Limitations of four-slice multirow detector computed tomography in the detection of coronary stenosis

Eugenio Martuscelli, Cinzia Razzini, Alessia D'Eliseo, Massimo Marchei, Eliana Pisani, Francesco Romeo

Division of Cardiology, Department of Internal Medicine, "Tor Vergata" University, Rome, Italy

Key words:
Computed tomography; Coronary angiography; Coronary artery disease.

Background. **Our aim was to compare 4-slice spiral computed tomography with conventional coronary angiography in the detection of significant (> 50%) coronary stenosis.**

Methods. **Sixty-two patients (41 males, 21 females, mean age 60 ± 8 years) with suspected coronary artery disease were submitted to coronary angiography and then to multislice spiral computed tomography (GE Light Speed 4 slice) performed 12 ± 5 days later.**

Results. **We excluded 25% of the patients from analysis because of a heart rate > 70 b/min or because of frequent ectopic beats. We also excluded from analysis 23% of all the angiographic segments judged not evaluable at multislice spiral computed tomography. Within these limits, the sensitivity was 65%, the specificity 98%, the positive predictive value 88%, and the negative predictive value 92%.**

Conclusions. **By considering the intrinsic limitations such as its low temporal and spatial resolution, 4-slice spiral computed tomography has a limited applicability and has to be used with caution in the evaluation of native coronary arteries.**

(Ital Heart J 2004; 5 (2): 127-131)

Received July 17, 2003; revision received January 16, 2004; accepted January 20, 2004.

Address:

Dr. Eugenio Martuscelli

Via Cola di Rienzo, 212
00192 Roma
E-mail:
e.martuscelli@libero.it

Multislice spiral computed tomography (MSCT), magnetic resonance and electron beam computed tomography are challenging selective coronary angiography as the elective diagnostic technique for the detection of coronary artery stenosis[1-4]. None of these non-invasive techniques has the temporal resolution, spatial resolution and all round applicability of coronary angiography[5].

However, rapid technical improvements in terms of multidetection and reconstruction algorithms have boosted MSCT and recently moved this procedure from a pure initial investigational field toward the clinical setting.

The ease with which these investigations are performed gives rise to the risk that radiologists or cardiologists may apply them in a clinical setting without fully understanding their limitations. Therefore, it is of paramount importance to define the limitations of the new techniques in order to identify an appropriate role for each modality in the management of coronary artery disease.

Our intention was to compare 4-slice MSCT and conventional coronary angiography in patients referred to coronary angiography because of suspected coronary artery disease.

Methods

Sixty-two patients (41 males, 21 females, mean age 60 ± 8 years), consecutively submitted to coronary angiography for suspected coronary artery disease, were then submitted to MSCT performed 12 ± 5 days later. The exclusion criteria were hemodynamic instability, arrhythmias, heart rate > 70 b/min despite therapy, renal insufficiency, severe lung disease, severe heart failure, and unstable angina. A beta-blocker (atenolol 50-100 mg/day) was given to all patients at least 2 days before MSCT, in order to obtain a heart rate between 50-70 b/min[6,7].

Coronary angiography. Coronary angiography was performed using a Philips Integris 5000 (The Netherlands) with Dicom digital storage on CD. Quantitative coronary angiography was performed off-line with an automatic edge detection program (PMS program). Stenosis was quantified only in vessels > 2 mm in diameter[6]. A diameter reduction > 50% was defined as a significant stenosis.

Multislice computed tomography scan protocol. MSCT was performed using a GE Light Speed (Milwaukee, WI, USA) instrument. The gantry rotation was 0.5 s, with 4 slices acquired at every rotation (collimation 1.25 mm). The voxel data acquisition was anisotropic (1.25 × 0.59 × 0.59) with an estimated volume of 0.435 mm^3. A volume data set covering the distance from the carina to the inferior border of the heart was acquired.

The scan delay was determined by means of a bolus injection of 40 ml having as its region of interest the proximal tract of the ascending aorta. A total volume of 145 ml (4 ml/s) of non-ionic contrast agent was injected via an antecubital vein during a 27-30 s period of breath holding.

Cross-sectional images with a slice thickness of 1.25 mm were reconstructed by means of retrospective ECG gating at 40, 70 and 80% of the cardiac cycle.

