CT Coronary Angiography with 16-Row Multi-slice Scanner: Do We Still Need Conventional Coronary Angiography?

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Background

Coronary artery disease (CAD) remains globally the leading cause of death and long-term morbidity. Among the many manifestations of CAD, acute coronary syndrome, ranging from unstable angina to acute myocardial infarction, is the most catastrophic event due to our inability to predict its occurrence. Despite improved treatments for CAD, acute coronary syndrome results in sudden death or permanent disability in a substantial percentage of patients. In patients who have an acute coronary syndrome, rapid and accurate risk stratification is crucial. If we could predict the timing of acute coronary syndrome or, better yet, prevent its occurrence, we could alter the otherwise unfavourable course of CAD.

Non-invasive visualisation of the heart is a demanding application for any imaging modality [1, 2]. The use of multi-slice CT (MSCT) for the evaluation of the heart and coronary arteries was born in 1999 with the introduction of four-row MSCT scanners [3]. The results of that generation of scanners were encouraging but still insufficient to ensure diagnostic confidence because of the high percentage of segments that could not be assessed [4]. The subsequent introduction of 16-row MSCT scanners significantly enhanced the spatial and temporal resolution, allowing the evaluation of almost all the coronary segments [4].

Technique

High temporal resolution is required to freeze cardiac motion and avoid motion artefacts due to the heart beat [4]. High spatial resolution is also

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needed for the depiction of small structures and the complex anatomy of the coronary arteries [4].

The heart volume must be examined within one breath-hold to avoid motion artefacts. Two different methods were developed to acquire motionless images of the coronary vessels, depending respectively on prospective triggering of the acquisition or retrospective reconstruction of a static image. With prospective ECG triggering, the heart volume is covered by single axial scans acquired after a selectable delay following the onset of an R wave. With retrospective ECG gating, the heart volume is covered continuously by a spiral scan. The patient's ECG signal is acquired simultaneously to allow retrospective selection of data segments for image reconstruction. It became immediately evident that retrospective ECG reconstruction was the winning technique for the study of the coronary vessels by CT angiography, because of its ability to overcome technical difficulties caused by the patient's hearth rate irregularities.

Cardiac scanning is characterised by spiral geometry with a very low pitch, generally 0.25, that implies an oversampling of the information throughout the cardiac cycle. Simultaneously the ECG is recorded [4]. During the acquisition a bolus of contrast medium is administered. A high flow rate (usually 5 ml/s) is necessary to obtain optimal coronary opacification during the acquisition [5–7]. After the scan is performed, the raw data are retrospectively reconstructed in the diastolic phase of the heart cycle using the ECG track as the reference point. Within the ECG, the R wave is widely used as a triggering point, because it is an easy wave for the software to recognise.

At this point the operator has to carry out the reconstructions to obtain a motionless dataset. Based on this dataset the radiologist performs the image reconstructions of the entire coronary tract. Sometimes motion artefacts due to irregularities of the heart rhythm necessitate additional reconstructions in order to obtain an image of the coronary artery that is diagnostic. To obtain diagnostic images the operator uses all the tools that the console will allow: multiplanar reformatting (MPR), curved multiplanar reformatting (cMPR), maximum intensity projection (MIP), 3D volume rendering, and 4D volume rendering [8–10]. The width of the temporal window that is used for the reconstruction is linked to the temporal resolution of the scanner. Modern scanners have high gantry rotation speed (0.4 s for the 16-row MSCT, Siemens Sensation 16) that allows high temporal resolution and a shorter temporal window. One image can be reconstructed using the information derived from 180° of gantry rotation. Therefore, if the gantry rotation time is 400 ms, the temporal resolution for a single image will be 200 ms [4]. This level of resolution is still far from the 50- to 100-ms range that characterises Electron Beam CT (EBCT) and magnetic resonance imaging.

Nevertheless, 16-row MSCT can provide high spatial resolution (< 0.5 mm) and retrospective reconstruction algorithms.

An important parameter that affects image quality is the patient's heart rate. The development of faster scanners has reduced the rotation time and increased the temporal resolution, but a high heart rate reduces the width of the temporal window available to the software to perform the reconstruction of a single fixed image. For these reasons, optimal motion-free cardiac phase can always be found in patients with heart rates below 65 bpm. When the heart rate is higher than 65 bpm, premedication based on beta-blockers is needed. Despite this, however, coronary imaging with MSCT appears promising and will probably soon come into clinical use in selected patient populations who have fewer limitations.

Results

MSCT coronary angiography (MSCT-CA) has been a reliable non-invasive tool for the detection of CAD in selected populations of patients since the introduction of 16-slice CT scanners (Table 1). High spatial and temporal resolution allows the evaluation of coronary segments down to 1.5 mm in diameter. Aggressive heart rate control remains of paramount importance for reliable results. Sensitivity and specificity for the detection of significant coronary artery stenosis (> 50% lumen reduction) have been reported in the range of around 94% and around 90%, respectively [11–18].

