Choosing a Cardiac CT Scanner

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

New Technology means more choices but tough decisions

When it comes to Cardiac CT, the place to find the latest technology and innovations is still the annual meeting of the Radiology Society of North America. RSNA's huge Chicago event the week after Thanksgiving is when every vendor unveils their newest products.

The biggest splash at this year's RSNA conference came from Toshiba. Their introduction of the Aquilion ONE 320-slice CT Scanner took everyone by surprise, including their own sales force. The expectation was that Toshiba and Philips would announce their new 256-slice machines. Instead, Toshiba leaped over 256-slice and went directly to an even larger detector array.

Physicians considering entering the world of Cardiac CT are now faced with a rapidly expanding range of choices in scanner configuration at a variety of price points. Deciding between a 64-slice, Dual Source, 256-Slice and now 320-Slice can be bewildering.

In this article, we try to give you some guidance on the pros and cons of spending more for the latest technology.

Wide Array Scanners:

There are advantages and disadvantages to the larger detector arrays to consider before opting to pay a lot more for the coolest new toy on the block.

The wider the detector array the more anatomy you scan per gantry rotation. But it is important to keep in mind that the two major mechanical determinants of scan quality are temporal resolution and spatial resolution.

The lower the temporal resolution time, the better. Faster temporal resolution means less motion artifact in the arteries. Temporal resolution is mainly dependent on the gantry rotation time. Creating a 3-D image requires scanning through at least 180 degrees of the patient plus the width of the X-ray fan beam. For a single source scanner this means the effective temporal resolution is usually a little more than half the gantry rotation time. This may be reduced by using multi-segment reconstruction where 90 degrees of rotation from two cardiac cycles are combined into one image. This often results in improved temporal resolution at the price of decreased spatial resolution because combining multiple cardiac cycles can may cause distortions if there is any variation in cardiac motion from beat to beat.

(With a dual source scanner each detector can image 90 degrees of the arc and the 2 datasets can be combined to yield 180 degrees of data with temporal resolution that is about one-quarter of the gantry rotation time without the need for multi-segment reconstruction.)

At rotation times of 300-330 msec, the rotating parts of a scanner are already subject to about 20-25 G's. It is unlikely that any scanner will achieve substantially faster rotation times in the near future. At these speeds, temporal resolution of about 165 msec is routinely achievable.

The gantry rotation time for a 256- or 320-slice scanner is not markedly different than for a 64 slice scanner. Therefore, there is little or no improvement in temporal resolution from a wide array scanner.

Spatial resolution is determined by the detectors. Toshiba currently has the smallest spatial resolution with detectors capable of 0.5 mm. The other vendors are generally about 0.6 mm. This is not a huge difference in resolution.

More importantly, the detectors used in the 256- and 320-slice scanners are exactly the same the detectors used in the 64-slice scanner. Therefore, the spatial resolution is essentially the same in wide-array scanners as in the 64-slice scanner.
So, if the temporal resolution and spatial resolution of the wide-array scanners are basically the same as the 64-slice scanner, why consider the extra expense associated with the latest scanners?

Wide-array scanners are aimed at the cardiovascular market. A 64-slice scanner, or even a 16-slice scanner, can do a wonderful job with just about any general radiology imaging. Wide detector arrays mean increased speed. For those scans where speed is important, such as cardiovascular and perfusion imaging, these new technologies have definite advantages.

On the advantage side:

The most compelling reason for the larger detector array is the increased anatomical coverage per gantry rotation. A 256-slice detector array will typically cover about a 5 inch slab with each rotation. The 320-slice scanner increases this to about 6 inches, just enough of a difference that the scanner can image the entire heart in a single rotation. Imaging in a single rotation means imaging the entire heart in a single heart beat. A typical 64 slice machine may require 5-10 beats and even a 256-slice scanner will likely need 2 heart beats for complete coverage. Fewer beats translates into several improvements-

- Less opportunity for slab registration artifacts. If the entire coronary artery tree can be imaged in a single rotation, the problem of reconstructing multiple cardiac cycles is eliminated. This means a much higher likelihood that the proximal portion of an artery is aligned with the distal portion.
- Less radiation. When multiple rotations have to be combined to create a complete image of the heart there has to be some overlap between each rotation. This is known as “pitch”. With a 50% pitch half of each rotation is covering the same anatomy as the previous rotation. This translates into more radiation dose. A single rotation scan completely eliminates the need for pitch and saves the radiation dose that would have gone into overlapping the rotations.
- Shorter Breath Holds. With a single beat image the patient needs to hold their breath for only 2-3 seconds.
- No table motion. The ability to cover the entire heart in one rotation means the table can be “parked” without the need to do a helical scan. The absence of table motion means another potential source of motion artifact is removed.
- Prospective Gating. Using Prospective Gating, i.e. imaging at just a narrow portion of the cardiac cycle, the radiation dose can be substantially reduced. Preliminary results indicate that a CTA can be done with as little as 2 or 3 mSv. At that dose range, CTA

becomes viable as a screening modality. Although Prospective Gating can be done on a 64-slice scanner, the ability to image the entire heart in a single beat without table motion improves the likelihood of getting adequate images of all the arterial segments.

