HOSPITAL CHRONICLES 2008, SUPPLEMENT: 112–115

ATHENS CARDIOLOGY UPDATE 2008

Non-invasive Coronary Angiography: The Role, Limitations and Future of 64-slice Spiral CT Coronary Angiography

Arkadios C. Roussakis, MD

CT, MRI & PET/CT Department, "Hygeia" Hospital, Athens, Greece

Conventional selective X-ray coronary angiography (SCA) remains the undisputed standard of reference for the assessment of the lumen of coronary arteries. However, this is an invasive procedure with a small but not negligible health risk that needs even short hospitalization and causes patient discomfort. Among the more than 2.5 million examinations of SCA performed annually in U.S.A. and Europe, approximately 25% do not reveal essential findings and more than 40% are not followed by any kind of interventional or surgical procedure. [1] On the other hand, SCA does not provide any information concerning the coronary wall, while almost 80% of deadly myocardial infarctions are attributed to vulnerable plaques which did not cause hemodynamically severe stenoses. [2] Thus, an effort for the development of non-invasive techniques for visualization of the coronary arteries is justified. Ideally, such a technique should be capable of reliably excluding or detecting significant stenoses of the coronary lumen and, at the same time, of assessing the coronary wall and plaque structure. By means of computed tomography (CT), this goal is being accomplished with two techniques; electron beam CT (EBCT) and multislice spiral CT (MSCT).

EBCT was the first CT modality capable to provide diagnostic images of the proximal and mid segments of the coronary arteries, around 1995, but it was abandoned soon after the advent of MSCT technology. [3,4]

MULTI-SLICE COMPUTED TOMOGRAPHY (MSCT)

MSCT technology was introduced in 1998 and the first systems were capable to acquire up to 4 slices at a gantry rotation time of 500 msec. In 2002, there became commercially available scanners capable to obtain 16 slices per 500 msec or 12 slices per 420 msec. Thus, the total duration of the scanning (performed within one breath-hold), could be reduced from 38 sec to 16 or 20 sec, respectively. With the advent of 64-slice technology in 2004, the data acquisition time was further reduced to 5-12 sec and, at the same time, the capability of obtaining very thin slices (0.6-0.75 mm) offered high isotropic spatial resolution. As mechanical scanners with rotating x-ray tubes, MSCT scanners have an inherently limited temporal resolution (the time needed for data collection per cardiac cycle), which cannot be better than 165 ms with the 16- and 64-slice technology and, in general, with any scanner that uses a single X-ray tube. At high heart rates (HR), motion artifacts are often observed and degrade the image quality. This problem can be managed by the use of oral or intravenous (IV) β-receptor blocking agents. A heart rate between 50 and 60 beats per minute (bpm) is considered to be ideal and, if it remains during the data acquisition, it significantly

Address for correspondence:
Arkadios C. Roussakis, MD
E-mail: arkrous@hol.gr

increases the number of assessable coronary segments. Also, sublingual administration of nitrates, just a few minutes before the CT coronary angiography (CTCA), was found to result in significantly larger proximal coronary diameters and is now widely recommended for routine examinations.

MSCT coronary angiography is performed during a single breath-hold and the coronary lumen is opacified by a very fast (bolus) IV injection of an iodinated contrast medium (100 ml are generally sufficient with the latest technology scanners), followed by a flush bolus of 100 ml of normal saline. ECG is simoultaneously recorded during data acquisition, allowing retrospective gating and slice reconstruction at the most appropriate position within the cardiac cycle; this is, typically, the mid-to-end diastolic period, in order to minimize motion artifacts, but it may vary for each coronary branch (particularly at faster heart rate). [5]

The evolution from 4-slice to 64-slice technology permitted significant decrease of the breath-hold duration (from 35-40 sec to 5-12 sec) and of the amount of iodinated contrast medium needed (from 180 to 100 ml). Also, the spatial resolution improved. The direct benefit was the significant improvement of the proportion of the evaluable coronary segments (from 70% to 95%, approx.). Additionally, a significant improvement of all the parameters of diagnostic performance of CTCA, both at patient and coronary segment level, was validated. [4-10]

