

Multislice Computed Tomography Coronary Angiography

a report by

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In vivo visualisation of the coronary arteries was first introduced by de Mason Sones in the 1950s. Selective invasive coronary angiography (CA) has significantly increased our understanding and management of coronary atherosclerosis and has precisely delineated coronary stenoses, which was a prerequisite for the development of coronary revascularisation techniques. However, it was almost 10 years before the first bypass operation was performed by Favoralo in the late 1960s, and another 10 years before percutaneous transluminal CA (PTCA) was performed by Grüntzig in the late 1970s. Today, invasive CA is still the cornerstone imaging modality for clinical decision-making in patients with suspected coronary artery disease (CAD), and it also serves as an indispensable roadmap for percutaneous coronary intervention (PCI). Over the past 15 years substantial advances have been made in non-invasive coronary imaging, initially with the introduction of magnetic resonance (MR) CA, which more recently has been superseded by the implementation of multislice CT-CA.^{1,2}

Multislice Computed Tomography Coronary Angiography – Basics³⁻⁸

Computed Tomography Coronary Angiography – Temporal and Spatial Resolution

A high temporal resolution is essential for the depiction of the coronary arteries, mainly because of the rapid motion of the coronary arteries. The motion velocity of the left anterior descending (LAD) is 22.4 ± 4.0 mm/second, of the left circumflex artery (LC_x) 48.4 ± 15 mm/second and of the right coronary artery (RCA) 69.5 ± 22.5 mm/second.^{9,10} It is estimated that a temporal resolution of 19–75ms is desirable to capture motion-free coronary images.

The temporal resolution of CT scanners used for the visualisation of coronary arteries is determined by the rotation speed of the gantry around the patient. As the coronary images are reconstructed from data acquired from a 180° gantry rotation, the temporal resolution is equal to half the gantry rotation speed. Current-generation 64-slice or dual-source (DS) CT scanners still have limited temporal resolution, ranging from 83 to 165ms, which may cause image blurring (motion artefacts), particularly during higher heart rates (<70bpm). To decrease the likelihood of the creation of unsharp images, the coronary images are usually reconstructed from data acquired during the relatively motion-free diastolic phase of the heart cycle. During lower heart rates (<65bpm), this relatively motion-free period increases and thus the likelihood of obtaining sharp images increases. Therefore, administration of B-receptor blocking agents 60–90 minutes before CT scanning is recommended to reduce the heart rate to less than 65bpm to prolong the rest period in the diastolic phase. To further reduce motion artefacts a segmented reconstruction mode is used, which improves the nominal temporal resolution by a factor of two to three. Segmented reconstruction selects data acquired during two or more cardiac cycles,

which are combined to form one image reconstruction. However, this technique is less robust and requires a very stable heart rate.

A high spatial resolution is necessary to allow assessment of small coronary artery details, such as severity of stenosis or detection of often small non-obstructive plaques. The spatial resolution of current CT scanners in a phantom setting is ~0.4mm, but in clinical CT imaging is estimated to be 0.6–0.7mm. A higher spatial resolution decreases partial volume effects, which allows improved delineation of, for instance, in-stent restenosis or cases of calcified lesions, and so minimises overestimation of the stenosis severity.

Computed Tomography Coronary Angiography – Contrast Agent

CT coronary imaging requires intravenous administration of iodinated contrast medium. Current 64-slice CT scanner protocols recommend using 80–100ml of contrast medium injection at a rate of 4–6ml/second; therefore, CT-CA is indicated only for patients with normal renal function.

Computed Tomography Coronary Angiography – Radiation Exposure

CT-CA is associated with radiation exposure and inherent lifetime attributable risk of fatal cancer. The radiation dose for coronary CT is usually given as the effective dose (E) expressed in SI units of milli-Sievert (mSv). E represents a rough estimate of the biological risk of partial body exposure (as occurs in CT-CA) relative to an equivalent whole-body radiation exposure. Recent clinical studies revealed that 64-slice CT-CA was associated with an effective dose ranging from 13 to 15mSv for men and from 18 to 21mSv for women. This is considerably higher than the effective dose of



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Table 1: Meta-analysis of the Diagnostic Accuracy of 64-slice Computed Tomography Coronary Angiography

Analysis	Patients (n)	Segments (n)	Non-evaluable Segments (%)	Prevalence CAD (%)	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%)	NPV (%)
Patient	875	–	1.2	57.5	97.5 (96–99)	91 (87.5–94)	93.5	96.5
Segment	1,251	17,695	4	19	86 (85–87)	96 (95.5–96.5)	83	96.5

CAD = coronary artery disease; PPV = positive predictive value; CI = confidence interval; NPV = negative predictive value.

