hays AG, et al. Dual source computed tomography coronary angiography in new onset cardiomyopathy. World J Radiol 2012;4:258–64.
[16] Manghat NE, Morgan-Hughes GJ, Shaw SR, Broadley AJ, Gogola L, Marshall AJ, et al. Multi-detector row CT coronary angiography in patients with cardiomyopathy—initial single-centre experience. Clin Radiol 2007;62:632–8.
[17] Manghat NE, Morgan-Hughes GJ, Shaw SR, Marshall AJ, Roobottom CA. Impaired left ventricular function has a detrimental effect on image quality in multi-detector row CT coronary angiography. Clin Radiol 2008;63:415–23.
[18] Pagali SR, Madaj P, Gupta M, Nair S, Hamirani YS, Min JK, et al. Interobserver variations of plaque severity score and segment stenosis score in coronary arteries using 64 slice multidetector computed tomography: a substudy of the ACCURACY trial. J Cardiovasc Comput Tomogr 2010;4:312–8.
[19] Austen WG, Edwards JE, Frye RL, Gensini GG, Gott VL, Griffith LS, et al. A reporting system on patients evaluated for coronary artery disease. Report of the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. Circulation 1975;51:5–40.
[20] Bashore TM, Bates ER, Kern MJ, Berger PB, Laskey WK, Clark DA, et al. American College of Cardiology/Society for Cardiac Angiography and Interventions clinical expert consensus document on cardiac catheterization laboratory standards: summary of a report of the American College of Cardiology Task Force on clinical expert consensus documents. J Am Coll Cardiol 2001;37:2170–214.
[21] Yusuf S, Pfeffer MA, Swedberg K, Granger CB, Held P, McMurray JJ, et al. Effects of candesartan in patients with chronic heart failure and preserved left-ventricular ejection fraction: the CHARM-Preserved Trial. Lancet 2003;362:777–81.
[22] Sweitzer NK, Lopatin M, Yancy CW, Mills RM, Stevenson LW. Comparison of clinical features and outcomes of patients hospitalized with heart failure and normal ejection fraction (≥55%) vs those with mildly reduced (40–55%) and moderately to severely reduced (<40%) fractions. Am J Cardiol April 15, 2008;101:1151–6.
[23] Gerber TC, Carr JJ, Arai AE, Dixon RL, Ferrari VA, Gomes AS, et al. Ionizing radiation in cardiac imaging: a science advisory from the American Heart Association Committee on Cardiac Imaging of the Council on Clinical Cardiology and Committee on Cardiovascular Imaging and Intervention of the Council on Cardiovascular Radiology and Intervention. Circulation 2009;119:1056–65.
[24] Task Group of Committees 2 and 3 of the International Commission on Radiological Protection. Radiation dose to patients from radiopharmaceuticals—ICRP Publication 106 (Addendum 3 to ICRP publication 53). Ann ICRP 2008;38:1–197.
[25] Betsou S, Efstathopoulos E, Katritsis D, Faulkner K, Panayiotakis G. Patient radiation doses during cardiac catheterization procedures. Br J Radiol 1998;71:634–9.
[26] Menke J, Unterberg-Buchwald C, Staab W, Sohns JM, Seif Amir Hosseini A, Schwarz A. Head-to-head comparison of prospectively triggered vs retrospectively gated coronary computed tomography angiography: Meta-analysis of diagnostic accuracy, image quality, and radiation dose. Am Heart J 2013;165:154–63.
[27] Jug B, Gupta M, Papazian J, Li D, Tsang J, Bhatia H, et al. Diagnostic performance of 64-slice multidetector coronary computed tomographic angiography in women. J Nucl Cardiol 2012;19:1154–61.
[28] Lipton MJ, Bogaert J, Boxt LM, Reba RC. Imaging of ischemic heart disease. Eur Radiol 2002;12:1061–80.
[29] Ichikawa Y, Kitagawa K, Chino S, Ishida M, Matsuoka K, Tanigawa T, et al. Adipose tissue detected by multislice computed tomography in patients after myocardial infarction. JACC Cardiovasc Imaging 2009;2:548–55.
[30] Schuleri KH, Centola M, George RT, Amado LC, Evers KS, Kitagawa K, et al. Characterization of peri-infarct zone heterogeneity by contrast-enhanced multidetector computed tomography: a comparison with magnetic resonance imaging. J Am Coll Cardiol 2009;53:1699–707.