256- and 320-row coronary CTA: is more better?

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This editorial refers to ‘The diagnostic accuracy of 256-row computed tomographic angiography compared with invasive coronary angiography in patients with suspected coronary artery disease’, by S.-P. Chao et al., on page 1916 and ‘Diagnostic accuracy of 320-row multidetector computed tomography coronary angiography in the non-invasive evaluation of significant coronary artery disease’, by F.R. de Graaf et al., on page 1908

The gold standard for evaluating coronary anatomy is invasive coronary angiography because of excellent spatial resolution. Significant advances in coronary CT angiography (CCTA) using multiple-row detectors (MDCT) have made it possible to evaluate the heart and coronary arteries non-invasively. The development of MDCT, beginning with four detector rows and improving to the current clinical standard of 64 rows, allows imaging of the heart in a sufficiently short breath hold as to minimize motion artefacts. However, research with much higher numbers of detector rows, such as the 256- and 320-row MDCT now makes it possible to image the entire heart in one or two heart beats.

With 64-row and higher MDCT, image quality is influenced by the cardiac volume imaged per gantry rotation, the high number of thin images obtained, as well as spatial and temporal resolution. Furthermore, to image a beating heart, high temporal resolution is needed which is determined by the gantry rotation, use of prospective or retrospective electrocardiographic (ECG) gating, and whether the image reconstruction requires significant data overlap during scanning. A further challenge of MDCT is obtaining diagnostic quality images with low radiation doses. Many factors influence radiation dose with MDCT, including type of ECG gating, ECG dose modulation where the tube current voltage is lower the average radiation dose further to 0.6 mSv.10

Two studies of CCTA have been published recently; Chao et al.1 use a 256-row and de Graaf et al.2 a 320-row scanner to evaluate the diagnostic performance of CCTA in patients with known or suspected coronary artery disease (CAD). The increased detector rows provide the possibility of increased image quality in a larger pool of patients not limited by requiring low heart rates and absence of arrhythmia. The current standard for CCTA uses 64-row MDCT, which has been extensively evaluated and consistently yields an excellent negative predictive value (NPV) of 99%.3 Diagnostic performance is influenced by the underlying prevalence of CAD.4 Several multicentre trials have studied the accuracy of 64-row MDCT for the diagnosis of CAD in patients with suspected disease and found varying specificities including 64%,5 83%,6 and 90%.7 This highlights the limited positive predictive value (PPV) of CCTA and dependence on the underlying prevalence of CAD in the population. Further progress is needed to enhance the PPV of CCTA, particularly in highly calcified coronary segments and in the smaller distal portions of coronary vessels. Compared with stress myocardial perfusion imaging, CCTA with calcium scoring provides a diagnosis of coronary atherosclerosis, which would not be detected on a normal perfusion study in patients with subclinical coronary plaque. Detecting coronary atherosclerosis could lead to more aggressive risk therapy.

Techniques have emerged to decrease the total radiation dose for CCTA. With either prospective or retrospective ECG tube current modulation, radiation exposure can be minimized and yet high quality imaging can still be obtained. Dual-source MDCT allows excellent temporal resolution (83 ms) with improvements in image quality despite increased heart rates.8 Dual-source MDCT using ECG tube current modulation and retrospective gating have radiation doses in the range of 7–9 mSv9 which can be further reduced by using a tube voltage of 100 kV in patients with a body mass index (BMI) < 35 kg/m². With prospective gating and the use of 100 kV in low BMI patients, it is possible to lower the average radiation dose further to 2.1 ± 0.6 mSv.9,10

Challenges remain in the clinical application of CCTA with 64-row MDCT, including factors that are related to the CT scan, patient selection, and vessel characteristics. These include the use of iodinated contrast in renal insufficiency, ECG gating with arrhythmias, limited image quality with high heart rates, and higher radiation doses for obese patients. The presence of significant coronary calcium, in-stent stenosis, small distal vessels, and disease in distal bypass grafts all contribute to the limited specificity of CCTA.

Chao et al.1 present the diagnostic accuracy of 256-row CTA for the detection of CAD stenosis ≥50% compared with quantitative

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coronary angiography in 104 patients with a high prevalence of CAD (84%). Patients with atrial fibrillation, bypass grafts, and obesity were a minority of subjects. However, 30 patients had heart rates >70 bpm and were imaged with retrospective ECG gating. Given the importance of heart rate control for prospective gating, only those with heart rates <70 bpm had prospective gating. The image quality was excellent, with only one segment excluded due to motion. Despite including patients with heart rates >70 bpm, the PPV for the diagnosis of CAD was excellent. However, the PPV was only 70.3%. With a patient-based analysis, there was high sensitivity of 98.8%; however, there was an inadequate specificity of 50%. When the 13.5% of patients with calcium score of >1000 were excluded, the patient-based test characteristics were significantly improved, resulting in a sensitivity of 97.1%, specificity of 94.6%, PPV of 77.3%, and NPV of 99.4%. The per-segment analysis had an excellent sensitivity (93.5%) and specificity (95%), with an area under the receiver operating characteristic (ROC) curve of 0.915 (0.847–0.982).

With respect to radiation exposure achieved with prospective gating, the average was 5.1 mSv compared with a lower average radiation dose of 2.1 mSv seen with prospective ECG gating used with 64-slice MDCT. The mean dose with retrospective gating was 14.8 mSv, which is likewise not an improvement. The current standard for CCTA with 64-slice MDCT is to use 100 kV tube voltage for non-obese patients. Further studies will need to compare dose reduction strategies of lower tube voltage with 256-row CTA.

