Introduction to 64-slice CT and its role in coronary imaging

Sixty-four slice technology offers the temporal and spatial resolution necessary to image the coronary arteries. Attention to the details of contrast administration, image acquisition, and postprocessing is critical to success.

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Computed tomography (CT) is constantly changing. The evolution in multidetector CT (MDCT) has been rapid, starting with the introduction of 4-slice technology in 1999, 8-slice in 2001, 16-slice in 2002, and 64-slice in 2004. Advances that are even more impressive will likely be announced at the 2005 annual meeting of the Radiological Society of North America. With each new generation of CT scanner, diagnosis becomes more accurate and efficient—and patients, clinicians, and radiologists benefit. Scanning speed has increased markedly. Today, a single image slice can be acquired in just 0.33 seconds. A slice thickness of approximately 0.5 to 0.75 mm has become the norm. Equally important, 64-slice CT technology enables acquisition of truly isotropic data sets. Because spatial resolution is the same in the x-, y-, and z-axes, we can look at image data equally well in any view or perspective.

Previous advances in MDCT technology were important but evolutionary. Sixty-four-slice technology is not evolutionary; rather, it is revolutionary. In fact, it could be considered a disruptive technology, as it completely changes how we think about CT: How we acquire data, how we postprocess data, and the applications for which CT can be applied.

More than ever, we are in an era of volume visualization. It may be possible to visualize a vessel on a single axial image, but describing its exact location and distribution is far more challenging. When we look at volumes, we often make better diagnoses. By selecting a data set composed of 2000 to 3000 axial slices, we can view an entire vascular map. Thanks to very high spatial resolution, we can visualize vessels that are 0.1 to 0.3 mm in diameter and can appreciate small branch vessels in a way that is not possible with individual slices. With volume visualization, the information in the final image is greater than its individual parts.

Volume data sets contain tremendous amounts of information, and we want to make the best possible diagnosis in the shortest possible time. Specialized tools enable us to quickly remove bone, muscle, and other information and to look only at the vascular map. We also have ways to postprocess data to minimize image artifacts, revealing anatomic structures in incredible detail.

Postprocessing techniques have potential pitfalls, however. If 3-dimensional (3D) displays are not created properly, the images may contain inaccurate information. For example, a maximum-intensity projection (MIP) can obscure information within a volume unless the slab thickness is limited to 1 mm. A volume rendering, by comparison, is not dependent on the size of the data slab for accurate visualization. Therefore, a thrombus that is obvious on a volume rendering may not be visible on a MIP.

Cardiovascular CT
Cardiovascular imaging is perhaps the most important beneficiary of 64-slice CT technology. Increased scan speed optimizes the ability to do pure arterial-phase imaging, eliminates venous contamination, and improves the definition of zones of differential enhancement. Higher spatial resolution enables more detailed vascular mapping, more accurate stenosis measurement, better soft-tissue detail, and optimization of data sets for 3D visualization across a range of tissue types. Moreover, radiation dose—once a focus of criticism—can be reduced by built-in dose modulation software, more efficient detectors, and better detector design.

Cardiac imaging is a dynamic field, and the state of the art is constantly changing. Our group from Johns Hopkins Hospital
recently published a “How We Do It” article on 16-slice MDCT evaluation of the coronary arteries in the American Journal of Roentgenology. By the time it was published in May 2005, the article would more accurately have been titled, “How We No Longer Do It.”

Studies have shown that 16-slice CT yields high-quality coronary angiograms in roughly 70% of patients. Such findings focused a spotlight on the potential for MDCT coronary angiography.

Interest intensified sharply following the introduction of the 64-slice scanner. This technology delivers the temporal and spatial resolution necessary to image moving coronary arteries ranging in size from 1 mm in the distal circumflex and distal left anterior descending coronary arteries to 4 mm in the left main coronary artery (Figure 1). Indeed, one of the earliest studies of 64-slice coronary CT angiography reported an overall sensitivity for classifying stenoses of 94%, a specificity of 97%, a positive predictive value of 87%, and a negative predictive value of 99%.

The timing of image acquisition is critical to the success of coronary CT angiography. During postprocessing, every image is dependent on the contrast medium being in the right place at the right time. This can be accomplished with a test-bolus injection of contrast medium or automated bolus tracking. In cardiac CT angiography, a preset scan delay is not recommended. Additional considerations are the selection of a contrast agent and the use of a saline flush. Excellent image quality demands attention to all of these details.

There is no single best way to interpret a cardiac MDCT study. Cardiovascular imaging specialists rely on a combination of axial images, multiplanar reconstructions, volume renderings, and

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**FIGURE 1.** Normal left coronary artery: CT angiography with volume rendering defines the left coronary artery anatomy.

**FIGURE 2.** Segmentation tools enable (A) color-coding and mapping of the vessels, (B) vessel segmentation, and (C) visualization of complex structures. The removal of bone by automatic segmentation helps with optimizing workflow.
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Each technique has advantages and limitations. At Johns Hopkins, we use all of the techniques at different times—depending on the individual patient and the specific vessels under evaluation. In some cases, we start with axial images and pursue each vessel one by one through coronal, sagittal, and oblique projections. We may supplement that information with 3D renderings for a global perspective, using an opaque volume rendering or a combination of MIP and volume rendering across a range of planes and perspectives. Whether we are looking at the axial images, oblique images, or 3D renderings, everything we do is dynamic and interactive, rather than static.

