Contrast Use in CTA Applications

How to do coronary CT angiography: A radiologist’s perspective

Cardiovascular disease is the leading cause of death in the United States. The vast majority of cardiovascular deaths—roughly 53%—are due to coronary heart disease. Clinicians and radiologists have long dreamed of having a noninvasive way to accurately assess the heart and coronary arteries. Today, technological advances in computed tomography (CT) have made coronary CT imaging feasible.

There are several requirements for successful coronary CT angiography. Temporal resolution must be very high in order to minimize motion artifacts. We achieve that with a fast gantry rotation. Spatial resolution must also be high to accurately depict the coronary anatomy. We achieve that with thin collimation. Coverage must be fast and continuous so that we can image the entire heart in 1 comfortable patient breath-hold. We achieve that with multislice CT. Imaging must be synchronized to the heartbeat, so that we can acquire data during a consistent cardiac phase. We achieve that with electrocardiographic (ECG) gating.

Advances in CT technology have markedly improved temporal resolution. Sixty-four-slice CT scanners now have a temporal resolution of approximately 165 msec. Still, electron-beam CT has a better temporal resolution—approximately 100 msec—and conventional cardiac angiography is better yet, with a temporal resolution of about 20 msec.

The spatial resolution of today’s multislice CT scanners is approaching that of conventional angiography. A 64-slice scanner has an isotropic spatial resolution of 0.4 mm, whereas conventional angiography has a spatial resolution of 0.2 mm. Electron-beam CT has a spatial resolution of just 3 mm.

Protocols

There are many advantages to coronary CT angiography. It is noninvasive, it provides both intra- and extraluminal information about the coronary arteries, and it provides information about myocardial function. Disadvantages include its high radiation dose, the need for intravenous contrast administration, and the frequent need for beta-blockers to slow the heart rate to <65 bpm. We believe that the heart rate is optimized at 50 to 60 bpm, if achievable.

Contraindications to coronary CT angiography include the inability to receive intravenous contrast material and cardiac arrhythmias. Relative contraindications include highly calcified coronary arteries and a high heart rate. In general, the higher the heart rate, the worse the image quality. However, the practical impact of a high heart rate depends on the objective of the study. Less-than-perfect images may be adequate in some cases, for example, when evaluating a coronary artery anomaly.

Figure 1 shows a 41-year-old patient who has exertional chest pain and is suspected of having a coronary artery anomaly. Unable to take beta-blockers, he was scanned at a heart rate of 94 bpm. The scan shows an anomalous left coronary artery coming off the right aortic cusp and crossing between the aorta and the pulmonary artery. The images, although not beautiful, were of diagnostic quality and identified the need for corrective surgery.

At New York University (NYU) Medical Center, we always perform coronary calcium scoring before coronary CT angiography. The scan protocol is outlined in Table 1. Coronary calcium scoring provides an overview of the coronary arteries and the degree of atherosclerosis. If the patient has diffuse calcification throughout the vessels and a very high coronary calcium score, we often forego coronary CT angiography, as heavily calcified vessels are very difficult to evaluate, even on a 64-slice CT scanner (Figure 2).

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We have not, however, set an absolute cutoff for the coronary calcium score that rules out CT angiography. Instead, our decision depends on the distribution of calcium and the indication for angiography. For example, many patients are very reluctant to undergo invasive cardiac catheterization. Therefore, even if the coronary calcium scan shows heavy calcification in 1 coronary artery, we may do CT angiography if we believe it will provide significant information about the presence or absence of stenoses in other coronary arteries, as this information may aid the patient in understanding whether conventional coronary angiography is needed.

The imaging protocol we use for coronary CT angiography is outlined in Table 2. We typically image from the tracheal bifurcation to the bottom of the heart. We extend that range in patients with bypass grafts, starting image acquisition at the top of the chest and continuing through the heart.