Despite technical advantages of 256-row scanners to reduce blooming artefact from high calcium scores, the diagnostic performance of CCTA was limited (86.4% specificity) when a calcium score >1000 was included. The ability to distinguish in-stent stenosis using the 256-row scanner was inadequate, with poor sensitivity (54.5%) and low specificity (54.5%). In contrast, although there were a small number of bypass grafts included in the study, the diagnostic performance was excellent. There was a selection bias wherein 70% of patients with suspected CAD on the CCTA did not agree to invasive angiography and the study was predominantly performed in men (76.9%).

The study by de Graaf et al. evaluated the diagnostic ability of 320-row CT in 64 patients with known or suspected CAD who were scheduled for invasive coronary angiography. The diagnosis of ≥50% and ≥70% stenosis on CCTA was compared with quantitative invasive angiography. In contrast to the study of Chao et al., patients with calcium score >1000, bypass grafts, and atrial fibrillation were excluded from the study. Prospective ECG gating was used in all patients, β-blockers were given for heart rate >65 bpm, and only four patients were excluded due to poor image quality. Tube voltage was adjusted based on patient BMI (100 kV if BMI <23 kg/m², 120 kV for BMI 23–35 kg/m²) although this is less aggressive than is done with 64-slice MDCT. The mean radiation dose depends on the ECG interval acquired: 75% of the RR interval had 3.9 ± 1.3 mSv, 65–85% of the RR interval resulted in a higher dose of 6.0 ± 3.0 mSv, and acquiring throughout the RR interval for functional analysis (25% of maximum tube current outside of the 65–85% RR interval) was associated with the highest dose of 10.8 ± 2.8 mSv. Similar to the study of Chao et al., patients had an intermediate–high prevalence of CAD and were non-obese (average BMI 26 kg/m²). The radiation dose was not lower than what is currently available with prospective gating for 64-slice MDCT. The conversion factors used to obtain the milliSieverts of radiation from the dose-length product were different between the studies, with Chao et al. using a factor of 0.017 and de Graaf et al. using a lower factor of 0.014. As a result, the radiation exposure would need to be compared using the dose-length product or CT dose index.

When excluding non-diagnostic segments or patients, de Graaf et al. found the test characteristics for diagnosis of CAD (>50% stenosis) on a per-patient analysis to be: sensitivity, 100%; specificity, 88%; PPV, 92%; and NPV, 98%. When using ≥70% stenosis as the reference, the NPV is unchanged, specificity improves to 95%, and the PPV falls to 88%. Even with addition of non-diagnostic scans, the NPV was 100%. On a per-segment analysis, the PPV was near 75% and the NPV was excellent at 99%, using for stenosis ≥50% or 70% stenosis. Compared with the study of Chao et al., the diagnostic category of ≥70% stenosis on CCTA is probably more clinically relevant for patients presenting with chest pain.

The increase in detector rows to either 256 or 320 offers several advantages for CCTA. First, there is a theoretical improvement in the blooming artefact seen with calcified vessels due to the increased scan speed. With the 256-row MDCT, reconstructed images may have less blooming artefact given that the Z-direction focal spot sampling and spherical detectors may reduce cone beam artefact. The increased detector number results in shorter scan times and therefore less taxin breath holds for ill patients. The volumetric data set obtained with 256-row MDCT covers 12 cm with each heart beat, whereas 320-row MDCT has greater coverage and acquires 16 cm at a time (Figure 1). The ability to image the entire heart in just one or two beats may reduce artefacts from poor ECG gating and motion. In addition, given the rapid whole heart imaging, variation in contrast enhancement of the left ventricle may be eliminated. The routine use of prospective ECG gating would eliminate the helical oversampling done with retrospective gating in order to ensure adequate image reconstruction.

Both studies confirm the high sensitivity and NPV of CCTA for the diagnosis of CAD in patients at intermediate–high risk. However, the specificity and PPV are still limited, and not significantly improved over 64-row MDCT. At this point, there is also little improvement in terms of diagnostic accuracy, radiation exposure, contrast dose, or NPV. Future studies should evaluate the image quality and radiation dose using a lower tube voltage of 100 kV in non-obese patients. Given the current mandate for cost-effectiveness evaluation and justification for expensive imaging tests, studies are needed to show a more favourable cost/benefit ratio for either 256-row or 320-row compared with 64-row MDCT. Such studies are needed to verify the diagnostic performance of 256-row and 320-row MDCT in low–intermediate risk patients before these techniques can be translated into clinical practice. As these patients are the most likely candidates for CCTA.

Further studies must increase the number of women participating, particularly with the opportunity to assess abnormal microvascular perfusion in the setting of non-obstructive epicardial coronary arteries. In addition, advancements are being made
with measuring cardiac function, ventricular scar assessment, and coronary plaque characterization using MDCT. For example, a recent study by Chow et al. using 64-slice CCTA in >2000 patients found that total plaque measured had incremental prognostic value over severity of CAD and left ventricular function for mortality and myocardial infarction.

In summary, the studies by Chao et al. and de Graaf et al. are promising early work in assessing the worth of newer generation CT scanners that are able to acquire volumetric data of the heart in one or two beats. Although both 256- and 320-row CCTA are highly sensitive for detection of CAD in an intermediate–high risk population, this strong NPV is also seen with 64-slice MDCT. With advances in multimodality imaging for CAD detection which employ stress perfusion imaging to determine the physiological significance of intermediate stenoses and non-evaluable coronary segments, the technical advantages of 256- or 320-row CCTA scanners may emerge. Finally, progress is being made in assessing myocardial perfusion with CT technology, so anatomic and functional information can be obtained with one imaging modality.

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References


