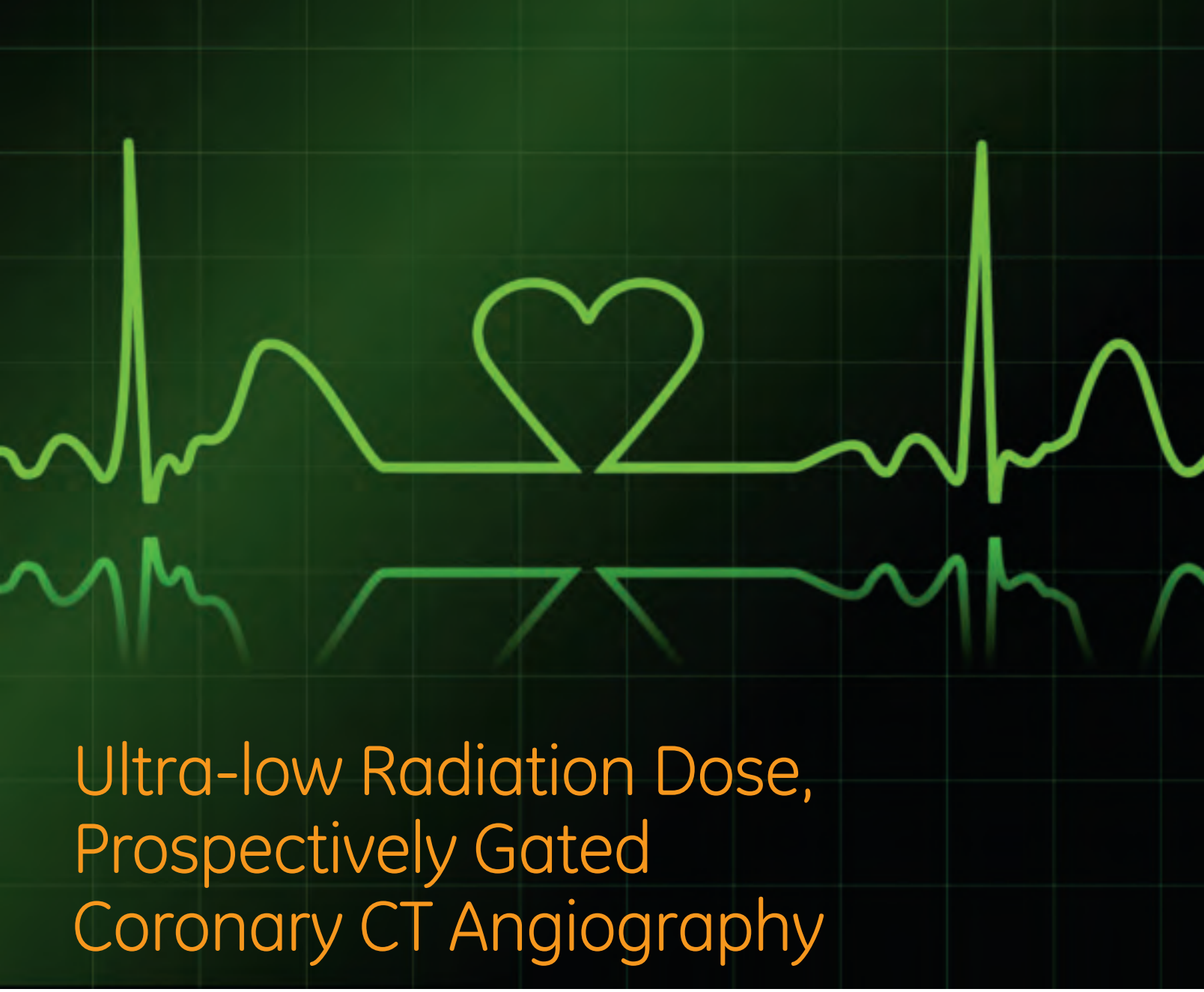

Ultra-low Radiation Dose, Prospectively Gated Coronary CT Angiography

State-of-the-art coronary CTA now possible with radiation comparable to a calcium score.