The data sets were analyzed by one cardiologist and one radiologist using the original axial images and multiplanar reconstruction. The coronary arteries were classified as evaluable or non-evaluable by visual estimation. In the evaluable arteries we assessed the presence of significant stenosis (> 50% diameter reduction).

The diagnostic accuracy of MSCT was evaluated in terms of its sensitivity and specificity for the identification of patients with significant coronary artery disease, for the evaluation of the extent of coronary artery disease, and for the identification of the single lesion.

Results

In 7 patients (11%) MSCT was not performed because of a heart rate > 70 b/min or due to the presence of frequent ectopic beats before contrast injection. MSCT was performed without complications in 55 patients.

Eight more patients were excluded from the analysis because of motion artifacts, due to an uncontrolled heart rate and/or ectopic beats during the infusion of contrast medium.

We analyzed the data of 47/62 patients (75%). The mean heart rate during infusion was 59 ± 3 b/min. The mean scan duration was 22 s (range 19-24 s).

Of 551 angiographic segments ≥ 2 mm, 416 (77%) were judged evaluable at MSCT. Table I shows the details of the vessels and segments evaluated.

The rate of evaluability was high for the left anterior descending coronary artery (93%), low for the right coronary artery (54%), and very low for the marginal branches (40%). The most frequent reasons for an impaired evaluability were motion artifacts and severe vessel calcification[8-11].

In the 416 segments evaluated at 4-slice MSCT, 89 coronary stenoses were detected at selective angiography. MSCT correctly identified 54 stenoses with a sensitivity of 65%, a specificity of 98%, a positive predictive value of 88%, and a negative predictive value of 92% (Figs. 1 and 2).

With the limitation of the evaluability of only 77% of the angiographic segments, the value of MSCT in evaluating the entire coronary tree was as follows:

Table I. Evaluability by multislice computed tomography (MSCT) for each coronary segment and entire vessel.

	LM	LAD	LAD			Diag	Cx	Cx		Marg	Inter	RCA	RCA			PDA
			Prox	Middle	Distal			Prox	Distal				Prox	Middle	Distal	
No. angiographic segments	47	44	46	45	47	47	46	47	46	47	5	44	46	44	44	47
No. MSCT evaluable segments	43	40	43	41	41	17	39	41	39	19	5	24	43	36	31	28
Percentage	91	91	93	91	87	36	85	87	85	40	100	54	93	80	70	59

Cx = left circumflex artery; Diag = diagonal branch; Inter = intermediate branch; LAD = left anterior descending coronary artery; LM = left main trunk; Marg = marginal branch; PDA = posterior descending coronary artery; Prox = proximal; RCA = right coronary artery.

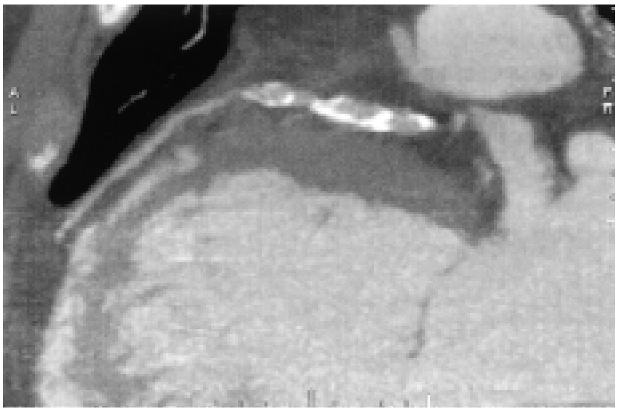

Figure 1. *Four-slice computed tomography shows multiple critical stenoses in the middle tract of the left anterior descending coronary artery (left anterior oblique 90°).*

Figure 2. *Angiography confirms the presence of multiple critical stenoses in the middle tract of the left anterior descending coronary artery (maximal intensity projection, multiplanar reconstruction).*

- the sensitivity and specificity of MSCT in identifying patients as having significant coronary artery disease were very high (sensitivity 94%, specificity 100%);
- the accuracy of MSCT in identifying patients as having 1-2-3 vessel disease is shown in table II;
- the accuracy of MSCT in identifying the single lesion is shown in table III;
- table IV shows the accuracy of MSCT in identifying

Table II. Accuracy of multislice computed tomography in the detection of patients with 1, 2 and 3 vessel disease.