Table 2: Diagnostic Performance of 64-slice Dual-source Computed Tomography Coronary Angiography

Per-patient Analysis							
Author	NP	Prevalence CAD (%)	Non-evaluable Patients (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Scheffel	30	50	0	93	00	100	94
Weustink	100	77	0	99	87	96	95
Leber	90	30	2	95	90	74	99
Heuschmid	51	75	0	97	73	90	92
Ropers	100	41	3	98	84	80	98
Brodoefel	100	73	0	100	82	94	100
Johnson	35	48	0	100	89	89	100
Achenbach	100	47	3	98	90	87	98

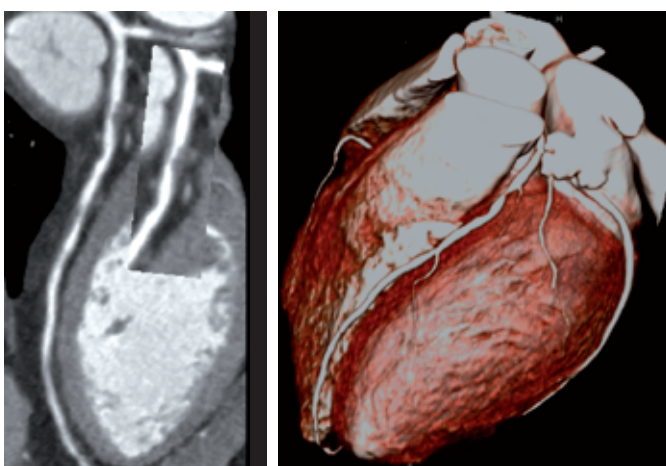
PPV = positive predictive value; NPV = negative predictive value.

Table 3: Diagnostic Performance of 64-slice Dual-source Computed Tomography Coronary Angiography

Per-segment Analysis						
Author	N segments	Non-evaluable Segments (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Scheffel	420	1.4	97	98	86	99.4
Weustink	1,489	0	95	95	75	99
Leber	1,216	1.3	90	98	81	89
Heuschmid	663	4.7	96	87	61	99
Ropers	1,343	4.0	90	98	79	99
Brodoefel	1,229	1.6	91	92	76	98
Johnson	481	2.0	88	98	78	99
Achenbach	1,337	3.5	93	99	84	99

PPV = positive predictive value; NPV = negative predictive value.

Figure 1: Volume-rendered Computed Tomography Coronary Angiogram



Left: Multiplanar image with blow-up of coronary stenosis.

Right: Significant stenosis in the left anterior descending coronary artery.

invasive coronary angiography, which ranges from 6 to 11mSv. The radiation dose can be reduced by several techniques. Electrocardiogram (ECG)-controlled tube current modulation decreases the current of the X-ray tube during systole – CT data during systole are not used for image reconstruction; this is carried out using data during diastole – and using this

technique E was reduced to 10–14mSv.¹¹ A recent study demonstrated in selected patients that by using a prospective ECG-triggered CT protocol (instead of helical scanning) the effective dose was dramatically reduced to 2.8mSv, an 83% reduction, compared with the helical CT technique.¹² It remains to be seen whether prospective CT scanning is sufficiently robust and applicable to all patients.

Multislice Computed Tomography Coronary Angiography to Rule Out Coronary Artery Disease

The diagnostic accuracy of current state-of-the-art 64-slice CT scanners is high, with improved spatial and temporal resolution allowing significant CAD to be detected or ruled out^{3–8} (see Figure 1). Abdulla et al. performed a meta-analysis of 19 studies concerning 1,251 symptomatic patients with a 57.5% prevalence of significant CAD who were referred for invasive CA (see Table 1).¹³ They showed that 64-slice CTCA had a high negative predictive value, and therefore could reliably rule out the presence of CAD. Recently, a new scanner generation has been introduced: the DS 64-slice CT scanner, which incorporates two X-ray tubes and corresponding detectors. The gantry rotation speed is 330ms and the temporal resolution has improved to 83ms, thanks to the DS configuration. This scanner is able to create almost motion-free coronary images – even in patients with higher heart rates (>70bpm) – and obviates the need for pre-scan B-receptor blockade to reduce the heart rate. The diagnostic accuracy of these scanners is high and the number of non-evaluative patients or