By David A. Dowe, MD, Medical Director, Coronary CTA Program, Atlantic Medical Imaging

In the October 2006 issue of Diagnostic Imaging, I wrote a brief article describing the benefits of using prospective gating axial (PGA) when performing coronary CT angiography.[1] Since then a number of software and technique improvements have occurred which make possible the use of PGA in the everyday clinical setting. In our practice, prospective gating is used in 98% of our coronary CTA patients as the initial and only scan technique. It has become rare for us to default initially to retrospective gating or reinject a patient to do retrospective gated helical (RGH) CCTA because of a failed prospective gated acquisition.

This article will briefly describe the prospective gating acquisition protocol. I will then present the ultra-low radiation exposure CCTA technique that results in radiation exposure comparable to that of a coronary artery calcium (CAC) score and compare the radiation exposure from cardiac imaging studies as they relate to CCTA.

Basics of prospective-gated coronary CTA

Prior to PGA, the most effective radiation dose reduction technique was EKG dose modulation. EKG dose modulation is used when performing RGH. It reduces dose by decreasing the millamperage (mA) of the X-ray beam in the systolic and near-systolic portions of the cardiac cycle where one is unlikely to be using the data to post-process the coronary arteries (Figure 1). This results in approximately 30% reduction in radiation exposure. What prevents this technique from reducing radiation dose further is that the X-ray beam remains on throughout the cardiac cycle even when no images will be reconstructed during the reduced exposure. This results in unnecessary radiation dose being delivered to the patient, which is inherent in all helical-acquired CCTA exams (Figure 2).

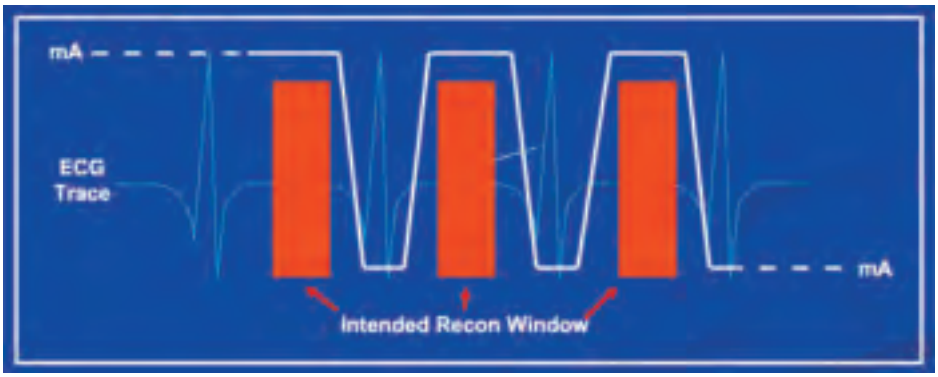

Figure 1. EKG dose modulation limits radiation exposure my decreasing the mA during the portions of the cardiac cycle where you will not be reconstructing the coronary arteries. EKG dose modulation decreases radiation exposure by 30%.

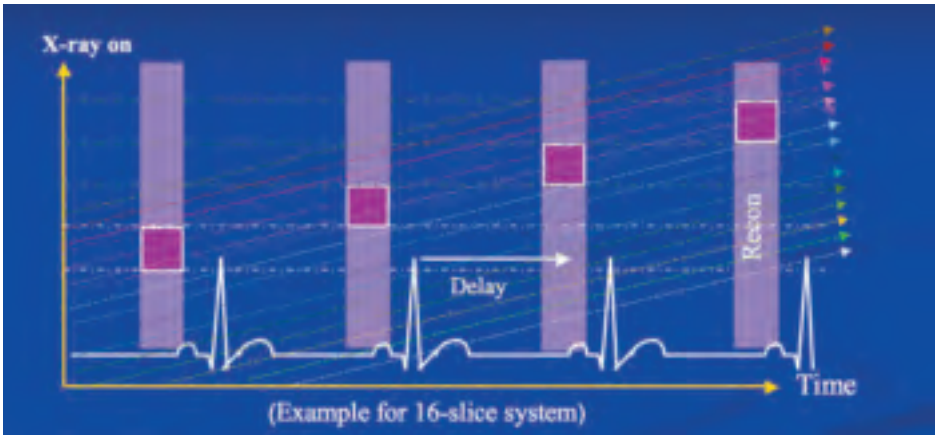

Figure 2. Although one routinely uses EKG dose modulation with Retrospective gated CCTA the X-ray beam is on throughout the cardiac cycle resulting in increased radiation exposure.