Table 2 lists an effective mAs of 700 to 900, but we most frequently use an effective mAs of 850 to 900, as many of our patients are large. We use a detector collimation of 0.6 mm, a slice thickness of 0.75 mm, and a reconstruction interval of 0.5 mm. We typically use a B30 kernel, but we increase that to B46 in the case of coronary stents or highly calcified segments.

Intravenous contrast administration consists of iodixanol 320 mgI/mL, 70 to 100 mL, depending on the patient’s weight (most patients receive approximately 80 mL). We inject contrast at a rate of 4 to 5 mL/sec (most commonly, 4 mL/sec) through a 20-gauge intravenous line in the antecubital fossa, preferably on the right side.

We follow contrast injection with a 40-mL saline chaser in all patients. There are many benefits to giving a saline chaser: It increases arterial enhancement; it helps maintain a tight contrast bolus; it reduces streak artifact from the contrast material in the right side of the heart, enabling more optimal imaging of the right coronary artery; and it reduces contrast volume by 15% to 20% percent, which can reduce costs and lessen the risk of contrast-induced nephropathy.

Patient preparation includes instruction to consume nothing by mouth for 3 hours prior to the study and to avoid caffeine on the day of the study. We are aggressive in attempting to achieve a heart rate of 50 to 60 bpm. Patients with a high heart rate first take 50 to 100 mg of oral metoprolol. If the heart rate does not slow enough after oral beta-blockade, we give an intravenous beta-blocker in 5-mg doses, up to a maximum of 15 mg. We have found that more than 3 injections do not produce a substantially greater reduction in the heart rate. Potential contraindications to beta-blockers include a history of asthma, aortic stenosis, atrioventricular block, or severe left ventricular dysfunction.

Just before scanning—after we have done the topogram, set up protocols for both calcium scoring and CT angiography, and positioned the patient—we give the patient 0.4 mg of nitroglycerin sublingually.

**Vascular enhancement**

Optimal vascular enhancement for coronary CT angiography is still controversial. Our target enhancement is 200 to 300 HU. Ongoing research may influence that target in some cases, however. Investigators are evaluating the ability of CT to detect and characterize vulnerable, lipid-rich plaques (image density, 0 to 50 HU), fibrous plaques (50 to 100 HU), and calcified plaques.
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Many factors affect arterial enhancement, specifically contrast factors, patient factors, and scanning techniques. Contrast factors include the total amount of iodine administered, the injection rate, the concentration of the contrast medium, the viscosity of the contrast medium, and the use of a saline chaser. Patient factors include weight and cardiac output. Scanning techniques also influence contrast enhancement.

Bae studied the effect of contrast injection rate on aortic enhancement. He showed that if the total iodine load is held constant, an increase in the injection rate increases the magnitude of enhancement and reduces its duration. Similarly, an increase in the concentration of contrast material increases the magnitude of enhancement and results in earlier peak enhancement. As cardiac output decreases, the magnitude of enhancement increases, but the time to contrast arrival and the time to peak enhancement are delayed.

It is readily apparent that the timing of contrast injection and image acquisition to achieve optimal contrast enhancement varies with several parameters; therefore, use of an empiric scan delay is inadequate. We can determine the optimal time to start image acquisition using either a test bolus or bolus tracking. The test bolus method involves a series of low-dose monitoring scans in the ascending aorta after injection of approximately 20 mL of contrast material at 4 to 5 mL/sec (the same rate as will be used during coronary CT angiography). We have found that the optimal scan delay is the time to peak aortic enhancement, plus 5 seconds.

At NYU Medical Center, we prefer to use the automatic bolus tracking technique. During the injection of contrast medium (which is immediately followed by a saline chaser), we do a series of low-dose monitoring scans in the ascending aorta, triggering image acquisition when aortic enhancement reaches approximately 200 HU.

The advantage of automated triggering is that only 1 contrast injection is needed. In addition, it is possible to visually monitor enhancement in the ascending aorta, which confirms that the intravenous line has not infiltrated. Also, the operator can override the preset triggering threshold, manually starting the scan if it is visually apparent that enhancement is peaking in the ascending aorta.

