Cardiac Computer Tomography (CT) in Practice

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There have been many exciting developments of cardiac CT study in the past few years mainly fuelled by a demand for a non-invasive yet accurate means to look at the coronary arteries. Nuclear medicine studies or functional analysis like stress echocardiogram provides insight into the result of coronary stenosis but do not provide direct pictures of the vessels. Physiological cardiac motion frequently blurs scans through the heart. Nowadays with ECG gating, higher temporal resolution (with higher tube rotation speed, segmented data acquisition and more recently dual source scanner) and higher spatial resolution (mainly advances in detector technology), motion free pictures of the coronary arteries are commonly obtained. These are still not yet the rule since patient with irregular heartbeats, frequent ectopics or inability to breath-hold are still difficult to be imaged. Heavily calcified vessels are also very difficult to assess on CT angiography.

Coronary calcium scanning

Detection of calcification in the coronary arteries started with fluoroscopy. Electron beam CT was first used for this purpose, which by virtue of its physical property has very high temporal resolution. It is only when multi-detector (16 and 64-slice) CT became available that the technique turned popular. Calcifications are located in atherosclerotic plaques in the coronary arteries (unless patient has calcium metabolism disorders). Finding calcium means identifying plaques. However this is frequently tip of the iceberg since only a variable portion of the plaques in a patient would be calcified. The plaques that eventually result in acute coronary event or causing the highest degree of luminal stenosis cannot be predicted from the calcium content and may not be calcified. Moreover calcified plaques are present in many subjects reaching middle age or beyond who are completely asymptomatic otherwise. Despite all these, there is increasing evidence that high calcium score is an independent predictor of adverse outcome in terms of coronary events. Calcium score (Agatston) is computed from the amount of calcification in the coronary arteries and also depends on how dense the calcifications are on the scan. It has limited reproducibility traditionally while new scanners with more precise ECG gating yet limited radiation dose are going to improve on this. Mass score tends to be more reproducible and less dependent on scan parameters. Currently there is no point supporting screening in general population. Coronary calcium study can be helpful in further stratifying the risk in patients who are deemed to have intermediate risk for cardiovascular disease by clinical criteria. There is a concept of cardiac age where a high calcium score compared with others of similar age would actually increase your age (and risk) as included in the Framingham score. The scan result may help to guide therapy or the need for further investigation.\(^{1,2,3}\)

Coronary CT angiography

Coronary angiography by CT is probably the most exciting area in cardiac imaging. Like CT angiogram (CTA) for other vessels, a tight bolus of contrast material is injected and scan done during maximal opacification of the coronary arteries. As the coronaries have tortuous three-dimensional course, good spatial resolution and thin section scans are essential for disease detection. Currently all vendors provide scanners capable of scanning at sub-millimeter thickness. Images have to be viewed on special workstations in various rendering modes to allow visualization of the whole length of coronary arteries in various planes. The viewing methods are quite different from conventional catheter angiograms which require special training and considerable amount of experience to avoid errors. Studies done in centres with less experience also show less satisfactory results compared with experienced centres.\(^4\) Despite all advances, spatial resolution of CTA is still just a fraction of that of conventional angiogram. Together with the small size of the coronary arteries (no more than 3-4mm in size proximally), assessment would be best done for the proximal and mid-segment vessels.

On an individual patient basis, CTA is performing very well. Many studies have shown that when correctly performed and interpreted, CTA has a high sensitivity and specificity for significant coronary artery stenosis in a patient. This is probably the most important criterion since this would prompt the clinicians for further investigation or intervention. All studies have demonstrated a high negative predictive value. This means when no significant luminal stenosis can be detected on CTA, the patient has a very high probability (>90%) being free from significant coronary artery disease. The results are still improving with the advances in CT technology. A recent systematic review has shown sensitivity and specificity (on a patient basis) of 16-slice CTA to be 95%, and 84%. Those for 64-slice are 100% and 94%. One of the limitations of the studies is that a significant portion of the coronary segments is not evaluable due to artifacts. From the same review, it seems this is getting less common: 9% in 16-slice to 4% in 64-slice.\(^5\)
Since scan data from all cardiac phases are included in the scan, the data can be reconstructed for analysis of global and regional ventricular function without additional radiation to the patient. Modification of the technique can also yield information on first pass perfusion of the myocardium and delayed enhancement of the myocardium. These are quite similar to the information obtained from cardiac MR though temporal resolution is lower. These may further help in the diagnosis of myocardial ischaemia and infarct.  

A lot of interest built up recently in the detection of soft plaques. They are not seen on plain scans and only visualised after the lumen is opacified by contrast. CT has the potential to characterise plaque since lipid rich plaque has a lower attenuation on CT than fibrous plaque. If we can get insight into the plaque composition, it may enhance our ability to identify vulnerable plaque that can lead to future coronary events. Currently the technique is still evolving and mainly hampered by the limited spatial resolution of CT scanner. However the ability to see the vessel wall has important implications. Angiogram only gives an image of the lumen. Plaque can be present with minimal luminal narrowing due to the positive remodeling phenomenon. Intravascular ultrasound is the gold standard but is invasive and expensive. We also know that many patients with acute myocardial infarction may not have pre-existing significant coronary stenosis but rather has complication from a non-stenotic plaque. In that sense CTA is not just a second option to angiogram but rather provides additional insight into the vessel pathology that is not available with conventional angiogram.

Radiation dose and contrast reaction

The radiation dose of CT calcium study is about 1-2 mSv with prospective ECG triggering. This is about half of the background radiation dose in Hong Kong in a year. Radiation dose of CT angiogram is significantly higher and depends on the hardware and scanning techniques. Quoted figures range from 4-10 mSv. As with any other radiological investigations, every examination should be justified on an individual basis and the radiologist performing the examination has the responsibility to make sure the lowest possible dose is delivered. Severe reaction to non-ionic water-soluble contrast used nowadays is very unusual but adequate resuscitation equipment should be at hand in any facility administering contrast to a patient. Contrast induced nephropathy is a concern especially in the patient group with high risk of coronary artery disease who may also suffer from renal disease or diabetes mellitus. Renal function monitoring and adequate hydration before the scan are essential.

Conclusion

Non-invasive cardiac imaging by CT and MRI would undoubtedly be areas of rapid expansion both in number and scope of service. At present the techniques of MDCT are not yet ‘perfect’. Utilisation should be fully justified on an individual basis. It appears that both coronary calcium detection by CT and CT angiography of the coronary arteries are best suited for the investigation of subjects with intermediate probability of cardiovascular diseases. Without cost effective analysis and outcome measurement study, the role of MDCT in daily patient management especially in the low risk group is till open to discussion.

References