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Dr. Dowe lectures nationally and internationally, has written several articles related to coronary CTA and collaborates on coronary research and development.

About the facility

Atlantic Medical Imaging (AMI) is a full service, outpatient imaging practice operating seven offices throughout New Jersey and providing professional services to three area hospitals. Since 1964, AMI's goal has been to provide the most advanced diagnostic imaging services to our patients and referring physicians. With 32 board-certified, sub-specialty trained radiologists and a staff of 350 technical, clerical and administrative personnel, AMI is committed to providing patients with unsurpassed service and care and will ensure that their visit is comfortable and relaxing. AMI offers a full spectrum of diagnostic imaging services including CT, Coronary CTA, MRI, Nuclear Medicine, PET/CT, Digital Mammography, Ultrasound, DEXA, General Radiology and Fluoroscopy, and Interventional Radiology.

AMI was one of the first diagnostic imaging centers in the country to install GE's 64-slice LightSpeed® VCT scanner, the most technologically advanced CT scanner available on the market today. The 64-slice CT scanner can produce extremely high-quality images at sub millimeter resolution in only a few seconds. Since 2001, Atlantic Medical Imaging has been performing Coronary CT Angiography (CTA) and has performed more than 10,000 exams to date.

PGA avoids this extraneous radiation dose by completely turning off the X-ray beam during most of the cardiac cycle (Figure 3). The portion of the cardiac cycle that is to be radiated is selected before the scan, hence the term "prospective." The radiated window (duration of the tube turned on) may be left wide, which makes it possible to reconstruct vessels across a range of cardiac phases. This comes at the expense of increasing radiation dose. Before the scan, the user must select the phase of the cardiac cycle in which the reconstruction will be centered. I routinely use the 75% phase, which in patients with heart rates <65 bpm places this within diastole. In the PGA protocol, there is a default time added to the window for the tube on-time (dynamic padding) based on the patient's heart rate. However, if the patient's heart rate is <65 bpm one can conclude that the post-processing will be successful, i.e., diagnostic images of all 15 American Heart Association (AHA) coronary artery segments, with the single 75% phase for reconstruction.
For this reason, I always override the default padding and manually enter a 10 msec padding surrounding the 75% phase (Figure 4). As an example, in a patient with a heart rate of 60 bpm, the duration of the cardiac cycle is 1,000 msec.
By radiating only 10 msec before and after the 75% phase, you only radiate 2% of the cardiac cycle, in addition to the window centered at the 75% phase (Figure 1).
Using PGA with the default padding reduces radiation by 52% to 74% when compared to RGH with no loss of image quality (Figures 5 to 7).

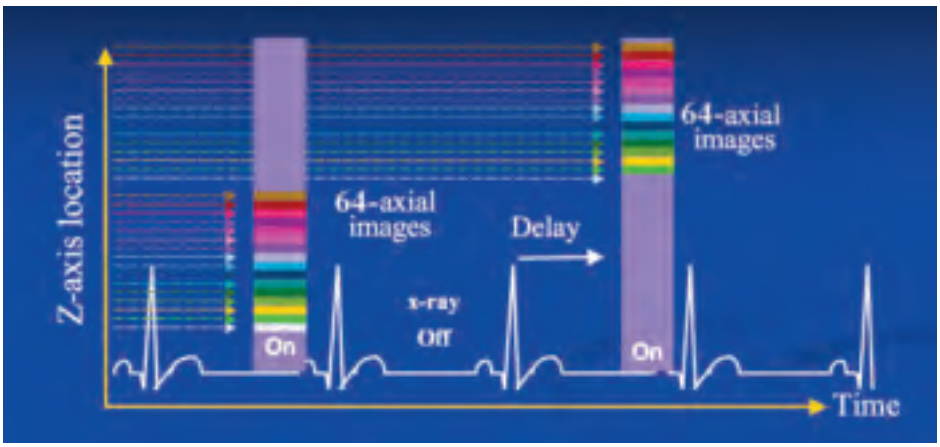

Figure 3. With PGA the X-ray beam is either on or off resulting in substantially decreased radiation dose. A prerequisite is having a heart rate <65 bpm.