Physicians play a central role in postprocessing. Even with the best technologists, it is the physician’s job to look at each image carefully. Unless the postprocessing is done correctly, the operator can create significant errors in the data set. During postprocessing, the physician can change MIPs—in any combination. Segmentation tools that have been perfected for other applications are proving to be equally valuable in cardiac imaging, easily enabling color-coding, mapping, and segmentation of the vessels, and visualization of complex cardiac structures (Figure 2). In addition, 4-dimensional (4D) imaging gives us the ability to take multiple reconstructed sequences and use computer processing to visualize information across the cardiac cycle, for example, observing the aortic valve as it opens and closes (Figure 3).

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the rendering parameters through a range of visualizations, choose the exact plane and perspective to show both calcified and soft plaque (Figure 4), or use a combination of rendering techniques to visualize vessel narrowing.

In addition to the assessment of coronary artery stenosis, MDCT can successfully evaluate coronary artery aneurysms, cardiac tumors, bypass grafts, congenital heart disease, and many other cardiac conditions.

Several challenges remain. Today, it is necessary to control the heart rate in patients undergoing cardiac CT. A future goal will be the ability to scan fast enough to obviate the use of beta-blockers. A major limitation of coronary CT angiography is the inability to exactly quantify the degree of stenosis. We need better tools for quantifying stenosis.

It is difficult to image patients with dense coronary calcification (Figure 5). Research will determine whether it is possible to obtain significant information across a series of different views, despite extensive calcification. We must also establish the effectiveness of MDCT for identifying and measuring non-calcified plaque. More work also needs to be done to optimize the visualization of stent patency (Figure 6). Finally, future developments will focus on the ability to look not just at anatomy, but physiology and function.

**Conclusion**

A relatively small number of physicians are doing cardiac CT today, but interest is strong. It is important to develop expertise in scanner and workstation technology, understand

**FIGURE 5.** Extensive coronary artery calcification. (A and B) It is difficult to perform coronary CT angiography in a patient with heavily calcified coronary arteries. This patient has an Agatston score of 2300.

**FIGURE 6.** CT angiographic evaluation of a coronary artery stent. Visualizing stent patency remains a challenge for multidetector CT, although with the right algorithm and postprocessing techniques, it is indeed possible.
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the strengths and pitfalls of postprocessing, and become proficient at study interpretation. The first step is the hardest, but tremendous opportunity lies ahead.

REFERENCES

Discussion

ELLIOTT K. FISCHMAN, MD: Why don’t we now take a few minutes for general discussion. I have a general question regarding 16- versus 64-slice CT scanners. Is there still any place for 16-slice CT in cardiac imaging? Beyond, for example, doing calcium scoring?

STEPHAN ACHENBACH, MD: In my opinion, you cannot just say 16-slice CT, because there are big differences between scanners. Even within 16-slice CT, there are various generations of scanners. Some have slower rotation and faster rotation, weaker tubes and stronger tubes. With a very high-end 16-slice CT with a strong tube and fast rotation, you can get images that are not the same, but close to 64-slice CT. You can do cardiac imaging on those scanners. But that is not the case with all of them; you cannot just say 16-slice CT scanners.

FISCHMAN: Jill, if you were referring one of your relatives for a study, what would you recommend they get?

JILL E. JACOBS, MD: We do all of our dedicated coronary angiograms on our 64-slice CT scanner. But we still use the 16-slice CT with a Stratom tube for patients who were having studies prior to atrial ablation. It’s just so that the EP physicians can use our data sets and map where their catheters are. It also depends what you’re trying to get out of the study—16-slice CT is certainly adequate for some applications.

MICHAEL POON, MD: We don’t have the luxury of having two scanners, though we actually switched over to the 64-slice a few weeks ago. Just from looking at the last 200 or so images from the 64-slice scanner, you do see a consistency that you don’t see on the 16-slice. So for a beginner, I think it would be much easier to do cardiac CT on a 64-slice scanner and get adequate study results. With a 16-slice scanner, it is a little bit finicky. It’s almost like baseball; the question is, what’s the batting average? The batting average on the 16-slice may be 70%, and the batting average on the 64-slice would be close to 90%. So you want a machine that consistently gives you good images that allow you to be confident in making a diagnosis. I think that 64 is the way to go.

J. JEFFREY CARR, MD, MSCE: I want to echo what the other participants have said. Our medical facility at Wake Forest actually has 4 or 5 different imaging sites; so, obviously, we can’t have 64-slice CTs in this first year at all those places. But we do triage individuals to the optimum system. So for the venous mapping we do for the electrophysiology (EP) lab, I think that can be done very well on a 16-slice scanner with cardiac gating.

