Current Status of Coronary Disease Diagnosis Using Multi-Detector Row Computed Tomography

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Coronary multi-detector row computed tomography (MDCT) has rapidly progressed since 64-slice MDCT significantly improved the temporal and spatial resolution of coronary anatomy. Coronary CT has recently become a standard clinical tool that can rule out coronary artery disease (CAD) and detect coronary lesions. Many reports have described the excellent accuracy of 64-slice MDCT in detecting significant stenosis. Coronary atherosclerotic plaque can also be visualized using MDCT and the most recent types of MDCT such as 320-slice and dual-source CT have rapidly spread. Thus, coronary MDCT technology is still under development.

Key words: ischemic heart disease, MDCT, coronary CTA, CAG, ACS

Low-invasive coronary angiography with MDCT

The first multi-detector row CT (MDCT) to become commercially available in 1998 provided very high temporal and spatial resolution. About two years later, ECG-gated 4-slice MDCT provided the first evidence of feasible mechanical CT scanning of the heart and coronary arteries. Thereafter, 8, 16, 64, 128, 320-slice CT and dual-source scanner type MDCT was developed. Coronary MDCT has rapidly progressed since the arrival of 64-slice MDCT in 2004, which offered significant-

ly improved temporal and spatial resolution. Coronary CT has become the preferred low-invasive method of ruling out CAD in patients with intermediate risk because it offers a high diagnostic success rate and excellent-quality images of coronary disease. During 2011 in Japan, the number of coronary MDCT tests (360,000) almost equaled that of coronary angiography (CAG) assessments. Although selective coronary angiography remains the gold standard for diagnosing coronary artery lesions, 64-slice MDCT provides significant information about coronary anatomy with excellent

Table-1 Ability of 64-slice computed tomography and dual-source computed tomography to detect significant coronary stenosis (luminal diameter>50%) on a per-segment basis.

	Number of Patients (n)	Not evaluated (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Total (n)	824	4.5 (525/11690)	89 (1290/1453)	96 (9350/9712)	78 (1290/1652)	98 (6350/9513)

Diagnostic performance of 64-slice computed tomography and dual-source computed tomography for detecting significant coronary stenosis (luminal diameter>50%) on a per-patient basis.

	Number of Patients (n)	Not evaluated (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Total (n)	701	3.8 (27/701)	98 (394/404)	90 (263/293)	93 (394/424)	95 (263/273)

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specificity and negative predictive values, and sufficient sensitivity and positive predictive values (Table-1)¹⁾. The number of diagnostic CAG evaluations decreased after 64-slice MDCT became available, whereas the number of percutaneous coronary interventions (PCI) has increased because ischemic heart disease started to become diagnosed earlier.

The latest cost-effectiveness analysis showed that the cost per correctly identified CAD patient has exponentially decreased with increasing pretest likelihoods of CAD. Coronary MDCT is more cost effective than conventional CAG up to a pre-test likelihood of 86%²⁾. Coronary MDCT is far less expensive than CAG and it is more cost-effective for most patients.

MDCT Protocol

The image quality of coronary CT angiography (CTA) is substantially improved in patients with heart rates < 65 beats per minute. The most common approach is to administer an oral β -blocker such as metoprolol (20-40 mg) 30-60 min before acquiring images. The intravenous β -blocker landiolol hydrochloride (0.125 mg/kg) can be administered 1-4 min before image acquisition for patients requiring control of a rapid heart rate. Sublingual nitroglycerin has also been administered to patients before scanning.

Coronary CTA typically proceeds using nonionic intravenous contrast agents (300 to 350 mg/ml) to assure adequate arterial opacification (> 300 to 350

HU) of the coronary artery lumen and sufficient contrast with the arterial wall. Normal saline is then injected to “push” the contrast.

Coronary and cardiac CT applications

Most data regarding the ability of CTA to accurately diagnose coronary stenosis have been acquired from groups of patients with suspected and stable chest symptoms. The consistently high NPV in all studies suggests that CTA is clinically useful to rule out coronary stenosis. ACCF/SCCT/ACR/ AHA/ ASE/ ASNC/ NASCI/ SCAI/ SCMR, the following appropriate clinical indications for coronary and cardiac CT have been suggested³⁾.

Coronary stenosis

Stable angina, risk assessment in asymptomatic patients without known CAD in intermediate group, acute symptoms with suspicion of acute coronary syndrome (ACS) based on normal ECG and cardiac biomarkers

Risk assessment post-revascularization

PCI or coronary artery bypass grafting surgery (CABG).

Evaluation of cardiac structure and function

Coronary anomalies, adult congenital heart disease, characterization of cardiac valve, and evaluation of cardiac mass.

Use of CTA in the setting of prior test results

Diagnostic impact of coronary calcium on the decision to perform contrast.

CTA in symptomatic patients.

Figure-1 Angiographic view of an 80-year-old man with hypertension
CT angiography shows 90% stenosis of LAD #6 that was subsequently treated by percutaneous coronary intervention.

