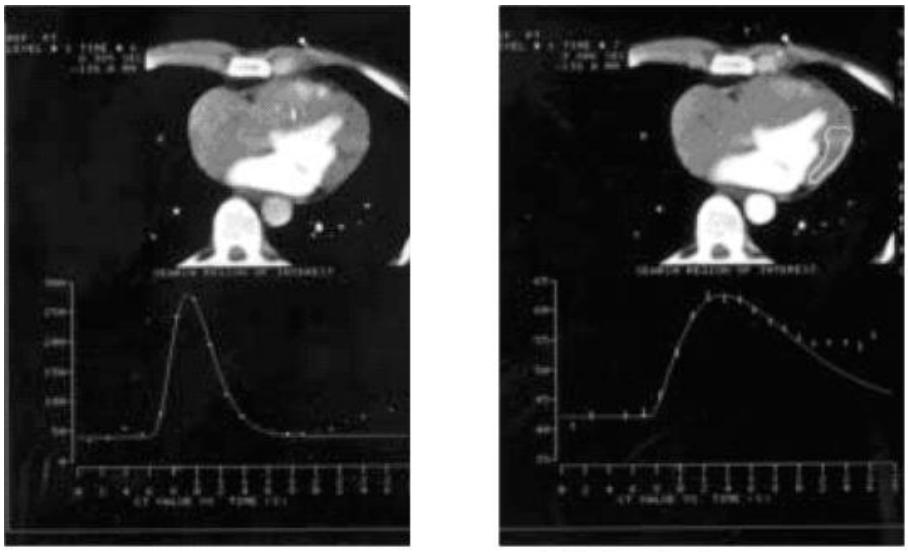
THE PROMISE OF NON-INVASIVE MYOCARDIAL PERFUSION IMAGING USING MDCT

by: John A. Rumberger, PhD, MD, FACC

The ability to non-invasively quantify heart size, function, perfusion, and coronary anatomy– the so-called 'one stop shop', has been the Holy Grail for cardiac imaging. Unlike anatomy and function, imaging of myocardial perfusion with CT at the same clinical session had remained somewhat elusive. With current MDCT technology, the issue of myocardial perfusion imaging has become not so much 'is it possible?' but rather 'is it practical?' In this newsletter we discuss this important clinical opportunity for MDCT.

As the natural development of MDCT has progressed with further improvements in both temporal resolution and, more importantly, in 'coverage' of the heart with higher detector array numbers researchers have returned to the potential of performing myocardial perfusion imaging. The concept of perfusion imaging using CT was actually first developed in the later 1970's for evaluation of brain perfusion. These principles, which are actually quite mathematically simple, were then expanded, developed, and validated in animal studies for myocardial perfusion imaging using EBT by Rumberger and Feiring.

Myocardial 'perfusion' is defined as flow per unit volume/mass of myocardium (i.e. cc/minute/cc or cc/minute/gram). To measure perfusion, iodinated contrast is injected as a 'bolus' and subsequent indicator-dilution curves are recorded over selected anatomic sites.



Indicator-dilution curve
In left ventricular chamber

Indicator-dilution curve
In lateral myocardium

Figure 1

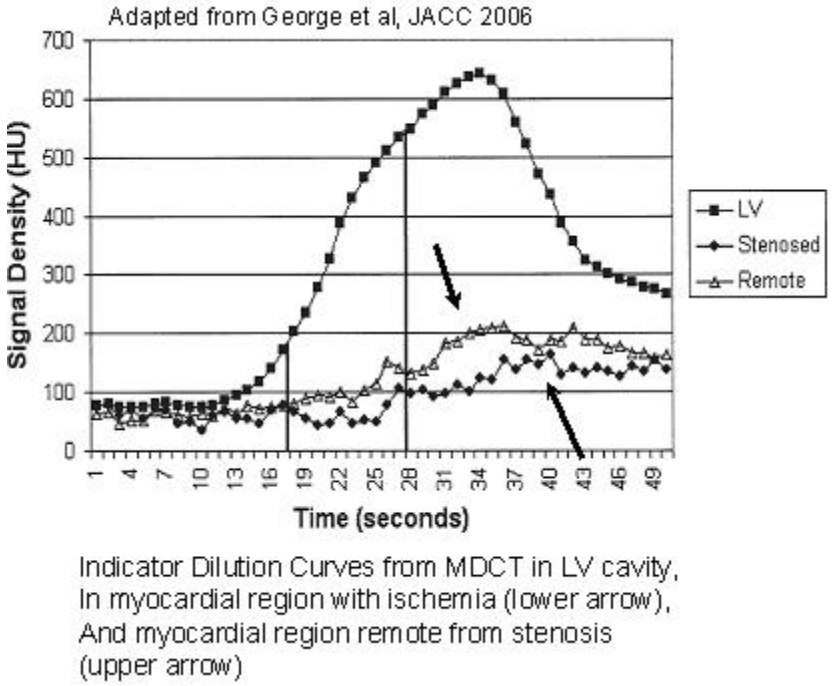
The perfusion or contrast clearance curve over the left ventricular cavity or the aorta (figure 1 - left) represents that of a purely vascular structure. By comparing a similar curve over an area of myocardium (figure 1 - right), which is partly 'vascular', an estimation of blood flow per unit of myocardial mass can be derived using the following equation.