Variable	1 vessel	2 vessels	3 vessels
Prevalence	11/47 (23%)	6/47 (13%)	13/47 (28%)
Sensitivity (%)	73	67	54
Specificity (%)	91	90	100
Accuracy (%)	87	87	87
Positive predictive value (%)	73	50	100
Negative predictive value (%)	91	95	85

Table III. Accuracy of multislice computed tomography in the detection of significant stenoses for each evaluable coronary segment and entire vessel.

Variable	LAD	LAD			Diag	Cx	Cx		Marg	Inter	RCA	RCA			PDA
		Prox	Middle	Distal			Prox	Distal				Prox	Middle	Distal	
Prevalence (%)	62	21	41	7	23	26	19	8	10	60	25	16	25	6	14
Sensitivity (%)	72	67	82	67	75	20	43	0	100	67	72	71	78	100	75
Specificity (%)	95	92	92	100	92	98	97	100	94	100	99	100	96	100	100
Accuracy (%)	90	87	88	97	88	88	88	92	95	80	96	95	92	100	96
Positive predictive value (%)	78	67	87	100	75	67	75	0	67	100	89	100	87	100	100
Negative predictive value (%)	93	92	88	97	92	89	89	92	100	67	96	95	93	100	96

Cx = left circumflex artery; Diag = diagonal branch; Inter = intermediate branch; LAD = left anterior descending coronary artery; Marg = marginal branch; PDA = posterior descending coronary artery; Prox = proximal; RCA = right coronary artery.

Table IV. Accuracy of multislice computed tomography in the detection of coronary occlusion depending on collateral circulation.

Variable	Occlusion	
	With collateral circulation	Without collateral circulation
Prevalence (%)	35	8
Sensitivity (%)	72	75
Specificity (%)	91	100
Accuracy (%)	85	98
Positive predictive value (%)	81	100
Negative predictive value (%)	86	98

total vessel occlusions depending on the presence or absence of distal evaluation via a collateral circulation.

When the coronary segments judged unevaluable at 4-slice MSCT were included in the analysis, the overall accuracy was obviously less, with a sensitivity of 59% and a specificity of 97%.

Discussion

In the setting of coronary imaging, conventional coronary angiography serves as the gold standard technique: its temporal resolution is about 7-10 ms/image and its spatial resolution permits the characterization of coronary branches as small as 0.3 mm; calcium deposits and the heart rhythm do not interfere with the quality of images; the mortality is close to zero, the morbidity is very low, the duration of the procedure is 15-20 min[5], the radiation exposure is 89.1-191.3 R, and the effective dose is 3-10 mSv[12,13].

Compared to coronary angiography, 4-slice spiral computed tomography presents major limitations including its low temporal and limited spatial resolution; moreover, because of the modality of acquisition and reconstruction of the images, MSCT cannot provide any information about the flow characteristics of the coronary circulation[6,14-16].

As far as radiation exposure is concerned, the dose exposure during 4-slice MSCT is usually higher than that of coronary angiography with an effective dose of 9-11 mSv[12].

The presence of arrhythmias, severe calcifications, a heart rate > 70 b/min and the patient's inability to hold his breath for the full duration of the scan may result in a degradation of the image quality, impairing the evaluability of single coronary segments. In our study, 25% of the patients were excluded from analysis and, with regard to the patients analyzed, 23% of the angiographic segments were judged unevaluable because of an insufficient image quality.

Considering only evaluable segments, the sensitivity we obtained was 65% and the specificity 98%, with relevant differences as far as each coronary segment was concerned (Table I). In patients with occluded vessels without a collateral circulation, the sensitivity was higher (75%), with a specificity of 100% and a positive predictive value of 100% (Table IV).

We have no data regarding patients revascularized by stenting or coronary bypass and this represents a limitation of our study.

Our study confirms the data of Achenbach et al.[6] that 4-slice MSCT has a limited applicability in the clinical scenario. The overall sensitivity (evaluable + unevaluable segments) in the Achenbach study was 55% and 59% in our study, which is quite low compared to other non-invasive techniques[17].

New generation MSCT, able to simultaneously acquire 16 slices (collimation 0.625 mm) and equipped with more recent image reconstruction algorithms, seems to consistently increase the percentage of evaluable coronary segments and the overall accuracy of MSCT[18,19].

In conclusion, our data confirm that 4-slice MSCT has to be used with caution in the diagnosis of significant coronary disease because of the limited evaluability of the coronary segments and because of its relatively low overall sensitivity.