For optimized imaging of the coronary arteries, it is important that image acquisition take place when contrast material is in the left side of the heart rather than the right. Figure 3A shows

| Table 1. Protocol for coronary calcium scoring, 64-slice CT scanner |
|-----------------|--------------------------------------------------|
| Range           | Tracheal bifurcation to the bottom of the heart  |
| kV              | 120                                             |
| Effective mAs   | 310                                             |
| Slice collimation | 1.2 mm                                       |
| Slice width     | 3 mm                                            |
| Pitch           | 0.2                                             |
| Kernel          | B30f                                            |
| NPO             | 3 hours prior (no caffeine)                     |
| Intravenous contrast | 70 to 100 mL iodixanol 320 mg I/mL             |
| Saline chaser   | 40 mL                                           |
| Injection rate  | 4 to 5 mL/sec                                   |
| Beta-blocker    | Oral metoprolol, 50 to 100 mg, 1 hr prior to study |
|                 | 5 mg intravenously, as needed (15 mg maximum)   |
| Nitroglycerin   | 0.4 mg sublingually immediately prior to study  |

| Table 2. Protocol for coronary CT angiography, 64-slice CT scanner |
|-----------------|--------------------------------------------------|
| Range           | Tracheal bifurcation to bottom heart             |
| kV              | 120                                             |
| Effective mAs   | 700–900                                         |
| Detector collimation | 0.6 mm             |
| Slice thickness | 0.75 mm                                         |
| Pitch           | 0.2 mm (0.18 for heart rate <50 bpm)             |
| Rotation time   | 0.33 sec (0.37 sec for heart rate <50 bpm)       |
| Reconstruction interval | 0.5 mm          |
| Kernel          | B30f                                            |
| NPO             | 3 hours prior (no caffeine)                     |
| Intravenous contrast | 70 to 100 mL iodixanol 320 mg I/mL             |
| Saline chaser   | 40 mL                                           |
| Injection rate  | 4 to 5 mL/sec                                   |
| Beta-blocker    | Oral metoprolol, 50 to 100 mg, 1 hr prior to study |
|                 | 5 mg intravenously, as needed (15 mg maximum)   |
| Nitroglycerin   | 0.4 mg sublingually immediately prior to study  |

FIGURE 3. (A) A large amount of contrast material in the right atrium at the time of image acquisition causes streak artifact over the right coronary artery. (B) With contrast material in the left side of the heart, enhancement of the right coronary artery is excellent, without streak artifact.
a patient with a large amount of contrast material in the right atrium at the time of image acquisition, causing streak artifact over the right coronary artery. With more optimal scan timing, contrast material is in the left side of the heart, and enhancement of the right coronary artery is excellent, without streak artifact (Figure 3B). The use of a small field-of-view over the heart also helps to increase spatial resolution and image quality.

**Reconstruction**

Coronary CT angiography should be done with retrospective ECG gating. Volumetric data are acquired throughout the cardiac cycle. We then retrospectively reference data for image reconstruction from specific parts of the cardiac cycle, typically late diastole. The result is a true match of the data to the ECG tracing.

Retrospective reconstruction can be accomplished by selecting a fraction of the R-R interval, typically 30%, 55%, and 70%. We always examine data throughout the cardiac cycle, reconstructing at 10% intervals. This enables...
us to do 4-dimensional (4D) CT, evaluating myocardial contractility over time.

Retrospective reconstruction can also be accomplished by selecting data at an absolute time point, either prior to or following the R wave. When we use this method, we typically select 350, 400, and 450 msec before the R wave.

The coronary arteries often move slightly differently from one another. It is, therefore, often necessary to look at more than one reconstruction to see all of the coronary arteries optimally. Viewing a preview series enables selection of the best point in the cardiac cycle for image reconstruction. Figure 4 shows images of the right coronary artery reconstructed at 20%, 30%, 40%, and 50% of the R-R interval. It is clear that the 40% reconstruction is the most motion-free.