CT CORONARY ANGIOGRAPHY: CLINICAL DATA

There are cumulative data from the literature, providing validation of CTCA in comparison to SCA, for detecting significant coronary artery stenoses. All the studies reported a very high negative predictive value (NPV) as a major strenth of this modality. Many recently published studies, comparing 64-slice CTCA with SCA in patients with suspected coronary artery disease (CAD), showed, at coronary segment level, a sensitivity of 88-97% (average 93%), a specificity of 96-97% (average 96%), a PPV of 66-87% and an excellent NPV of 99% for detecting stenoses >50% at coronary segments with a lumen diameter >1.5 mm. Overall 85-100% of all coronary segments could be evaluated with CTCA, depending on the selection criteria of the population of each study. At patient-based detection, sensitivity and specificity were up to100%. However, high-performance results achieved at academic sites with high expertise are propably not reproducible at a wider practice of CTCA. Additionally, the results are influenced by the patient selection criteria. [10-17]

Very recently, the technology of 64-slice dual-source MSCT, introduced by Siemens, became commercially available and established new milestones in non-invasive coronary imaging. By using two coupled X-ray tubes, it is the first MSCT scanner to achieve a true temporal resolution of 83 ms, thus permitting reliable visualization of the distal coronary arteries even with high heart rates and, in most cases, obviating the need for β-blockers. Examinations of good to excellent quality, even in cases of arrhythmia or atrial fibrillaton, are now routenily acquired with that new technology. Additionally, a significant decrease of the mean radiation dose seems to be achievable. [18,19]

INDICATIONS FOR CT CORONARY ANGIOGRAPHY (CTCA)

Until now, there are no official guidelines or a generally accepted consensus for the use of CTCA. Evolving and proposed indications include: [20]

a. detection of congenital anomalies of the coronary arteries: this goal can be reliably accomplished with magnetic resonance imaging (MRI), obviating the need for iodinated contrast medium and without exposure to ionizing radiation.
b. exclusion of CAD in individuals with low-to-moderate pretest propability: asymptomatic high-risk, patients with atypical chest pain and/or equivocal stress-test results.
c. patients with a SCA that was incomplete or failed to visualize a major coronary branch or posed the suspicion of left main coronary artery stenosis.
d. evaluation of by-pass grafts: CTCA is highly accurate in confirming patency or occlusion, but its accuracy for evaluating the degree of graft stenosis has not been well established yet. Since the advent of 64-slice scanners, it seems to be reliable in assessing graft stenosis, patency of the anastomosis with the native artery and visualization of the lumen of the more distal coronary segments. [21]
e. evaluation of the coronary arteries in patients scheduled to undergo non-coronary cardiovascular surgery, such as valve replacement and aortic aneurysm repair.
f. patients with atrial fibrillation, prior to administration of anti-arrhythmic drugs and catheter ablation.
h. patients presenting with acute chest pain in the emergency department, without specific ECG-changes and normal levels of cardiac enzymes: CTCA can be used effectively for detecting or excluding (with a single examination) CAD, aortic dissection or rupture and pulmonary embolism (“triple rule-out”). [22-24]

LIMITATIONS

It should be noted that CTCA is not yet proven to be suitable for evaluating patients with already known or very propable CAD, since its accuracy for grading the degree of lumen stenosis -especially from heavily calcified plaques- is not yet established.

CTCA may be impaired from artifacts caused by dense calcifications and other hyperdense structures, such as surgical clips, sternal sutures and stents. Practically, patients with a high calcium score cannot be reliably evaluated by CTCA. Heavily calcified plaques, especially those with a concentric pattern, are accompanied by the "blooming artifact" which often precludes accurate evaluation of the degree of lumen stenosis, usually leading to overestimation. [13,25] Obese patients can now be examined more reliably, by using the latest 64-slice technology, even accepting the lower image quality and at the expense of higher radiation dose. The lumen within coronary stents cannot be routinely well visualized, but patency of the stented segment can usually be assessed. The assessability of a stent depends on its particular structure and size and varies significantly among the different stent types. A recent study using the 64-slice technology showed very promising results for assessing in-stent restenosis, but wider studies are needed to validate this reported high diagnostic performance. [26]

The need for IV injection of a significant quantity of iodinated contrast medium and the exposure to radiation are the main disadvantages of CT, compared to MRI, and preclude its use in patients with renal insufficiency or allergy to iodine and in pregnant women. However, the image quality of a non-invasive coronary angiography (in terms of spatial resolution and contrast-to-noise ratio) using CT, is by far better compared to MRI.

