Progress in noninvasive coronary artery imaging using multislice CT

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Conventional coronary angiography (CAG) has been the reference standard for the assessment of coronary artery disease since its introduction in 1958. However, several studies have shown that diagnostic CAG has an average morbidity of 2% and a mortality of approximately 0.1%.[1,2]

In the last decade, progress in medical imaging has opened the way to noninvasive assessment of the coronary arteries at lower cost and risk. Of the different modalities, multislice CT (MSCT) has made the biggest step forward. At the 2005 European Congress of Radiology (ECR), experiences with the latest developments in noninvasive coronary artery imaging were reported.[3] This report summarises the advances in the use of MSCT in coronary stenosis detection, emergency decision-making, plaque imaging, and the analysis of cardiac function and late enhancement. Also, attention is paid to new strategies to reduce MSCT-related radiation exposure. (*Neth Heart J* 2005; 13:312-4.)

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Multislice CT

In 1998, the four-slice CT scanner was introduced. It could acquire four slices simultaneously, and at high rotation speed. This made detailed imaging of the whole heart within one breathhold feasible. Rapid advances led to the introduction of the 16-slice CT in 2001 and 40- and 64-slice CT in 2004. In selected populations, 16-slice CT was demonstrated to detect coronary artery stenosis in vessels over 2 mm diameter with 63 to 95% sensitivity, 96 to 98% specificity, 64 to 87% positive predictive value and 96 to 99% negative predictive value in a per-vessel analysis.[4,5] Especially its high negative predictive value may enable coronary CT angiography (CTA) to serve as a reliable preselection tool for CAG in patients with atypical chest pain or inconclusive stress tests. The technique may also be able to correctly determine which patients with acute coronary syndrome (ACS) would benefit from percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG), and thus lead to a reduction in diagnostic CAGs. MSCT has always suffered from several practical limitations. Firstly, due to limited temporal resolution heart rate must be low and regular to achieve good results. Therefore, most centres reduce heart rate with medication. However, adequate heart rate reduction is not achievable in every patient. Arrhythmias, especially atrial fibrillation and ventricular extrasystoles, may prevent adequate scan quality. Even ECG editing, a software approach to improve scan quality with an irregular heart rhythm, is often insufficient. Secondly, temporal and spatial resolution with 16-slice CT is still inadequate to reliably evaluate distal segments and stent lumen. Thirdly, coronary calcium frequently causes artifacts that lead to overestimation of plaque size, and hence of stenosis. Fourthly, the radiation dose seems too high to justify screening in low risk or young populations. Last year's developments, especially the advent of the 40- and 64-slice MSCT scanner, were expected to (partially) overcome these problems.

Wintersperger (Munich, Germany) evaluated the impact of heart rate on image quality using the Siemens 64-slice CT scanner. Image quality for a heart rate <65 beats/min was significantly higher than a heart rate

>65 beats/min. Dual-sector reconstruction, an approach to compensate for higher heart rhythm, did not significantly improve image quality in patients with heart rates >65 beats/min. While in heart rates <70 beats/min the best quality was consistently found in diastole, in heart rates >75 beats/min the best quality was achieved in systole. Cademartiri (Rotterdam) used the 64-slice scanner to evaluate diagnostic accuracy for the detection of significant obstructive coronary artery stenosis in patients with stable angina or an acute coronary syndrome. Only patients in sinus rhythm, with no history of PCI or CABG, were included. If heart rate was >70 beats/min, patients received oral β-blockade. When compared with CAG, sensitivity, specificity, positive and negative predictive value for detection of significantly obstructed vessels were 96, 89, 85 and 97%, respectively. No patients or segments were excluded from analysis. However, these values are based on a per-vessel analysis, not on a per-person analysis. Nikolaou (Munich, Germany) evaluated the same scanner in patients with known or suspected CAD. Without excluding any patients or segments, they report a sensitivity, specificity and diagnostic accuracy for stenosis detection on a per-patient basis of 95, 89 and 94%, respectively. Rist (Munich, Germany) reported that, due to a significantly higher spatial resolution, the 64-slice CT enables more exact assessment of stent lumen than the 16-slice CT. Still, assessment of stent lumen remains problematic. Sperandio (Rome, Italy) evaluated 350 bypass grafts with 16-slice CT. Motion artifacts due to high heart rates prevented the evaluation of 30 grafts. For the remaining 320 grafts, a sensitivity of 97% and a specificity of 100% was found. From these reports we can conclude that the 64-slice CT offers improved stenosis detection. Visualisation of distal segments and stent lumen has been improved. Bypass grafts can also be evaluated by MSCT. However, in clinical practice the need for heart rate reduction and stable heart rhythm remains.

Emergency department

Cardiac CT may have an important role in emergency decision-making by serving as a preselection tool. Previous studies have demonstrated that, in the emergency department, calcium scoring on CT contributes to prediction of therapy for patients with chest pain.[6] However, since calcium scoring appears to have only limited predictive value, its clinical use seems limited. The higher predictive value of CT angiography may improve preselection.