Editing the data set can also be helpful. Figure 5 shows an initial image reconstruction at 400 msec prior to the R wave. Substantial motion is visible through the distal right coronary artery, and there is a duplication artifact, in part as a result of the patient’s irregular heartbeat. The solution is to edit the data set, removing the irregular heartbeats and changing the reconstruction interval to 60% of the R-R interval. The result is a very nice reconstruction through the distal right coronary artery, without motion artifact (Figure 5, bottom).

Acquisition of volumetric data throughout the cardiac cycle exposes the patient to a substantial radiation dose. Electrocardiographically controlled dose modulation can reduce that exposure. Dose modulation involves nominal tube output during diastole, accompanied by a 20% reduction in tube output during systole. The result is a total dose reduction of 30% to 50%, depending on the patient’s heart rate.

When coronary CT angiography is performed on a 16-slice CT scanner without ECG-controlled dose modulation, the average radiation dose to men is approximately 11.5 mSv and to women is 16.1 mSv. With ECG pulsing, the radiation dose drops to 4.3 mSv, on average.

When coronary CT angiography is performed on a 64-slice CT scanner without ECG-controlled dose modulation, assuming an effective mAs of 880, men receive an average radiation dose of 13.4 mSv and women, 18.9 mSv (Figure 6). Dose modulation can reduce radiation exposure to approximately 8 mSv in men and 11.3 mSv in women. By comparison, a diagnostic coronary catheterization exposes the patient to a radiation dose of 3 to 10 mSv.

Image evaluation

We typically begin image evaluation by scrolling through the axial images to get an overview of the data set. We then do maximum-intensity projections (MIPs). We may also do curvilinear reconstructions, which enable us to examine the length of the vessel for areas of plaque. Volume rendering is most useful for conveying information to clinicians and patients. We send clinicians copies of volume-rendered images with labels that enable ready identification of cardiac structures and pathology. We also send some axial images to clinicians. Patients understand the findings of coronary CT angiography much better with volume-rendered images, so we use these images as teaching tools.

CT angiography produces beautiful images of the coronary arteries. It is also an excellent way to examine coronary arterial plaques. Figure 7 shows a 41-year-old man with atypical chest pain, a normal stress thallium test, and a low calcium score of 6.5. CT angiography showed eccentric noncalcified plaque in the left anterior descending coronary artery (LAD) that was confirmed on both cardiac catheterization and intravascular ultrasound.

One of the best ways to look at areas that are suggestive of plaque is through the use of biorthogonal projections, particularly short-axis views. The short-axis view in Figure 8 shows large amounts of eccentric noncalcified plaque adjacent to the enhancing lumen of the coronary artery.

We have had variable success with CT angiography of stented coronary arteries. Figure 9 shows images acquired on a 64-slice CT scanner. In this case, it was very easy to see through the stent and observe good contrast opacification. However, many stents are very difficult to see through. Further studies are needed to determine which stents are most easily imaged, and whether visualization depends on orientation, stent size, or other factors.

We always do 4D CT on our patients in order to examine myocardial contractility. Four-dimensional CT...
FIGURE 7. A 41-year-old man with atypical chest pain, a normal stress thallium test, and a low calcium score of 6.5. CT angiography shows eccentric noncalcified plaque (arrows and boxes) in the left anterior descending coronary artery (LAD) on both (A and B) maximum-intensity projection views and (C and D) volume-rendered images. (E and F) Cardiac catheterization confirms stenosis in the proximal LAD, and (G and H) intravascular ultrasound showed eccentric plaque (echogenic crescentic area outlined in white) adjacent to the arterial lumen.
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may help to show dyskinetic segments, areas of ischemia and infarction, ventricular aneurysms, and septal hypertrophy. In addition, 4D CT is useful for assessing valve function.

We are beginning to look at the cardiac valves in all patients. In a patient with aortic insufficiency, CT angiography shows improper coaptation of the valve leaflets. In patients with aortic stenosis, coronary CT angiography reveals calcification and restricted motion of the valve leaflets.