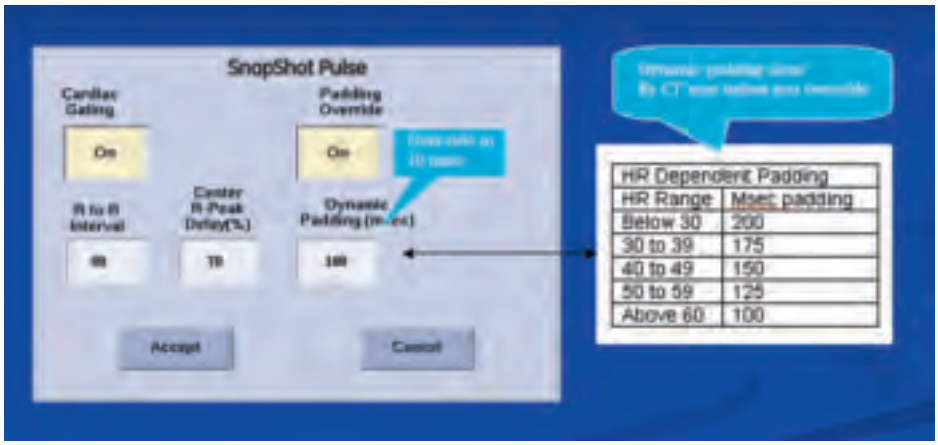

Figure 4. The CT scanner will set the radiation padding length on either side of the 75% window based on the heart rate. I routinely override this function and use a 10 msec pad.

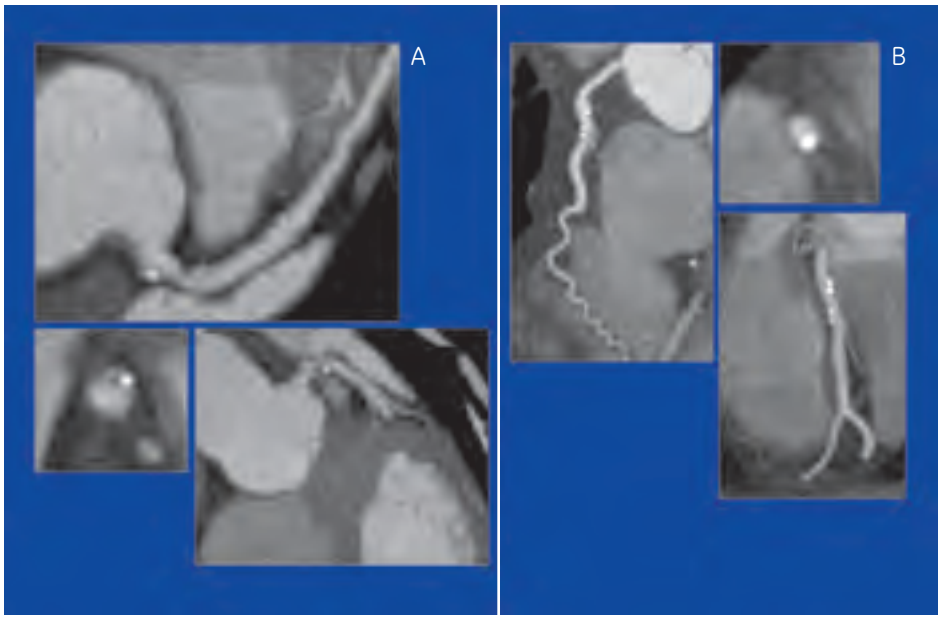

Figure 5. Retrospectively gated (A) and prospectively gated (B) images on the same patient. There is no loss in image quality or diagnostic accuracy with 70% dose reduction.