Figure-2 After CABG
Image shows LITA-LAD, RITA-PL, SVG-#4 PD-#4, AV

Figure-3 Noncalcified plaque

Table-2 Comparison of CAG vs. 64- and 320-slice coronary MDCT

	CAG	64-slice coronary MDCT	320-slice coronary MDCT
Spatial resolution	0.02 mm	0.4~0.5 mm	0.4~0.5 mm
Temporal resolution	8 msec	165~250 msec	165~250 msec
Dimension of data	Two dimensional	Three dimensional	Three dimensional
Quantity	Good	Very good (CT value)	Very good (CT value)
Heart rate	Independent	Dependent	Dependent
Invasiveness	High	Low	Low
Radiation dose	7 mSv Diagnostic CAG	8~18 mSv With modulation (5~9 mSv) Prospectively triggered (3 mSv)	1~4 mSv

Issues associated with coronary MDCT

The coronary artery lumen can be visualized and stenosis can be detected using MDCT with retrospective ECG gating and intravenous contrast agents. One of the most serious limitations is that excessive calcification of the coronary arteries reduces the diagnostic accuracy for stenosis.

A trial of a subtraction method for eliminating calcification in which non-contrast-enhanced CT (pre-contrast CT) image data are subtracted from contrast-enhanced CT (postcontrast CT) image data with 320-slice MDCT is under way.

The introduction of CT units with ≥ 64 -slice MDCT has resulted in unprecedented spatial and temporal resolution for CTA compared with 16-slice MDCT. However, respiratory artifacts are important with 64-slice MDCT and they can be eliminated by scanning with the more rapid 320-slice MDCT. The latest 320-slice CT enables wide Z-axis coverage and imaging of the entire heart with one gantry rotation. Therefore, all scan data can be acquired within the same R-R interval, and patients with an irregular HR can be scanned without generating stair-step artifacts.

Exposing patients to the radiation that is involved in coronary MDCT imaging is associated with the risk of developing cancer of the lung and breast. The radiation dose (RD) during coronary CT has been reduced and most scanners are now equipped with ECG-controlled dose modulation that reduces tube current during the systolic phase, resulting in a 30%-50% reduction in the amount of effective radiation. A lower RD is achievable with prospective ECG triggering and more recent 320-slice MDCT imaging techniques (prospective gating) have also remarkably decreased the RD compared

Figure-4 Vulnerable plaque

with retrospective gating.

Evaluation of coronary artery stenosis, atherosclerotic plaque and vascular remodeling estimated by coronary CT

The reported diagnostic accuracy of 64-slice MDCT to detect significant stenosis is excellent. In addition to delineation of the coronary artery lumen, MDCT can also identify atherosclerotic plaque. Accumulating evidence indicates that MDCT can assess the presence, volume and composition of non-calcified atherosclerotic plaque and the degree of coronary remodeling as well as intravascular ultrasound. The presence of non-calcified or mixed plaques or both is associated with cardiac events regardless of the severity of coronary stenosis. The characteristics of vulnerable plaque on coronary MDCT images are supposed to be low CT attenuation (< 30 HU), positive remodeling (> 1.05 -fold enlargement of vessel area) and spotty calcification.

Future direction of coronary and cardiac MDCT

The results of coronary CTA during the emer-

gency assessment of patients with acute chest pain have been compared with expert clinical assessment of the final diagnosis using combined clinical and marker data.

The ACCF/ SCCT/ ACR/ AHA/ ASE/ ASNC/ NASCI/ SCAI/ SCMR 2010 Appropriate Use Criteria for Cardiac Computed Tomography indicate that cardiac CT should be applied to rule out ACS when assessing symptomatic patients without known heart disease for CAD³⁾. Overall, the results of studies of stable angina have shown that negative coronary CTA findings improve the diagnostic certainty that significant coronary disease can be ruled out in patients with a low-pretest probability of CAD. Ad hoc PCI often proceeds based on semi-quantitative measures of percent luminal diameter narrowing of arteries visualized during invasive CAG. The relationship between stenosis and ischemia has been determined by myocardial blood flow reserve. The present gold standard for assessing the hemodynamic significance of coronary stenosis is the fractional flow reserve (FFR) of CAG that determines the ratio of maximal coronary blood flow through a stenotic artery to blood flow using a pressure wire. The Fractional Flow Reserve Versus Angiography for Multivessel Evaluation (FAME) trial of 1,005 patients with multivessel coronary artery disease of CAD associated FFR-guided revascularization ($FFR \leq 0.8$) to be found with a 28% lower rate of major adverse cardiac events compared with an angiography-guided strategy. Recent advances in computational fluid dynamics have enabled coronary flow and pressure fields to be calculated from anatomical imaging data. The Diagnosis of Ischemia-Causing

Stenosis Obtained Via Noninvasive (FFR DISCOVER-FLOW) trial showed that the pre-vessel accuracy, sensitivity, specificity, PPV, and NPV of FFR_{CTA} for lesions causing ischemia were 84.3%, 87.9%, 82.2%, 73.9% and 92.2%, respectively⁴⁾. Thus, FFR_{CTA} data enables the low-invasive assessment of lesion ischemia. These methods might enable predictions of changes in coronary flow and pressure from therapeutic interventions such as PCI and CABG.

Cardiovascular disease is the leading cause of death worldwide. We anticipate that cardiac MDCT will predict outcomes more accurately than risk factors and other noninvasive tests, and lead to more effective identification and management of patients worldwide.

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