Conclusion

Coronary CT angiography has become a very powerful diagnostic tool. It yields information not only on arterial plaque but also on myocardial contractility and valve function. It is easy to perform and is well tolerated by patients. Continued improvements in CT temporal and spatial resolution and further CT radiation dose reductions are needed before cardiac CT angiography will be capable of replacing diagnostic cardiac catheterization.

REFERENCES


FIGURE 8. An excellent way to look at areas that are suggestive of plaque is with biorthogonal projections, particularly short-axis views. This short-axis view shows large amounts of eccentric noncalcified plaque (arrow) adjacent to the enhancing lumen of the coronary artery.

FIGURE 9. (A and B) Maximum-intensity projections acquired on a 64-slice CT scanner. Visualization through the stent and good contrast opacification are easily accomplished. (C) A volume-rendered image shows stent in the left anterior descending coronary artery.
Discussion

ELLIOT K. FISHMAN, MD: Thanks very much, Jill. Why don’t we open it up to the panel again?

MARILYN J. SIEGEL, MD: I think one of the major issues you brought out, which was also discussed earlier, is the radiation issue, which is obviously important. CTA of the coronary arteries requires a high radiation dose, but I think one of the important things to recognize is how this dose compares with catheter angiography. What are the exposure doses that you have for coronary CTA versus catheter angiography?

JILL E. JACOBS, MD: The radiation dose of basic catheter angiography will really vary depending on whether there’s therapy at the time. It depends on the operator and how much fluoroscopic time there is.

SIEGEL: The dose for diagnostic studies.

JACOBS: For diagnostic cardiac catheterization, most of the literature I’ve seen is on the order of about 7 mSv, although it does vary. The radiation dose is greater for a cardiac CT angiogram. The thing that you have to keep in mind, though—and Stephan also brought this out—is that, if you are going to do a cardiac CT angiogram, you don’t do a study trying to save radiation dose and ending up with a nondiagnostic study. Especially in the United States, a lot of our patients are big patients, and it is critical, even though they may get slightly more radiation, to give a dose that will be adequate to penetrate them and to say something diagnostic about the coronaries.

STEPHAN ACHENBACH, MD: Also, if you think about other tests that are performed frequently, ie, nuclear medicine studies, they have those studies done in the same dose range, and sometimes even higher, and there’s not too much consideration about that. I think dose spent to obtain clinically useful information is well spent. You should not do this test if you don’t expect clinically useful information out of it, or for screening purposes. But when you need the clinical information, that’s dose well spent.

SIEGEL: I agree. The radiation dose needs to be selected to give a diagnostic study. You don’t want to end up with a nondiagnostic examination. Everything we do is a risk-versus-benefit issue. We can expect the use of coronary CTA to increase and radiation exposure is an issue that needs to be recognized.

ACHENBACH: Absolutely.

J. JEFFREY CARR, MD, MSCE: I want to make a point about larger patients. It’s a common misconception that increasing the technique is linearly related to a greater dose to the individual. Effective dose is based on the volume and the radiosensitivity of the organ that you’re imaging. So, as people get larger, when you increase mA, you’re not necessarily increasing that individual’s dose over your standard protocol. I know that’s counterintuitive, but the radiosensitive structures are primarily the bone marrow and the breast tissue around the heart. As you get larger patients, the signal-to-noise ratio is actually an indicator of how much dose you’re depositing in the tissue. So, by increasing your technique, you may maintain an effective dose for those individuals that are over 250 and 300 comparable to your standard technique in an average-sized individual.

Given what I’ve heard, my primary concern is that when you have a thin patient, we need to lower the dose, this is particularly true in pediatrics. You may not want to be up there at 800 and 850 mAs on, for instance, a 90- or a 110-pound woman when you’re doing these studies.

SIEGEL: In larger patients, you’ll get more superficial absorption, whereas, in thinner patients, you’ll get deeper absorption. Dose adjustment needs to be considered in thinner patients. It’s not only in the pediatric age groups that radiation needs to be addressed, but we need to think about it in younger, thin adults.