The issue of radiation exposure has to be seriously considered, especially when the possible role of CTCA as a screening tool in high-risk asymptomatic patients is discussed. Using state-of-the-art 64-slice scanners, the effective radiation dose during CTCA was measured equal to 10-15 mSv in men and 14-21.4 mSv in women. [10-14] This is higher of the average dose of diagnostic SCA (up to 11.4 mSv) and comparable to that of thallium or technetium myocardial scintigraphy (8-18 mSv). However, recent data and our initial personal experience by using dual-source 64-slice CTCA with ECG-tube modulation (which reduces the X-ray tube current and, cosequently, the radiation exposure during the part of the cardiac cycle where data are not selected) show a significant decrease of the average radiation dose. [27] In any case, CTCA should be avoided in young patients and, especially, young women.

CORONARY VESSEL WALL ASSESSMENT

Besides evaluating the coronary lumen, CTCA is currently the only available tool for non-invasive assessment of the coronary vessel wall. By using 64-slice and newer technology, the coronary plaques can now be reliably detected and classified, according to their density, into calcified, non-calcified (soft) and mixed. Exact localization and estimation of the total atherosclerotic plaque burden (plaque volumetry) and, also, detection of the positive or negative remodeling of the coronary vessel wall, are now feasible. The capability of accurate and reproducible plaque volumetry could be used in monitoring the therapeutic result of lipid lowering therapy. However, current resolution of CTCA does not allow detection of certain characteristics of the vulnerable plaque, such as a thin fibrous cap, a lipid core or inflammation. [28-30]

CARDIAC ANATOMY & FUNCTION

Beyond the visualization of coronary arteries, the same data set that is acquired during CTCA, also contains valuable information that can be used for assessment of the morphology and function of cardiac ventricles, with accuracy similar to that of MRI, morphological and functional evaluation of cardiac valves, with results comparable to echocardiography, and estimation of myocardial viability, with an accuracy comparable to that of MRI. [31-34]

FUTURE PERSPECTIVE

Awaiting the results of large studies using the 64-slice double-source technology, the first 256-slices single-source scanners, allowing examination of the entire heart during one heartbeat, are already available in a few academic sites. There is, also, an ongoing promising research on flat-pannel CT technology. In parallel, there is a continuous and intense effort for effective reduction of the radiation dose.

REFERENCES

1. American Heart Association. Cardiovascular facts sheets: cardiovascular procedures. http:www.americanheart.org/statistics/htm.2008.
2. Burke AP, Farb A, Malcom GT, et al. Coronary risk factors and plaque morphology in men with coronary disease who died suddenly. *N Engl J Med* 1997;336:1276-82.
3. Moshage W, Achenbach S, Seese B, et al. Coronary artery stenoses: three dimensional imaging with electrocardiographically triggered, contrast enhanced, electron beam CT. *Radiology* 1995;196:707-714.
4. Leber AW, Knez A, Becker C, et al. Non-invasive intravenous coronary angiography using electron beam tomography and multislice computed tomography. *Heart* 2003;89:633-9.
5. Dewey M, Hamm B. CT coronary angiography: examination technique, clinical results and outlook on future developments. *Rofo* 2007;179:246-60.
6. Achenbach S, Giesler T, Ropers D, et al. Detection of coronary artery stenoses by contrast enhanced, retrospectively electrocardiographically-gated, multi-slice spiral computed tomography. *Circulation* 2001;103:2535-8.
7. Becker CR, Knez A, Leber A, et al. Detection of coronary ar-