Table 4: Diagnostic Accuracy of 64-slice Computed Tomography Coronary Angiography for Bypass-graft Disease

Author	Patients (n)	Per-segment Analysis				Stenosis or Occlusion (>50%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
		Graft Arterial (n)	Venous Type (n)	Excluded Segments (%)						
Pache	31	23	73	6	98		89	90	98	
Ropers	50	37	101	0	100		94	92	100	
Malagutti	52	45	64	0	100		98	98	100	
Meyer	138	147	259	2	97		97	93	99	
Onuma	54	72	74	6	100		98	94	100	

PPV = positive predictive value; NPV = negative predictive value.

Table 5: Diagnostic Performance of 64-slice Computed Tomography for In-stent Restenosis

	Patients (n)	Stents (n)	Not Assessable (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Van Mieghem	70	162	0	100	91		
Oncel	30	39	0	89	95	94	90
Rixe	64	102	42	86	98	86	98
Ehara	81	163	12	91	93	77	98
Cademartiri	182	192	7	95	93	63	99
Carbone	41	88	28	79	84		
Pugliese *(DS)	100	247	5	94	92	77	98
Rist	25	46	2	75	92	67	94

*Dual source computed tomography coronary angiography. PPV = positive predictive value; NPV = negative predictive value.

coronary segments has decreased, making this scanner quite reliable for clinical implementation (see Tables 2 and 3).^{14–21} The versatility of the DS 64-slice CT scanners also allows scanning of patients with atrial fibrillation. Oncel et al. evaluated 15 patients with atrial fibrillation: only 5% of the coronary segments were non-evaluable and the sensitivity, specificity and positive and negative values to detect a coronary stenosis were 84, 98, 78 and 99%, respectively.²²

Multislice Computed Tomography Coronary Angiography for Coronary Artery Bypass Graft Assessment

Assessment of a total occlusion of an arterial or venous bypass graft or establishment of its patency has been extremely reliable with an almost 100% success rate. The detection of a stenosis (not totally occlusive) is more difficult, but the diagnostic accuracy of the 64-slice CT scanner is high (sensitivity >90%) and the negative predictive value is almost 100% (see Table 4).^{2–27} Remaining diagnostic problems include the severe calcification of native coronary arteries and the presence of surgical clips at the site of arterial graft anastomosis, which hamper accurate diagnosis.

Multislice Computed Tomography Coronary Angiography for In-stent Restenosis

Accurate diagnosis of in-stent restenosis has been challenging because the metal struts cause significant 'blooming' of the stent, which often prevents accurate visualisation of the lumen within the stents. The diagnostic accuracy of 64-slice CT-CA is reasonably good for the evaluation of larger stents (≥ 3 mm diameter), but often fails for smaller stent sizes (see Table

5).^{28–35} Routine use of CT scanning for the evaluation of stents is currently not recommended.

Multislice Computed Tomography Coronary Angiography to Replace Invasive Coronary Angiography

The sensitivity and negative predictive value of 64-slice CT-CA is excellent, allowing reliable ruling out of significant coronary stenosis in the case of a negative CT-scan (see Tables 1–3). However, the specificity and the rather high number of false-positive outcomes (particularly apparent in the segmental analysis) associated with the limited temporal and spatial resolution make a positive CT scan insufficiently reliable, and these patients still require conventional catheter-based coronary angiography.

Applications of Multislice Computed Tomography Coronary Angiography

The appropriate indications for coronary CT are still developing. Consensus for the appropriateness of CT has been achieved in several clinical scenarios: symptomatic patients with intermediate pre-test probability of CAD and unequivocal or non-interpretible stress test; patients with acute chest pain syndrome and low risk of CAD (normal ECG, no elevated biomarkers); patients with new occurring heart failure to establish ischaemic origin; total occlusion or patency of bypass grafts; and coronary anomalies. Multislice CT-CA may help interventionalists to determine pre-PCI which strategy should be selected. This may include assessment of ostial lesions, bifurcations, chronic total occlusions, post-bypass graft or abnormal coronary course. ■

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