Computed Tomography of the Coronary Arteries

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Introduction

In an earlier issue of this newsletter, I have briefly reviewed the recent development in computed tomography (CT) of the heart. In this issue, I would like to go into greater details discussing the utilisation of CT angiography (CTA) in the investigation of ischaemic heart disease and other coronary artery pathologies.

Indications

Up to this moment, there are no agreed indications for CTA of the coronary arteries. There had been many studies addressing the issue of diagnostic performance of CTA as compared with a gold standard, usually catheter coronary angiogram, sometimes with addition of intravascular ultrasound. Most of these studies were performed in centres with enormous experience in CTA under the supervision of very experienced radiologists and cardiologists. Whether their results can be extrapolated to daily clinical practice in a centre with average experience is not completely sure. Moreover study designs are usually recruiting subjects who have moderate to high pre-test probability of coronary artery disease. They were referred for catheter angiograms and were scanned by CT to compare the diagnostic performance of the 2 tests. It may quite be the contrary in daily practice in that we are using a less invasive test to stratify patients before they are subjected to a more invasive and expensive test. Good performance of CTA in the study environment may not be reproduced in the more commonly encountered situation where the pre-test probability is lower.

There are a number of better-established indications for CTA of the coronary vessels. It has proved to be of great value in the investigation of anomalous coronary arteries, partly because we do not need the superb spatial resolution to visualise the vessel lumen for stenosis. Coronary artery bypass graft status is also well suited for CTA since grafts do not move as much as epicardial vessels in the cardiac cycle and are larger than native vessels. Surgical clips and wires can however introduce unique artifacts in this setting.

CTA in detection of coronary artery stenosis

Older studies using 4 or 8-slice multi-detector CT (MDCT) are probably no longer of significant clinical relevance. 16-slice MDCT is relative new and most studies were published in the past 1-2 years. The number of studies is still relatively small. . There are even fewer studies using 64-slice MDCT. In the about 10 studies published in the last 2 years, the quoted sensitivity and specificity ranges from 82-100% and 83-98% respectively. The high negative predictive value that has been consistently noted since early days of coronary CTA still holds. The quoted figures are 85-100% with most studies reporting one higher than 90%. The positive predictive value is more variable with a range of 71-100%. As previously discussed, diagnostic performance varies with different ways of analysis. It tends to do better on a per patient basis than on a vessel-by-vessel basis.

We have to interpret this in the correct context. Spatial resolution of CT is at present far inferior to that of catheter angiogram. Individual pixel size is about 0.4-0.5mm (that of angiogram is 0.1-0.2mm). That means assessment of vessels smaller than 1.5mm or so is very difficult. That also explains why CT studies usually define significant coronary artery disease as 50% or more luminal stenosis because more detailed assessment is not always possible. Whether this can guide clinical management when 'significant' disease is detected on CTA is subject to discussion. It may seem more prudent to include or exclude patients from further invasive investigation base on the result of a high quality CTA. CTA also tends to over-estimate stenosis comparing with catheter angiogram.

As with any other investigation, the proof of diagnostic accuracy is just the first step to establish a test as useful. We need proof that this test can optimise patient outcome and improve cost-effectiveness before we can recommend this to our patients as a routine. In this area I do think technology is advancing very fast and an adequate body of scientific evidence is not yet available. Many patients are aware of this non-invasive and attractive modality. Clinical judgement and risk analysis on an individual patient basis may be the best guide before a more unified guideline is available. Some centres are using CTA as a secondary test to further characterise the risk of patients with inconclusive stress test findings and/or atypical symptom. Patients deemed to be at high risk by clinical or other non-invasive tests should not be referred for CTA but would benefit more from angiogram with a view for re-vascularisation.

Who should not be referred for CTA?