tery stenoses with multislice helical CT angiography. *J Comput Assist Tomogr* 2002;26:750-5.
8. Niemann K, Cademartiri F, Lemos PA, et al. Reliable noninvasive coronary angiography with fast submillimeter multislice spiral computed tomography. *Circulation* 2002;106:2051-4.
9. 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.
10. Stein PD, Beemath A, Kayali F, et al. Multidetector computed tomography for the diagnosis of coronary artery disease: a systematic review. *Am J Med* 2006;119:203-16..
11. Leshka S, Alkadhi H, Plass A, et al. Accuracy of MSCT coronary angiography using 64-slice technology: first experience. *Eur Heart J* 2005;26:1482-7.
12. Leber A, Knez A, von Ziegler F, et al. Quantification of obstructive and non obstructive coronary lesions by 64-slice computed tomography; a comparative study with quantitative coronary angiography and intravascular ultrasound. *J Am Coll Cardiol* 2005; 46:147-54.
13. Raff G, Gallagher MJ, O'Neill WW, Goldstein JA. Diagnostic accuracy of nonnivasive coronary angiography using 64-slice spiral computed tomography. *J Am Coll Cardiol* 2005;46:552-7.
14. Mollet NR, Cademartiri F, van Mieghem CA, et al. High-resolution spiral CT coronary angiography in patients referred for diagnostic conventional coronary angiography. *Circulation* 2005;112 :2318-23.
15. Nikolaou K, Knez A, Rist C, et al. Accuracy of 64-MDCT in the diagnosis of ischemic heart disease. *Am J Roentgenol* 2006;187:111-7.
16. Ropers D, Rixe J, Anders K, et al. Usefulness of multidetector row spiral CT with 64- X 0.6-mm collimation and 330-ms rotation for the noninvasive detection of significant coronary artery stenosis. *Am J Cardiol* 2006;97:343-8.
17. Hammon M, Biondi-Zoccai GG, Malagutti P, et al. Diagnostic performance of multislice spiral CT of coronary arteries as compared with conventional invasive coronary angiography: a meta-analysis. *J Am Coll Cardiol* 2006;48:1896-910.
18. Flohr TG, McCollough CH, Bruder H, et al. First performance evaluation of a dual-source CT (DSCT) system. *Eur Radiol* 2006;16:256-68.
19. Achenbach S, Ropers D, Kuettner A, et al. Contrast-enhanced coronary artery visualization by dual-source computed tomography-initial experience. *Eur J Radiol* 2006;57:331-5.
20. Schmermund A, Erbel R. Non-invasive computed tomographic coronary angiography: the end of the beginning. *Eur Heart J* 2005;26:1451-3.
21. Gilkeson RC, Markowitz AH. Multislice CT evaluation of coronary artery bypass graft patients. *J Thorac Imaging* 2007;22:56-62.
22. Goldstein JA, Gallagher MJ, O'Neill WW, et al. A randomized controlled trial of multi-slice coronary computed tomography for evaluation of acute chest pain. *J Am Coll Cardiol* 2007;48:863-71.
23. Vrachliotis TG, Bis KG, Haidary A, et al. Atypical chest pain: coronary, aortic and pulmonary vasculature enhancement at biphasic single injection 64-section CT angiography. *Radiology* 2007;243:368-76.
24. Schussler JM, Smith ER. Sixty-four-slice CT coronary angiography: will the „triple rule out" change pain evaluation in the ED? *Am J Emerg Med* 2007;25:367-75.
25. Ong TK, Chin SP, Liew CK, et al. Accuracy of 64-row multidetector CT in detecting coronary artery disease in 134 symptomatic patients: influence of calcification. *Am Heart J* 2006;151:1323.e1-6.
26. Cademartiri F, Schuijf JD, Pugliese F, et al. Usefulness of 64-slice multislice CT coronary angiography to assess in-stent restenosis. *J Am Coll Cardiol* 2007;49:2204-10.
27. Weustnik AC, Meijboom WB, Mollet N, et al. Reliable high-speed coronary CT in symptomatic patients. *J Am Coll Cardiol* 2007;50:786-94.
28. Hoffman U, Butler J. Noninvasive detection of coronary arherosclerotic plaques by multidetector row CT. *Int J Obes* 2005;29(suppl2):546-53.
29. Carrascosa PM, Capunay GM, Garrdia-Merletti P, et al. Characterization of coronary atherosclerotic plaques by multidetector CT. *Am J Cardiol* 2006;97:598-602.
30. Motoyama S, Kondo T, Anno H, et al. Atherosclerotic plaque characterization by 0.5-mm-slice multislice CT imaging. *Circ J* 2007;71:363-6.
31. Orakzai SH, Orakzai RH, Nasir K, Budoff MJ. Assessment of cardiac function using multidetector row computed tomography. *J Comut Assist Tomogr* 2006;30:555-63.
32. Juergens KU, Fischbach R. Left ventricular function studied with MDCT. *Eur Radiol* 2006;16(2):342-57.
33. Pannu HK, Jakobs JE, Lai S, Fischman EK. Gated cardiac imaging of the aortic valve on 64-slice multidetector row CT: preliminary observations. *J Comut Assis Tomogr* 2006;30:443-6.
34. Francone M, Carbone I, Danti M, et al. ECG-gated multidetector row spiral CT in the assessment of myocardial infarction: correlation with non-invasive angiographic findings. *Eur Radiol* 2006;16(1):15-24.