# 28 Multislice CT Coronary Angiography in Evaluation of Coronary Artery Disease

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**Abstract:** The investigation and treatment of coronary disease impose a significant burden on health service resources. Catheter coronary angiography remains the gold standard for the investigation of suspected coronary disease. Given the invasive nature and high costs of invasive coronary angiography, there is an increased interest in non-invasive methods to image the lumen of the coronary arteries. Recent publications of the utility of 64-slice scanners indicate further improvement in both interpretability and diagnostic performance. When referral to catheterization is questionable, CT coronary angiography may identify subjects with normal angiograms and consistently decrease the number of unnecessary invasive procedures. Multislice CT coronary angiography of the clinically relevant coronary segments, as designated by the AHA classification, is now possible. Significant coronary stenoses were detected with the latest 64-slice CT scanner with a sensitivity of 99% and a specificity of 95% compared with conventional invasive diagnostic coronary angiography.

## INTRODUCTION

Coronary artery disease is acquiring epidemic proportions in south-Asians. It strikes 10 years earlier, is more extensive and severe than in westerners. Investigations used to screen for Coronary Artery Disease at present are ECG, Stress Test, Stress Echo, Stress Thallium, Electron Beam CT and Catheter Coronary Angiography.

ECG is the most commonly used and available test to evaluate chest pain for diagnosis of coronary artery disease unfortunately an ECG is the most insensitive means to answer this question as a normal ECG, neither can exclude ischemia nor infarction.

The investigation and treatment of coronary disease impose a significant burden on health service resources. Stress testing may help select patients who require coronary imaging, but catheter coronary angiography remains the gold standard for the investigation of suspected coronary disease. However it is invasive, with a small associated morbidity and mortality, resource intensive and is inconvenient for patients as it requires hospitalization. Some 40% studies require no further intervention after exposing patients to the unnecessary procedure risks.

Given the invasive nature and high costs of invasive coronary angiography, there is an increased interest in non-invasive methods to image the lumen of the coronary arteries. Non-invasive coronary angiography has made great strides over the last decade to become a clinically useful tool to augment conventional coronary angiography.

The ideal screening test for coronary artery disease would be a noninvasive test which does not stress the heart to produce potential complications. Electron Beam CT initially showed a lot of promise especially with its ability to quantify the amount of calcium in the coronary arteries. The presence of significant coronary calcium is a strong indicator to the presence of coronary artery disease. However, it is more commonly the presence of lipid rich plaques which precipitate an acute coronary event. The unstable lipid plaque ruptures and embolizes downstream to occlude the coronary artery with consequent myocardial infarction. Therefore, it is more important to detect soft plaques than calcific plaques. EBCT further lost out to Multi detector CT as the spatial resolution of MDCT was higher at 10lp/cm as compared to 7 lp/cm for EBCT. Of course MDCT had an obvious advantage as it was not restricted to the heart like EBCT and can evaluate non cardiac causes of chest pain.

### Indications

There are no established algorithms for using the MDCT. Potential indications are:

- Early detection of stenosis in patients from high-risk families.
- In those with atypical chest pain.
- Refractory chest pain with doubtful coronary origin.
- Non-conclusive stress test.
- Evaluate congenital anomalies of the coronary arteries or great vessels.
- Coronary vein assessment for pacemaker implantation
- MDCT may replace coronary angiography in patients with
- Aortic disease; and
- Prior to major non-cardiac surgery.

### Preparing for the Procedure

The patient will be asked not to eat or drink for 2 hours and to avoid caffeinated drinks and exercise for 6 hours prior to the procedure. The patient will be asked to complete a safety questionnaire to identify any allergies to foods, drugs, and iodine. In certain situations, the patient may need a blood test to assess kidney function and to exclude pregnancy prior to the scan.

### Technique of Multi-Detector Row CT Coronary Angiography

Imaging is most likely to be successful if the patient has a slow and regular heart rate, the breath holding and scanning times are short, and the spatial and temporal resolutions are high. The acquisition and processing of data are geared to achieving these goals.

### Optimizing Heart Rate

The heart is in constant motion, more so in systole than in diastole. The duration of diastole depends on the heart rate and the time spent in systole. The proportion of the cardiac cycle spent in systole increases with increasing heart rates and decreases with lowering of the heart rate. With higher heart rates, there is shortening of the end-diastolic interval. To obtain nearly motion-free images, acquisition or reconstruction of data is performed during diastole. Diastolic times are higher with heart rates of less than 75 beats per minute. A longer diastole increases the window of time available to acquire optimal images, especially if the acquisition time is relatively long. The temporal resolution of multi-detector row CT has improved, but technological limitations still require optimizing the heart rate for satisfactory imaging. Medications can increase diastole by decreasing the heart rate or shortening the systolic component. The diastolic time can be increased by giving patients Beta-blockers to lower the heart rate. For example, for patients with a heart rate of greater than 65 beats per minute, 100 mg of metoprolol has been administered orally 1 hour prior to CT.