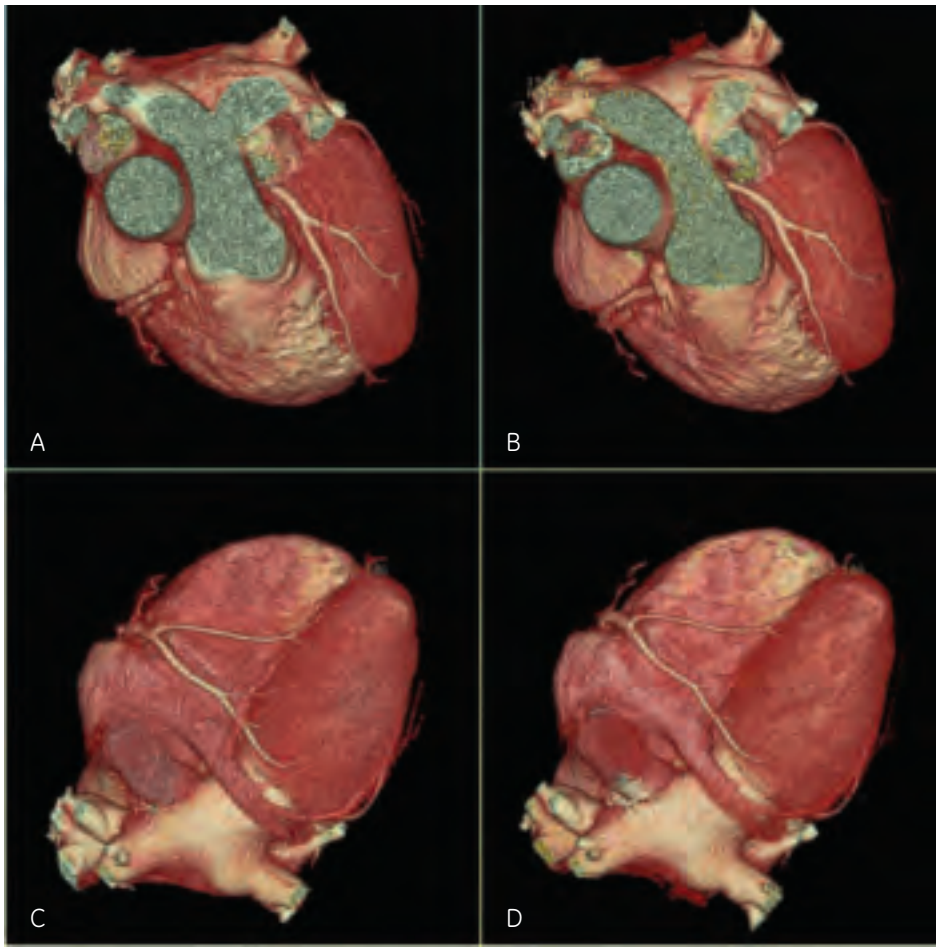

Figure 6. Images A and C are prospectively gated and B and D are retrospectively gated. The images are indistinguishable with 70% dose savings.