JACOBS: That’s why I think the timing issues are also so critical because we vary not only the radiation and the mAs that we give thin patients, but we also decrease the amount of contrast we give them. We vary both the contrast amount and the injection rate, depending on the size of the patient.

FISHMAN: But I think one of the best ways of reducing radiation is to do the study right the first time. One of the highest uses of radiation doses is in repeating studies that were done poorly—always somewhere else, of course—but studies that are done poorly don’t really help anybody.

Let me ask another question. One of the questions that’s often asked is how long does it take to analyze the study? Once you’ve scanned the patient, all 10 sequences are processed, the data is sent to the workstation, and you sit down. How long does it take you to analyze an average patient?

JACOBS: Now that we’ve been doing this for several years, for a normal study, it’s approximately 10 minutes. You scroll through, look at the different views, and take some pictures for the clinicians. For a difficult patient in whom there is a lot of calcium and a lot of plaque, it can take on the order of 30 minutes, sometimes slightly longer, to go through the data. It really depends on how much calcium there is. Larger amounts of calcium tend to increase our evaluation time.

RICHARD D. WHITE, MD: Elliot commented on the influence of dedicated technologists. What is your experience with them from the acquisition standpoint and their potential impact on postprocessing?

JACOBS: I think it’s very important to have well-trained technologists. We started out with 1 or 2 technologists who were trained. In fact, most of our technologists were a little nervous about doing these studies in the beginning. But now they all fight over who gets to work with us because they love doing them. We started out with a couple of well-trained technologists doing these studies; now we’re moving into training all of our technologists. It’s a very easy study to perform, as long as they know our workflow and they know what instructions to give the patients. Elliot’s point was very well taken—you don’t want somebody who will go in there aggressively and almost yell at the patient. One of the most important things in these studies...
is to have the patient in a very calm atmosphere. We dim the lights for our study also.

But if you work with your technologists to teach them how you like your studies done, the actual protocols are very simple. Our technologists are now being trained how to do volume-rendered images. They love doing them, and they label them for us, which significantly decreases the amount of time we spend actually just creating the images that we send to our clinicians.

ACHENBACH: I would like to add a few not-so-important issues to the topic of image acquisition. One is that 10 mL of contrast is absolutely sufficient for the test bolus. So you can save another 10 mL of contrast there, as long as you flush with saline. That’s a very important point. The second issue—I happened to see it on one of your slides—is that you try to use a small field of view, which is very, very important. It also makes the interpretation a lot easier.

Another thing that should be taken into account is that you should try to position the patient’s heart in the center of rotation when you position them, because the temporal resolution of the scanner is best in the center of the scan field, in the center of rotation. If you get your objects out of the center of the scanner’s rotation, then the temporal resolution may go down. So you should position the patients carefully, especially the height—that’s the hardest—in the center of the scan field. It takes a little bit of experience, but usually it goes quite well. It does increase the temporal resolution that you have.

JACOBS: We always do that also. Our technologists are trained to find the isocenter.

MICHAEL POON, MD: In our center, we always have a physician present during the scanning because the quality varies so dramatically with the technologists. One of the questions is about the mAs. We believe that if we do a study right and get the timing right, we probably can do with a lower mAs. So we look at the calcium study first. If you don’t see a lot of calcium in that patient with a slow heart rate, you really don’t need a very high mA to do that study.

So, we will lower that to around 700 or 720, to just reduce the dose. We know that the study is going to be good enough; the heart rate is steady enough. So these are the on-the-fly decisions that have to be made on a case-by-case basis, and we believe that a well-trained person can probably do that.

In terms of the postprocessing time, I think it depends on how many fellows you have. The more people you have, the less time you have to do it. We don’t use the technologists for that. It would just be time consuming; you’d have to teach them for an extended period of time.

Right now, we’re mostly using physicians for getting the data, selecting the best image in the best phase, and for getting the ejection fraction calculated, and so forth.