$$F/V = PH/A$$

(Equation 1)

Where F = absolute flow (ml/min), V = myocardial volume; PH = peak height (from baseline) of the contrast clearance curve in the region of myocardium under investigation; and A = area under the indicator-dilution curve in the aorta (or LV cavity).

In 2006 researchers at Johns Hopkins used a canine model to provide semi-quantitative information of myocardial perfusion using MDCT in a manner similar to that done previously with EBT (Figure 3).



Indicator Dilution Curves from MDCT in LV cavity, In myocardial region with ischemia (lower arrow), And myocardial region remote from stenosis (upper arrow)

Figure 3

Note that the 'peak height' (PH – equation 1) of the myocardial curve from baseline for the ischemic segment is lower than the PH for the non-ischemic myocardial segment

Most recently this same group published an abstract validating transmural myocardial perfusion ratios (at rest) using 256-slice MDCT in a group of patients as compared with SPECT perfusion imaging.

Methods for Myocardial Perfusion

In order to determine contrast timing in the systemic circulation using MDCT it is common to perform a 'test bolus' where the contrast clearance characteristics are determined, most commonly in the aorta. Essentially this is a 'perfusion' curve for the aorta. By also acquiring indicator-dilution curves over a region of interest in the myocardium and comparing the data (equation 1), an estimation of myocardial perfusion (flow per unit volume)

can be defined.

Thus, in principle, myocardial perfusion imaging is now possible using the currently installed 64+-slice MDCT scanners throughout the world. However, this is a bit more difficult to put into standard clinical practice due to a variety of logistical issues as well as the potential for significant radiation exposure to the patient.

In principle the methods could be summarized as follows:

- Perform 'whole heart' CCTA every few seconds for 10+ exposures beginning prior to intravenous 'bolus' injection of iodinated contrast and past the pre-determined 'circulation time' – so as to provide information to develop indicator dilution curve characteristics in the aorta/left ventricular cavity and myocardium. Such studies would be best done at end-systole rather than end-diastole to maximize the thickness of the myocardium
- This procedure should be repeated during continuous infusion of adenosine or possibly following a bolus injection of an A2A-adenosine receptor agonist.
- Perform post-processing of the indicator dilution curves from the aorta and any operator defined myocardial region of interest and apply the subsequent data using Equation 1.

Technical Issues and Radiation

The major obstacle to performing myocardial perfusion imaging using MDCT relates to radiation exposure to the patient. Using retrospective gating methods to perform CCTA, the effective radiation to the patient ranges from 6-15 mSv. If one were to then repeat this 'resting' study with another similar study during adenosine infusion of bolus injection of an adenosine receptor agonist – the total radiation dose would at least be doubled.

However, the introduction of newer prospective gating protocols for CCTA reduce radiation dose considerably, generally to below 5 mSv. Performing two such studies would then result in generally no more radiation exposure than an original retrospective examination.

The introduction of 256-slice MDCT (Phillips) and 320-slice MDCT (Toshiba) allows imaging of the entire heart without the requisite spiral overlap required for similar imaging using 64-slice CT. This then can result in even further reduction of radiation exposure to perhaps one-quarter to one-fifth of that of any other 64-slice examination. 'Whole Heart' perfusion imaging could potentially be done with 256- 320-slice MDCT (perhaps with also providing information on regional epicardial coronary anatomy) at a single setting with rest and 'stress' images for radiation doses significantly below that possible with standard Technecium-99 SPECT imaging (currently at 10-15 mSv).

Conclusions

The promise of defining regional myocardial perfusion using MDCT could potentially complete the long term efforts to have a practical, clinical, non-invasive imaging method which provides details on cardiac size, cardiac function, coronary anatomy, and coronary blood flow; the recent development of methods to use MDCT effectively but reduce the overall radiation exposure to the patient and/or provide simultaneous whole heart imaging make this goal potentially achievable.
Of course, as with all such investigations, additional validation will be necessary and more practical methods of implementation and advanced image processing must be found prior to allow wide-spread application – but the future is indeed most promising.