On the negative side:

- First and foremost is the price. Although a definite price has not been announced yet, wide-array scanners look to be about 1-1.5 million dollars more than a 64-Slice machine. You can probably buy two 64-slice scanners for what a 256- or 320-slice scanner is likely to cost.

- While there might be some technical advantages, the fact is that there are no studies that you can do on a 256 or 320 slice scanner that you can't do on a 64 slice scanner. Simply put, for another million dollars, you don't increase your revenues by even a penny.

- Shorter breath holds are nice. But a CTA on a 64 slice scanner takes about 5-10 seconds. If your patient can't hold their breath that long, a CTA is probably not the test they need.

- Minimizing radiation dose is a tremendous advantage but there are other trade-offs associated with achieving lower dose. The technique of Prospective Gating means that only a single phase of the cardiac cycle is imaged. In other words, only about 150-200 msec of the R-R interval is included in the scan acquisition. Without imaging through the entire cardiac cycle it is not possible to measure ventricular function, wall abnormalities or cardiac output. We have seen numerous cases of patients referred for chest pain or shortness of breath who had normal coronary arteries but abnormal LV function. This valuable information is lost with prospective gating. We are even more concerned about the implications of Prospective Gating for properly interpreting the coronary artery anatomy. In our experience only about half the scans can be fully interpreted with review of a single phase. In the remainder, multiple phases must be viewed to find the phase of the cardiac cycle where a particular arterial segment is best analyzed. It is not at all unusual for a lesion to be undetectable at one phase and appear severe at another phase. It is even more common for a lesion that looks obstructive in one phase to be clearly non-significant when a different phase is chosen.

- We are very concerned that the driving force behind some recent publications and conference presentations claiming that Prospective Gating is desirable in CTA is based on marketing rather than science. The ability to do Prospective Gating provides some vendors with a competitive marketing advantage in an arena where the differences between various brands and scanner configurations are really not substantial. While minimizing radiation dose is laudable, it remains to be seen what affect Prospective Gating will have on the specificity and sensitivity for detecting hemodynamically significant stenoses and how the loss of LV function data affects the utility of CTA. It is very possible that in the long run, Prospective Gating results in increased radiation exposure for many patients because of the need for additional scans or tests to further evaluate their clinical condition.

- Prospective Gating works only in patients with very low heart rates. So, the need for beta-blockers is not eliminated.

Dual Source CT

Only one manufacturer, Siemens, is currently offering a Dual Source CT Scanner (DSCT). The Dual Source Scanner places two X-ray tubes and two detector arrays on a single gantry at a 90 degree angle to each other.

The current primary advantage of DSCT is the improved temporal resolution. Image reconstruction can be done with about 90 degrees of gantry rotation for each detector. With a gantry rotation time of 330 msec, this means a temporal resolution of about 83 msec.

With faster temporal resolution there is less motion artifact in the coronary arteries. This translates into scans that are acceptable even at higher heart rates. Data presented at recent conferences compared patients who took beta blockers and underwent 64-slice CTA with patients who were not pre-medicated with beta blockers and underwent DSCT. These studies found that the sensitivity, specificity, negative predictive value, and positive predictive value of both tests were no different and the number of evaluable segments was significantly increased in the DSCT group as compared with the 64-slice group (98% vs 91%, $p<0.001$), despite the fact that heart rates were significantly higher in the DSCT group.
Pre-medicating patients with beta blockers can create logistical and staffing hurdles. Beta blockers are also contraindicated in patients with asthma or heart failure. Some imagers are hesitant to prescribe them, particularly for patients who have been referred for imaging and are not previously patients of the imaging physician.

DSCT does not mean that the need for beta-blockade is eliminated. Better results are still obtained when the heart rate is lower. But by allowing adequate imaging at higher heart rates DSCT means that CTA can be a viable option for those patients who can not tolerate beta blockade or when the time savings of avoiding beta blockade, such as patients with possible ACS in the Emergency Department, is a significant consideration.

The faster temporal resolution of DSCT also obviates the need for multi-segment reconstruction. This makes DSCT more tolerant of R-R variability during the scan, although still less tolerant than a wide-array scanner where a single heart beat may be sufficient for imaging.

Dual Source imaging can also be advantageous in high BMI patients. With a combined output of 160kW from the two X-ray sources, DSCT can image obese patients with a much lower signal-to-noise ratio. In areas where patients with a BMI over 35 are common, this can be a significant consideration.

DSCT also allows for imaging at two different energy setting for each X-Ray source. Dual energy imaging improved automated removal of bone in peripheral vascular and coronary scans. In general radiology, dual source imaging is aiding in characterization of renal stone composition and potentially allows for obtaining both contrast and non-contrast images in a single scan.

The Future

CT Scanners will continue to rapidly evolve. Some new developments, such as Spectral CT, are already on the horizon. New detectors with higher spatial resolution and new technologies for improving temporal resolution will be debuting in coming years.

It is not realistic to expect that any scanner you purchase in 2008 will still be the state-of-the-art in 2011. But it is reasonable to believe whether you have a 64-, 256-, 320-slice or DSCT, you will have an excellent platform for obtaining high quality cardiovascular imaging for years to come. There are advantages to each of the newest machines. But they also require a hard decision as to whether those advantages are likely to translate into higher revenues or a sufficiently better level of patient care to justify the additional expense.