The usual contraindications to CT apply for coronary CT like pregnancy, renal impairment and severe contrast reaction. We have to be very cautious in young subjects especially ladies in reproductive age since the radiation dose is significant. Patients who have difficulty lying flat or cannot hold their breath are also poor subjects for the test. Patients in atrial fibrillation or other cardiac arrhythmias are unlikely to yield high quality images. Although there are studies coming out using 64-slice CT and so call 'sharp kernel' for image reconstruction to look for in-stent re-stenosis, coronary stents are still introducing beam hardening and partial volume artifacts. The vessel lumen always appears smaller than it is and a diagnosis of blocked stent can solely be a result of these artifacts. We may expect improvement in this area with advances in CT technology. More recent stents introduce less artifacts thanks to the different metal alloys used. Along the same line, calcium can also bloom and make CTA difficult to interpret. If a patient has a high calcium score (eg. >1,000), contrast enhanced CTA may not yield further useful information about the lumen.

More slice the better?

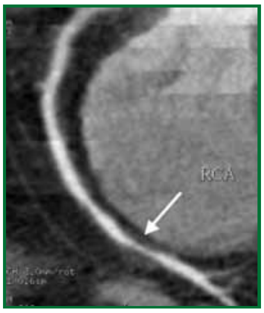
The simple answer to this question is yes. To make matter more complicated, the answer lies in spatial resolution, temporal resolution and breath-hold duration. 64-slice scanners have better spatial resolution than 16-slice scanners with various improvements in design, yielding higher quality images. Good temporal resolution means you have a fast shutter speed so you get a clear snap shot of a fast moving object. It depends mostly on the tube rotation speed and best temporal resolution is about half of the tube rotation time (for one complete circle). Newer 64-slice MDCT scanner has faster tube rotation time down to about 0.35s. Older 16-slice CT is about 0.4-0.5s. I would not discuss dual source CT here but it basically further reduces the tube rotation time by half. We are also using multi-segment reconstruction methods to shorten acquisition window during each heartbeat by re-binning data from multiple heart beats to form one image. Experience has shown that it can improve image quality in some cases but can introduce artifacts in others.

64-slice CT covers 64xslice thickness (up to 4cm) in one scan and 16-slice CT covers 16xslice thickness in one scan. That means if you have more slices, you can scan the heart in shorter time and less heart beats. If you have enough slices to cover the whole heart, you can basically scan the heart at one go. It is important because a long breathhold (which is essential during cardiac scan) always entails variability in heart rate and cardiac return. These in turn introduce artifacts because the coronary arteries are at variable spatial locations during different part of the scan. Since 64-slice CT scans the whole heart in just a few heart beats, this variability tends less to be a problem and produces superb image quality. There are various physical hurdles to further increase the tube rotation speed or number of detectors (or using a large area flat panel detector). Many scientists are working on those and a motion-less cardiac scan is no longer a dream that can never be realized.

Conclusions

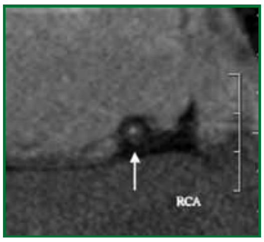
Cardiac MR and CT are fast emerging as good partners in the non-invasive investigation of ischaemic heart disease. It is noted that the number of diagnostic (especially normal ones) coronary angiograms are decreasing in some centres. This is paralleled by an increase in proportion of percutaneous coronary interventions. When properly utilised, these tests should benefit both the patients and the cardiologists.

Figure 1. Visualisation of vessel wall by CTA.



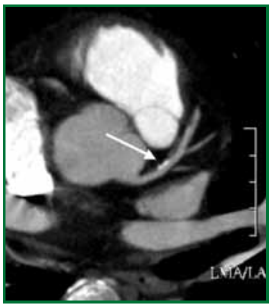
a. Curved planar reformation

b. Thin slab maximal intensity projection (MIP)



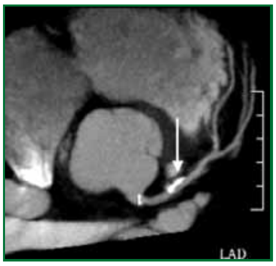
c. Orthogonal section showing the vessel lumen in a patient with soft plaque in the distal RCA. There is only mild luminal stenosis present. Note there is positive remodelling with focal dilatation in this segment of the vessel. (arrows)

Fig 2. Effect of coronary calcification on CTA.