Clinical Applications

One of the main indications for MSCT is non-invasive coronary artery imaging. Although at the moment only selected populations of patients are suitable candidates for this method, there are many of them and they only partly overlap with the population traditionally selected to undergo conventional coronary angiography. In particular, they include young asymptomatic patients at high risk of cardiovascular disease, symptomatic patients with inconclusive conventional tests (e.g. ECG, ultrasound, stress echocardiography), and patients being followed for coronary stent and graft patency (Table 2).

With this new approach we can scan patients with unclear symptoms and inconclusive tests in a very short time: the patient preparation for the scan, if the heart rate is below 65 bpm, is the same as for a normal CT angiography scan and requires only few minutes; the image reconstruction and evaluation by a trained radiologist require about 15–30 min. The advantages of this technique are obvious in view of the vascular wall and plaque characterisation, which allows plaque morphology to be studied via a non-invasive exam

Table 1. Diagnostic performance of MSCT to detect coronary stenosis, with conventional angiography as the standard of reference (16-slice CT)

Reference	Study population (n)	Assessment[a]	Diameter reduction[b] (%)	Stenoses per patient[c] (n)	Excluded[d] (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Overall sensivity[e] (%)
[11]	58	> 2.0-mm branches	50	1.1	-	95	86	80	97	95
[12]	77	> 1.5-mm branches	50	1.0	12	92	93	79	97	73
[16]	60	Segments	50	1.2	6	72	97	72	97	NR
[13]	128	Segments	50	1.6	-	92	95	79	98	92

PPV, positive predictive value, and NPV, negative predictive value, regarding the assessable segments or branches; NR, not reported

[a] Branch- or segment-based assessment

[b] Diameter reduction considered significant

[c] Mean number of stenosed vessels or segments per patient

[d] Percentage of excluded segments or branches

[e] Overall sensitivity including missed lesions in non-assessable segments or branches

Table 2. Potential applications of CT coronary angiography

Early detection of stenosis:
Non-symptomatic high-risk patients
Exclusion of stenosis:
High-risk patients [14, 17, 18]
Prior to major (non-cardiac) surgery
Detection and/or exclusion of stenoses:
Atypical (unstable) chest pain [17]
Refractory chest pain of doubtful coronary origin
Non-conclusive stress tests
Substitution for conventional coronary angiography:
Prior to percutaneous coronary intervention [21]
High-risk patients: aortic disease
Adjuvant to coronary angiography:
Plaque characterisation [19, 20, 22, 23]
Complicated coronary catheterisation
Total coronary occlusion [21]
Follow-up:
Percutaneous coronary intervention
Bypass surgery [24, 25]

that takes only a short time to perform and does not require admission of the patient for 1 day.

A new approach to the unstable patient is now possible. Usually when a patient presents with atypical chest pain and non diriment ECG and blood marker results, the normal approach is to admit the patient to a semi-intensive coronary unit to monitor the development of the situation and to collect enough data to make a correct diagnosis and perhaps eventually to treat the coronary stenoses or occlusion. Multi-slice CT in the emergency department could be useful in this setting in order to exclude an acute coronary syndrome immediately (without needing to await cardiac enzyme confirmation) and allow the patient to be discharged directly or the referring doctor to be pointed in another direction. If, on the other hand, the MSCT is positive, the patient can undergo the proper treatment sooner.

Role of MSCT in Acute Coronary Syndrome

Several studies have demonstrated that most acute coronary syndromes develop from previously mild to moderate stenoses. Based on these and autopsy studies, sudden disruption or rupture of the non-obstructive 'vulnerable' atherosclerotic lesion is currently considered to be the cause of acute coronary syndrome [19, 20].

MSCT can display coronary arteries – both lumen and wall – non-invasively with good performance. It has been shown that good results can be obtained in stable and unstable patients. Plaque visualisation, quantification, and sometimes characterisation appear feasible in preliminary reports. The potential role of MSCT coronary angiography in acute coronary syndrome could be in anticipating and extending the ability to visualise the coronary tree and, in particular, the coronary wall in those groups of patients with intermediate probability to develop an acute myocardial infarction and/or more atypical findings and symptoms. The use of MSCT coronary angiography prior to conventional coronary angiography could be of help in identifying subtle lesions causing atypical chest pain or typical chest pain with normal coronary artery tree. In addition, MSCT coronary angiography could be used to target sub-groups of patients defined as 'vulnerable' in whom the likelihood of acute coronary syndrome is higher.

Other Applications

Other applications of MSCT are non-invasive evaluation of the supra-aortic trunks for suspected cerebrovascular diseases: CT for this application is robust, easy to perform, patient-friendly, and operator-independent. With the implementation of brain perfusion assessment, it could be applied in the acute settings. In non-invasive peripheral artery evaluation, too, MSCT can rely on robustness and ease of application.

Conclusions

MSCT coronary angiography is a promising technique for the non-invasive visualisation of coronary arteries. Based on the current literature, it is expected to have a role in the diagnosis of acute coronary syndrome. Its capability to visualise coronary artery plaques will play a role in the targeting of culprit/vulnerable plaques.

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