The incorporation of multiple detectors into spiral computed tomography (CT) scanners has expanded the clinical role of CT in cardiac imaging, including coronary CT angiography (CTA). Advances in both the speed at which the X-ray source rotates and the number of detectors have improved the ability of CT to resolve smaller anatomic detail and have enabled imaging of the native coronary arterial tree. At present, and for at least the near future, CT is the most robust modality to noninvasively image the coronary arteries. CTA contributes largely to cardiovascular diagnoses, but one of the most important and one of the most promising contributions is its high negative predictive value for coronary artery disease (CAD). That is, using the protocol detailed in this chapter, CAD can be reliably excluded in minutes without arterial catheterization. Moreover, in a single CT acquisition, native coronary imaging can be extended to include the beating myocardium, valve motion, ventricular outflow tracks, and coronary bypass grafts. In this chapter, in addition to detailing a basic cardiac imaging protocol, examples of examinations are illustrated.

Introduction

Protocols for electrocardiogram (ECG)-gated cardiac CT have evolved with rapid improvement in technology. The technique has progressed from early cardiac CT [4-slice multidetector CT (MDCT) with 1-s gantry rotation] to current standards (ECG-gated 64-slice MDCT with gantry rotation times as low as 330 ms). Technology has developed at a rapid rate, fueled primarily by the promise of a robust, noninvasive method of performing diagnostic coronary angiography (Fig. 1). Additional MDCT imaging includes coronary bypass grafts and evaluation of cardiac valves. This chapter fo-
cuses on the coronary CTA protocol and also described how the basic protocol can be modified or extended for problem solving.

**Temporal Resolution**

Successful cardiac imaging by any modality relies on the ability of the technology to produce motion free images or to scan faster than the heart beats. Thus, cardiac CT is founded on (1) imaging faster than the heart beats, or (2) slowing cardiac motion. Temporal resolution is the metric that measures imaging speed. For a CT scanner with a single photon source, the temporal resolution is one half of the CT gantry rotation time. This is because image reconstruction requires CT data acquired from one half (180°) of a complete gantry rotation. At the time of publication, all manufacturers have gantry rotation times less than 500 ms, with a minimum of 330 ms. With a 330-ms gantry rotation, an ECG-gated cardiac image can be reconstructed (using single-segment reconstruction described below) with CT data acquired over 165 ms of the cardiac cycle. Thus, the reconstructed images display the average of the cardiac motion over the 165 ms during which the data was acquired. This is how ECG gating enables coronary CTA. Without gating, cardiac images are nondiagnostic because the reconstruction “averages” the motion over the entire RR interval – 1,000 ms for a patient with a heart rate of 60 beats per minute.

Temporal resolution can be improved in single-source scanners by adopting a so-called “multisegment” image reconstruction. The principle underlying multisegment reconstruction is that the acquisition over several heart beats is summed to obtain the one half gantry (i.e., 180°) CT data. For example, in a two-segment reconstruction, two heart beats are used to generate a single axial slice, and thus the temporal resolution is halved. Similarly, if four heat beats are used (four segment reconstruction), only 45° of data are used from each heart beat. This would yield a four-fold reduction in the temporal resolution. Since multiple heart beats are used to fill the 180° of gantry rotation necessary for the reconstruction, stable periodicity of the heart is essential. Moreover, multisegment reconstruction requires a lower CT pitch, resulting in greater data oversampling and a higher radiation dose. Radiation considerations and a simple formula to estimate effective patient dose are given in an upcoming section.

A recent approach to improving temporal resolution involves the use of two independent sources and two independent (64-slice) detector systems (Siemens Definition; Siemens Medical Solutions; Erlangen, Germany). The second X-ray source is positioned 90° from the first X-ray source, and the second detection system is positioned 90° from the first detection system. With respect to temporal resolution, the practical consequence of this CT configuration is that 180° of gantry rotation can be achieved in half the time (e.g., 82.5 ms as opposed to 165 ms). This improvement in the temporal resolution is expected to eliminate the need for multisegment reconstruction. In fact, in patients with a higher heart rate or a heart rate that is difficult to control with beta blockade (described below), the CT pitch can be increased without compromising image quality.

**Beta Blockade for Heart-Rate Control**

As suggested from the discussion on temporal resolution, beta blockade is an important component of most cardiac CT examinations. A useful rule of thumb for the target heart rate is “the first number is a 5°” – i.e., an ideal heart rate between 50 and 59 beats per minute. While this goal is not achieved in every patient, it provides a useful reference frame. IV metoprolol is routinely administered at our institution; with cardiac monitoring, 5-mg increments are given every 5 min up to a total dose of 25 mg. Doses greater than 15 mg are rarely needed. Beta blockade can be safely performed by a radiologist or a cardiologist. An alternative approach involves the use of oral beta blockade. Although this approach has the disadvantage of a longer serum half life, most patients arrive for the study with a heart rate already in the target range. This can simplify patient preparation on site and has the potential to increase patient throughput. The tradeoff is the extra step of premedicating the patient and issues surrounding patient compliance.

In theory, using the multisegment reconstruction approach described above, beta blockade can often be avoided because using multiple heart beats in the reconstruction enables the scanner to have an effective temporal resolution in the range of 40–50 ms. However, when multisegment reconstruction is used, image quality becomes highly dependent on cardiac beat-to-beat variability. In our experience, multisegment reconstruction works well in patients with high heart rates who are being studied for clinical indications where the highest image quality may not be required, for example, coronary bypass graft location and patency. For coronary CT angiography, beta blockade is still recommended.

**ECG Gating**

ECG gating refers to the simultaneous acquisition of both the patient’s electrocardiogram (ECG)