FISHMAN: One of the things we’re touching on now is that you have to get very good at using a workstation. We also do it physician-driven, but I think the speed of how fast you can do a study is based in great part on how good you are and how good your software is.

I think changes in software will benefit all of us over the next months or years. Most of the software we’ve used for doing cardiac imaging was developed to do the aorta; it was not designed for cardiac imaging. Now you’re seeing much more dedicated software that is really focused on and developed for cardiac imaging, which can do the calculations of stenosis.

Quantification is a very critical thing. At times, it’s something we don’t probably do as well as we should in radiology. I think software can solve those issues. That will be a big boon in terms of getting the process done faster. It’s also very interesting how people use technologists at individual sites. Again, in some ways, it depends on the supply of technologists, access to workstations, and how physicians feel comfortable working.

I’ll speak for the radiologists, not for cardiologists, but I think a lot of radiologists are still not super-comfortable with workstations. Most people did not have much experience with them in their training. It’s changing a bit now, but most radiologists have never pressed a button on a CT scanner. They’re afraid it’s going to explode. I guess. The workstation training has just not been there. It’s becoming very popular now, but at Hopkins, we never train residents on workstations per se.

WHITE: Our chairman said that cardiac training has been most useful because it’s the first time that the residents actually have to touch the workstation. So I guess we introduced something that I thought had been introduced elsewhere. I think it’s vitally important.

CARR: I want to make one other point about your workflow. We’re doing the same thing in that we just force our residents and fellows to use the workstation as part of how we review the scan. I think the key thing with 64-slice CT is the large amount of data that you now have.

So it’s not necessarily just having the workstation, but if you’re going to have a busy cardiac imaging practice, you need to have the proper workflow—that is, getting the patient done on the scanner, getting the images from the scanner to the workstation, and getting the report to your referring physicians rapidly.

There are a lot of parts in that information chain that you need to think about. One is actually the network and how the scanner is connected to that workstation. I would recommend against having those >15,000 images go to your PACs, then rerouted from your PACs to your workstation for analysis, because that’s fraught with difficulties. We have our own little subnet for cardiac imaging where the images flow directly to our image analysis workstation, and this has worked really well.

FISHMAN: That is a very important point. One of the issues with these large data sets is that everybody runs into bottlenecks. It varies by institution, but everyone has the same issues. So we’ve changed all of our networking to and away from the big networks, because everything was just way too slow. Infrastructure is critical. Infrastructure and workflow, those are the things that are
really tend to be bottlenecks. Truly, using 64-slice CT across all applications really brings out that everything works well, including things that were not working well at your institution before using 64. You learn that quickly.

Training is something worth commenting on. Like many of you, we have a lot of fellows, perhaps 9 or 10 fellows in cross-sectional imaging, and essentially none of them had prior workstation training. With residency training, it’s interesting that people argue about a few months of nuclear training or a few months of other training. Radiology has changed so much, and, especially, CT has changed with applications in coronary imaging, virtual colonoscopy, and 64-slice data of the lung, pancreas, liver, etc. It has been such a paradigm shift. Now you really can’t survive without using a workstation. It’s not an extraneous piece of equipment that you use once a month. It is basically core to your functionality now and you need core capabilities.

POON: Don’t think that this is only problematic to radiologists. Cardiologists don’t even know what workstations are about, particularly for tomography imaging. We are not trained to do that. Actually, most of the people who come for training spend more time learning how to use the workstation and how to read the CT than they do actually doing CT. Now with 64-slice, doing the scan is actually the easy part.

Reading is really the major bottleneck. Training is really a crucial part of the process. A major part of the training is teaching cardiologists how to work with the workstation, and how to read MIP, MPR, and volume-rendered images.

FISHMAN: One of the issues we’ll discuss in later discussions is the panel’s recommendation. What is it that you really need to learn? How do you get trained? What specific subset of skills do you need to do cardiac imaging beyond acquiring the data? I agree 100% that acquiring data may be the easiest thing in some ways. What happens after you have the data is a whole other issue.