For some of our inpatient studies, we can also do coronary artery bypass graft mapping and we can do combined aortic scans on the 16-slice scanner well. But, with that said, there’s no doubt that, just like your computer at home, as you get bigger, better, faster computers, you have more options. As was alluded to, your likelihood of having an extremely high-quality cardiac scan goes up significantly with a 64-slice scanner. But I think there’s still a role for 16 and above systems; 16-slice can do calcium scoring exceptionally well, and I think there are certain inpatient procedures that it can also do well.

RICHARD D. WHITE, MD: I completely agree. The issue is that it’s 2-dimensional, the scan rotation, the temporal resolution, and the spatial resolution. If I had a 16-detector rotating at 0.37, I might actually favor that over a 64-detector operating at 0.5. You just can’t look at the number of detectors and make that decision. From outside the coronaries, a 16-detector system working optimally is perfectly adequate. It is not as simple as just the number of detectors. But an optimally working 64 really shines when it comes to coronary imaging. But beyond that, or below that, it’s not absolutely necessary.

MARILYN J. SIEGEL, MD: I agree with the other speakers. I have more of an interest in congenital cardiac imaging, and the 16-slice CT scanner certainly suffices for that application. The lesions in congenital heart disease are often fairly large and the 16-slice scanner is adequate for depicting the anatomic defects. With the 64-slice scanner, you would no doubt see some of the lesions a little bit better. For evaluation of the coronary arteries, I think the 64-slice scanner is the scanner of choice, and that’s certainly what we prefer to use for these examinations. But the 16-slice scanner still continues to play a role in other cardiac applications.

FISCHMAN: Since you do a lot of pediatric imaging, what are your thoughts about the pediatric patient?

SIEGEL: In general, the 16-slice CT scanner does well in studying congenital heart disease in infants and children. Experience with the 64-slice scanner in this population is still limited, but undoubtedly very small structures will be seen better on a 64-slice scanner. In addition, the likelihood of getting high-quality scans, particularly in infants and children who cannot suspend respiration, should increase with use of the faster scan technology.

WHITE: I think another way to think of this, Elliot, is that if you have a 64-detector, you may not always be running it flat out. You may be running it more like a 16-detector, or even less, for the sake of saving an X-ray dose to the
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patient. So the other thing to think about is whether you need a 64 operating as a 64 all the time. How do you consider “numbing it down” for the sake of patient care? If you are going to be doing coronaries, then you probably want the benefit. But there are lower levels of performance that the same system could be used for that would be perfectly adequate and probably should be considered.

**FISHMAN:** If your chairman asked you, “Okay, we’re going to buy a new scanner. What do you want, a 16 or a 64?” Which one are you going to take? That’s the first question.

The second question would be if you were advising somebody who wants to do coronary imaging. Would there be any choice in the decision process?

**ACHENBACH:** I think the answer to that is very clear. You would always want to get a 64-slice scanner if you can get one. Because as we have said, it just gives you a little bit better performance. As I said before, there are many adequate studies that you can get on a 16-slice scanner if it’s a good one; but of course, the studies are going to be a little bit better and you will get them more consistently with a 64-slice. There’s no question about that. So if you have the option of getting a 64-slice scanner, of course, you would always want to get one.

**FISHMAN:** I think the interest in coronary CT really grew at 64-slice CT. Some people were interested in it—you’ve been doing it forever—but the interest level was low in the general population of radiologists and cardiologists. Now, with 64-slice CT, it’s really become intense.

**ACHENBACH:** It has gotten so much easier to get a good-quality study on a 64-slice scanner with a very fast scan rotation. As Dr. White has so correctly pointed out, it’s not just the number of detectors. It’s the other improvements that came along with it—faster rotation and stronger X-ray tubes. It has gotten so much easier to get a good scanner that gets a good scan. So that’s why the interest in it has gone up.

Previously, with a 16-slice scanner, you could see publications of excellent results in centers that had been doing those studies for a long time and had gained significant experience. They use little tips and tricks on how to prepare the patient and get very good quality scans on a scanner even with less sophisticated specifications. It just has gotten so much easier with a 64-slice scanner.

**CARR:** From my perspective, if you look at the continuum from 4- to 8- to 16- to 64-slice scanners, the technological advancement really improves the experience for both the patient and the physician. Because your scan time and your temporal resolution have improved so much, the breath-hold time has reduced dramatically. It is easier to time the contrast so that you’re in the optimum phase, as was alluded to earlier. In the early days, there was a 20% chance of having beautiful enhancement of the coronary arteries. Now we have a >95% chance with the 64-slice scanner.

Each of the improvements adds to improved diagnosis and throughput—from the ability to process the images instantaneously while the patient is on the table, to timing the scan—all of those features have created a package that makes it both easy for the patient and easy for the technologist. The remaining question, which we’ll probably talk about later, is the interpretation—that remains very challenging, as does knowing what to do with the information once we have come to a diagnosis. In 2005, we have developed the capability to rapidly generate a huge amount of data on the heart and coronary arteries, and we still have lots of unanswered questions about how we then translate that information into patient care.

**FISHMAN:** We’ll pick that up again later, because one of the things we’ll address will be whether 64-slice CT is the end of the road. What else is necessary? Again, it is important to think about progress, not just the number of slices in a scanner, but the entire spectrum.