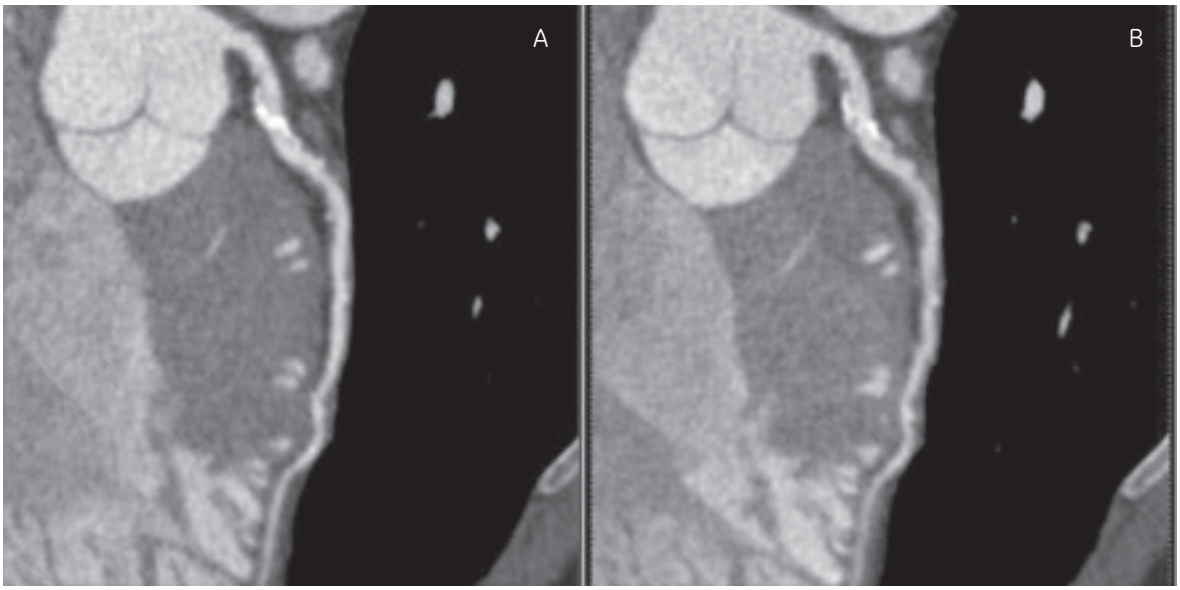

Figure 7. Indistinguishable curved MPR images with prospectively gated (A) and retrospective gated (B) on the same patient.

When manually decreasing the padding to 10 msec, the radiation exposure can be reduced by up to 83%. This dramatic reduction in radiation exposure easily justifies administering beta-blockers in order to decrease the heart rate to 65 bpm or less. PGA may, in fact, be used in patients with heart rates between 65 and 70 bpm but it is somewhat less consistent in obtaining all 15 AHA coronary artery segments at post-processing. A drawback of PGA is that functional evaluation of the heart is not possible since images are not collected at all phases of the cardiac cycle.

Ultra-low dose, 100 kVp, prospective gated CCTA

Before one can consider the topics of spatial and temporal resolution as they pertain to CCTA, you must be able to obtain images with an adequate signal-to-noise ratio (SNR) in order to visualize the coronary arteries. The demands for an increased SNR are most apparent in the obese and morbidly obese patients. In these patients the use of 650 to 800 mA may be necessary to obtain diagnostic images. In scanners whose maximum tube current is less than this, you may be forced to increase kVp to 140 kVp from the usual 120 kVp. Each incremental increase of 20 kVp results in a 38% increase in radiation exposure. Obviously, a reduction in 20 kVp decreases radiation exposure by 38% (Figure 8). It is important to titrate your technical factors to the minimum needed for adult patients of different body mass indices (BMI) and body habitus. BMI is the variable I use to select the kVp and mA for both PGA and RGH. Out of the development of PGA has come the realization that image quality can be preserved in many patients by using 100 kVp instead of the 120 kVp I routinely used with RGH. Using 100 kVp results in ultra-low radiation dose CCTA. In many patients, the dose from this scan is comparable to coronary artery calcium score (Table 1).

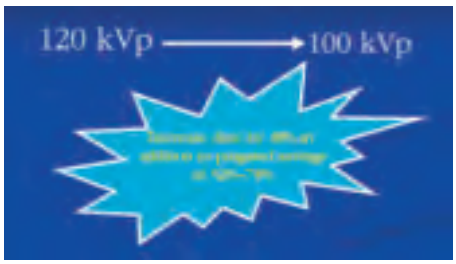

Figure 8. A 38% dose reduction results by reducing the kVp from 120 to 100.

Table 1.
Window Padding Centered at 75%

At a heart rate of 60 bpm, the RR interval is 1000 msec in length.
Using the rate determined by computer padding, we would irradiate 200 msec of the RR interval or 20% in addition to the 75% phase.
Using the override padding, we would radiate only 20 msec of the RR interval or only 2% in addition to the 75% phase.