It is not yet possible to predict whether MSCT will become a viable alternative to selective coronary angiography in a substantial proportion of patients, or whether it will develop a niche role as an adjunct to other non-invasive methods.

Acknowledgments

Mark M. Gallagher, MD, MRCPI, for his contribution to the elaboration of the manuscript. Andrea Romagnoli, MD, for his relevant help in acquiring and analyzing the computed tomographic images.

References

1. Van Geuns RJ, de Bruin HG, Rensing BJ, et al. Magnetic resonance imaging of the coronary arteries: clinical results from three-dimensional evaluation of a respiratory gated technique. Heart 1999; 82: 515-9.
2. Achenbach S, Moshage W, Ropers D, Nossen J, Daniel WG. Value of electron-beam computed tomography for the noninvasive detection of high-grade coronary-artery stenoses and occlusions. N Engl J Med 1998; 339: 1964-71.
3. van Ooijen PM, Nieman K, de Feyter PJ, Oudkerk M. Noninvasive coronary angioscopy using electron beam computed tomography and multidetector computed tomography. Am J Cardiol 2002; 90: 998-1002.
4. Fayad Z, Fuster V, Nikolaou N, Becker C. Computed tomography and magnetic resonance imaging for noninvasive coronary angiography and plaque imaging: current and potential future concepts. Circulation 2002; 106: 2026-34.
5. Davidson CJ, Fishman RF, Bonow RO. Cardiac catheterization. In: Braunwald E, ed. Heart disease: a textbook of cardiovascular medicine. 6th edition. Philadelphia, PA: WB Saunders, 2001; 11: 359-86.

6. Achenbach S, Giesler T, Ropers D, et al. Detection of coronary artery stenoses by contrast-enhanced, retrospectively electrocardiographically-gated, multislice spiral computed tomography. Circulation 2001; 103: 2535-8.
7. Nieman K, Oudkerk M, Rensing BJ, et al. Coronary angiography with multi-slice computed tomography. Lancet 2001; 357: 599-603.
8. Woodhouse CE, Janowitz WR, Viamonte M Jr. Coronary arteries: retrospective cardiac gating technique to reduce cardiac motion artifact at spiral CT. Radiology 1997; 204: 566-9.
9. Kennedy J, Shavelle R, Wang S, Budoff M, Detrano RC. Coronary calcium and standard risk factors in symptomatic patients referred for coronary angiography. Am Heart J 1998; 135: 696-702.
10. Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M Jr, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. J Am Coll Cardiol 1990; 15: 827-32.
11. Haberl R, Becker A, Leber A, et al. Correlation of coronary calcification and angiographically documented stenoses in patients with suspected coronary artery disease: results of 1764 patients. J Am Coll Cardiol 2001; 37: 451-7.
12. Morin RL, Gerber TC, McCollough CH. Radiation dose in computed tomography of the heart. Circulation 2003; 107: 917-22.
13. Cusma JT, Bell MR, Wondrow MA, Taubel JP, Holmes DR Jr. Real-time measurement of radiation exposure to patients during diagnostic coronary angiography and percutaneous interventional procedures. J Am Coll Cardiol 1999; 33: 427-35.
14. Achenbach S, Ulzheimer S, Baum U, et al. Noninvasive coronary angiography by retrospectively ECG-gated multislice spiral CT. Circulation 2000; 102: 2823-8.
15. Nieman K, Rensing BJ, van Geuns RJ, et al. Usefulness of multislice computed tomography for detecting obstructive coronary artery disease. Am J Cardiol 2002; 89: 913-8.
16. Nieman K, Cademartiri F, Lemos PA, Raaijmakers R, Pattynama PM, de Feyter PJ. Reliable noninvasive coronary angiography with fast submillimeter multislice spiral computed tomography. Circulation 2002; 106: 2051-4.
17. Froelicher VF. Test da sforzo. In: Hurst Il cuore. X edizione italiana. Milano: McGraw-Hill, 2002: 535-7.
18. Ropers D, Baum U, Pohle K, et al. Detection of coronary artery stenoses with thin-slice multi-detector row spiral computed tomography and multiplanar reconstruction. Circulation 2003; 107: 664-6.
19. Flohr T, Bruder H, Stierstorfer K, Simon J, Schaller S, Ohnesorge B. New technical developments in multislice CT, part 2: sub-millimeter 16-slice scanning and increased gantry rotation speed for cardiac imaging. Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr 2002; 174: 1022-7.