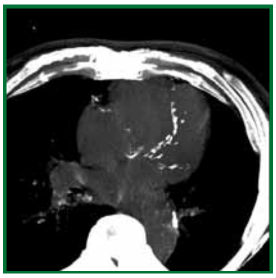


a. A tiny eccentric calcification in LAD. On this CTA image, the lumen is well appreciated and only mild stenosis is seen.

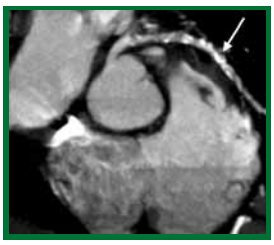
b. A larger speck of calcification on this plain scan done for calcium scoring in another patient.



c. CTA in the same patient as b shows moderate stenosis while the lumen is still well seen.

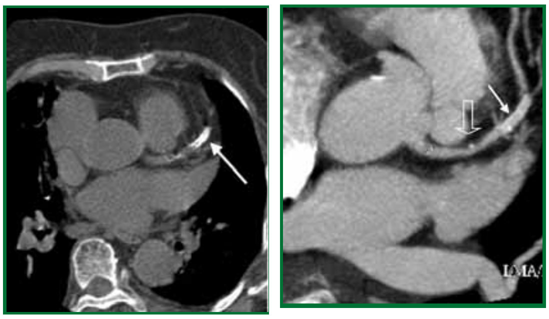


d. MIP image of plain scan showing extensive calcification in the coronary arteries in another patient.



e. The same patient as d, CTA shows the lumen is difficult to assess with significant artifacts from the calcification. (arrows)

Fig 3. Visualisation of stented coronary artery lumen by CTA.



a. Plain CT showing the metallic density of the coronary stent. (arrow)

b. Thin slab MIP image of the same patient showing enhancement of the stented lumen suggesting patency. (arrow) Note also the mixed soft and calcified plaque just proximal to the stent with minimal lumen stenosis. (open arrow)

Fig 4. Volume rendered image of CTA showing anomalous origin of the RCA (arrow) from the L coronary cusp.

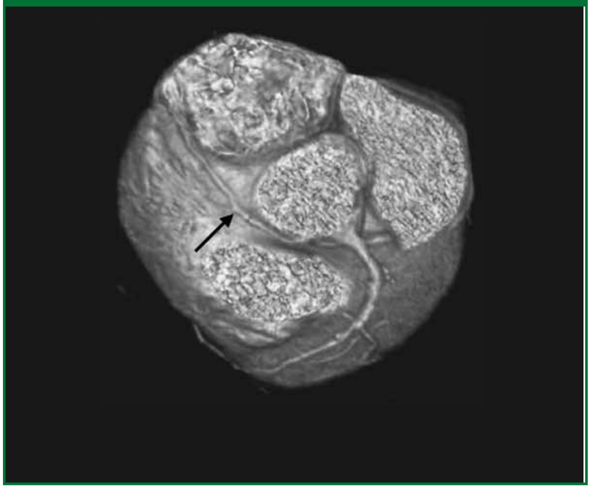
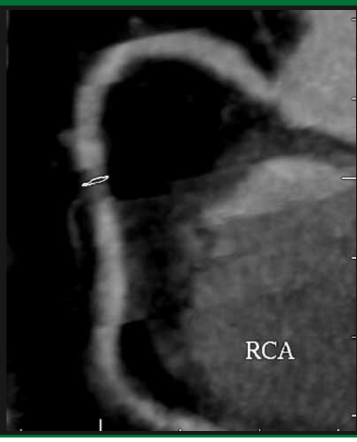


Fig 5. Volume rendered image of CTA showing the patent LIMA graft to LAD. (arrows) Note presence of multiple surgical clips.

Fig 6. Thin slap MIP image of CTA of the coronary arteries from a patient who has frequent ectopic beats during the scan. There are significant step artifacts present making interpretation difficult.



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