Conclusion

PGA is now achievable in the overwhelming majority of patients needing CCTA. It requires a heart rate of <65 bpm, which is easily and safely obtained by the administration of beta-blockers. Given the massive reduction in radiation exposure, I feel that PGA should become the standard of care and will likely force the hand of all CT vendors to develop this capability. Given that PGA radiation is now on par with that of a calcium score, CCTA could quickly become the initial exam used in symptomatic patients suspected of having CAD. ■

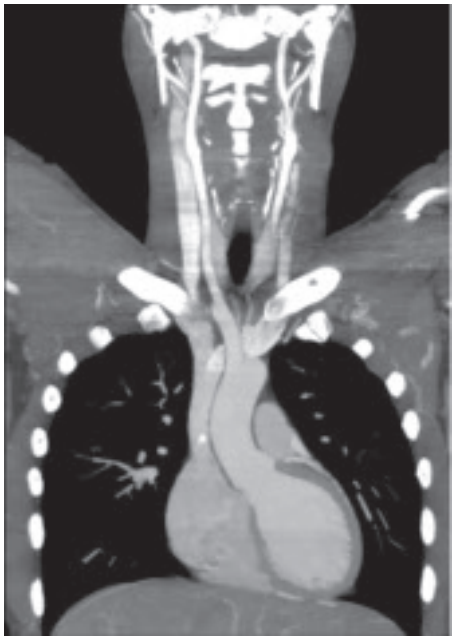

Figure 9A.

Figure 9B.

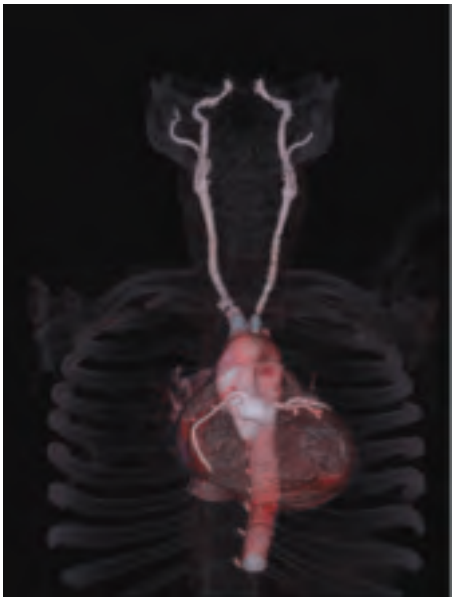

Figure 9C.

Quadruple rule-out examination. Arterial phase opacification of the carotid arteries, aorta, and coronary and pulmonary arteries. This acquisition was obtained with 5.8 mSv of radiation exposure. Curved MIP (A) and 3D volume rendered (B). Cardiac transparency image of a quadruple rule-out (C).

Figure 10A.

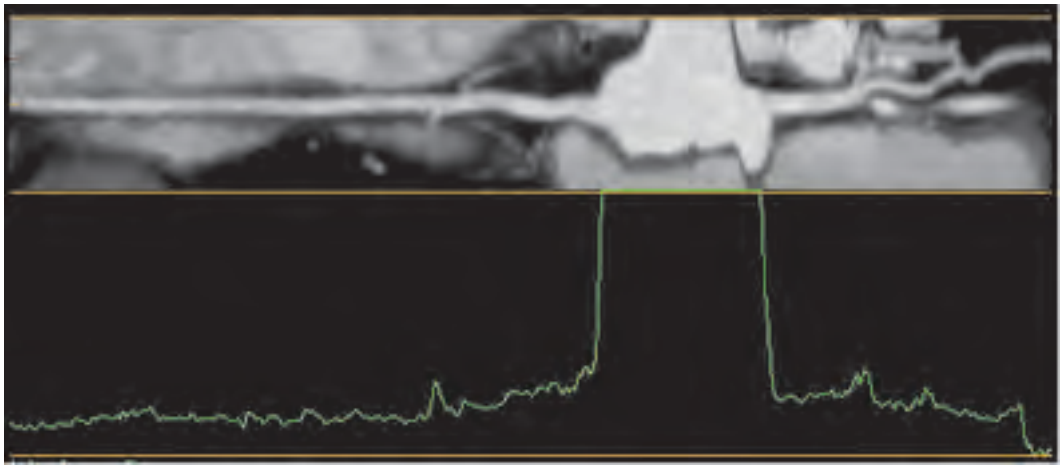

Figure 10B.

Quadruple rule-out examination. Curved multiplanar reformat (10A) and lumen view (10B).

References:

1. Dowe D. Prospectively gated computed tomographic angiography dramatically reduces radiation dose. Diagn Imaging 2006:28(suppl):1-5.