Houwers (Groningen) performed CTA in patients presenting to the emergency department with non-ST-elevation ACS and evidence of myocardial ischaemia. These patients are routinely scheduled for CAG to determine whether patients should receive either no treatment, PCI or CABG. She demonstrated in 30 patients with ACS that MSCT was able to predict correct treatment in 79% of cases. She concluded that by using data obtained with MSCT, a significant proportion of CAGs could have been avoided. Cardiac CTA has a promising future in emergency decision-making. Challenges to be met are suboptimal patient monitoring with the scanner, and the requirement of a low heart rate and stable heart rhythm.

Coronary plaque imaging

CAG is only a moderate predictor of time and location of future coronary occlusion that will produce a myocardial infarction.[7] It is thought that most acute coronary syndromes are caused by small, rupture-prone plaques, associated with positive remodelling. Using intravascular ultrasound (IVUS), Schoenhagen demonstrated that patients with unstable angina have more noncalcified plaques when compared with patients with stable angina.[8] If MSCT could provide reliable information on plaque phenotype, this would greatly increase its ability to predict cardiac ischaemic events. This may change treatment strategies in the (near) future. Schroeder and Leber found a different radiation attenuation for soft, fibrous and calcified plaques.[9,10] However, these classifications have limitations for application in individual plaques, since overlap between different plaque groups was present. At the ECR 2005, Pasowicz and coworkers (Krakow, Poland) reported the comparison of MSCT with IVUS in the detection and assessment of plaque morphology. They analysed 119 coronary artery segments of 14 patients. MSCT correctly assessed 36 of 46 (78%) soft plaques, 19/24 (79%) intermediate plaques, and 16/16 (100%) calcified plaques. However, plaque imaging is influenced by several factors. Cademartiri reported that lumen contrast densities significantly modify the attenuation of noncalcified coronary plaques. In an ex-vivo study, the same group demonstrated that the difference in radiation attenuation between calcified and soft plaque can be increased or decreased depending on the reconstruction algorithm used. This makes discrimination of soft and intermediate plaque harder. Cademartiri also used MSCT to evaluate coronary plaque burden in patients with stable and unstable angina. In accordance with Schoenhagen's findings, patients with unstable angina had significantly more noncalcified plaques when compared with stable patients. Houwers found that purely calcified lesions are associated with a much lower occurrence of >50% stenosis compared with mixed lesions. In conclusion, progress has been made in plaque characterisation by MSCT. However, for reliable clinical application a further increased resolution and more dedicated software, and standardised protocols are required.

Radiation reduction

CTA gives a radiation exposure of around 10 mSv, compared with 3-10 mSv for CAG.[11] Reduction of radiation exposure is important to make CTA employable for low-risk and young patients. Several methods can be used. In 'prospective triggering' radiation is administered only in a predefined interval of the cardiac cycle. Usually, the 70% phase (diastole) is chosen. Prospective triggering results in over 70% reduction in dose when compared with retrospective gating, a procedure in which radiation is administered during the entire cardiac cycle. Radiation exposure with retrospective scan protocols can be reduced by 'dose modulation'. In this procedure full dose is administered only during predefined intervals, usually the diastolic phases. This results in doses comparable with conventional CAG. Due to the high susceptibility for cardiac arrhythmias, prospective triggering and dose modulation can only be used in highly stable heart rhythms. Therefore, in most of the presented studies these features were not used. In thoracic CT 'automatic exposure control' (AEC) is used to reduce radiation exposure. AEC systems compensate for changes in attenuation of the X-ray beam by adjusting the tube current. Keat (London, UK) developed a phantom to test several AEC systems for coronary CTA. He concluded that these systems largely succeeded in achieving their aims, with consistent image quality. In vivo tests with AEC are awaited.

Cardiac MR angiography

Cardiac MR angiography (cMRA) offers radiation-free imaging. Di Roma (Rome, Italy) compared cMRA with MSCT. Only 69% of segments were evaluable by cMRA, in contrast to 91% of segments by MSCT. It can be concluded that the relatively low spatial resolution of 1.5 T MR only allows visualisation of the larger segments.

Cardiac function and late enhancement

Cardiac CTA can give valuable additional information. Several groups reported that quantification of left and right ventricular function, and visualisation of valve components is possible. High correlations with echocardiography and cardiac MR were found. Also late enhancement and myocardial perfusion analysis are feasible with contrast-enhanced MSCT. Late enhancement requires an additional late phase scan after CTA. This is feasible at a very low dose of 1 mSV, as demonstrated by Rutten and De Vos (Utrecht). CT may prove to be of value for these indications in patients with contraindications to cardiac MR and for the development of 'one-stop cardiac imaging'. This would be one noninvasive test to evaluate all cardiac and coronary anatomy and function in ACS patients.

Conclusion

New hardware and software developments continue to improve the performance of MSCT, and to increase the indications for which it can be employed. ■

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