### Decreasing Scanning Time

Reducing the scanning time decreases the likelihood of breathing artifacts and enhancement of the cardiac veins. The heart rate also tends to decrease or be relatively stable in the first 20 seconds of breath holding but may increase after that.

### Optimizing Spatial Resolution

Spiral CT allows volume acquisition and reconstruction of overlapping sections, which improve z-axis resolution. The resolution of 16 detector row CT is up to 0.5x0.5x0.6 mm. This resolution is approaching, but remains inferior to, that of conventional angiography, which is 0.2 × 0.2 mm.

### Decreasing Motion Artifact

With multi-detector row spiral CT, the data are acquired as a volume and retrospective electrocardiographic (ECG) gating is performed to reconstruct the images. An ECG tracing is obtained simultaneously with the acquisition, and a certain time interval from the R wave is chosen to start reconstruction.

Images are reconstructed during the time of least motion or between the T and P waves. Images are reconstructed with a predefined temporal offset relative to the R waves of the patient's ECG signal; this delay can be either relative (given as a certain percentage of the R-R interval time) or absolute (given in milliseconds) and either forward or reverse (Figs 28.1 and 28.2). In the relative delay method, a certain delay from the prior wave is determined as a percentage of the R-R interval. This delay is used to start reconstruction. In the absolute delay method, a fixed time delay after the R wave determines the start of image reconstruction. Finally, in the absolute reverse method, a fixed time before the next R wave is the point for starting reconstruction. The relative delay method is usually used for reconstruction.

### Optimizing Temporal Resolution

The temporal resolution equal to one-half the gantry rotation time (rotation time/2) works for low heart rates but can give blurring and stair step artifacts with higher heart rates. The temporal resolution for higher heart rates is improved by using data from more than one cardiac cycle to reconstruct the image. The data from one, two, or three consecutive cycles are used, depending on the heart rate. The higher the heart rate, the more cycles are used. The resulting temporal resolution can be as good as the gantry rotation time divided by $2N$ ($N$= number of cycles). For example, if the rotation time is 500 msec and if data from two cycles are used, the temporal resolution goes up to 125 msec. The temporal resolution with this approach is not constant but depends on the heart rate.

### Technique Summary

Initially, the patient's heart rate is determined. If the rate is greater than 65-70 beats per minute, a beta-blocker such as metoprolol can be given orally 1 hour prior to CT or the appropriate intravenous dose can be administered just prior to scanning. Nitroglycerin (0.4 mg) has also been given to dilate the coronary arteries but may result in reflex tachycardia (Figs 28.3 and 28.4).

A 120-ml dose of nonionic iodinated contrast material is injected intravenously at approximately 4 ml/sec for CT angiography. A saline solution bolus can also be given following contrast material injection to decrease artifact from contrast material in the right heart. If a saline solution bolus is used, the total amount of contrast material injected is reduced. Scanning is triggered once contrast material is seen in the ascending aorta, or a test bolus is administered to calculate the appropriate delay. Typical delays in one study were 10-18 seconds.

The images are reconstructed by using a medium soft-tissue kernel with retrospective ECG gating. One or multiple image sets are reconstructed in diastole by using the methods described earlier, such as a 40-70% relative delay or 300-550 msec absolute reverse ECG gating. In general, reconstruction is avoided at 10-30% or greater than 80% of the R-R interval, as these times is particularly susceptible to motion artifacts. On a four detector row unit, 1.25 mm thick sections are reconstructed at 0.6-mm intervals; on a 16 detector row unit, 1 mm thick sections are reconstructed at 0.5 mm intervals. On a 16 detector row unit, additional 0.75 mm-thick sections can be reconstructed for detail viewing of severely calcified coronary arteries or stents at the expense of increased image noise.

### Accuracy

Using 16-slice MDCT reported sensitivity to detect 50% diameter reduction was 82% and specificity 84%. Recent publications of 64-slice scanners indicate further improvement in both interpretability and diagnostic performance. The sensitivity, specificity, and the positive and negative predictive values of 64-slice CT were 99%, 96%, 78% and 99%, respectively, on a per-segment basis. The values obtained on a per-patient basis were 100%, 90%, 96% and 100%, respectively. When referral to catheterization is questionable, CT coronary angiography may identify subjects with normal angiograms and consistently decrease the number of unnece-ssary invasive procedures.

### Recent Developments

The newest 64-slice CT scanners have a shorter rotation time (330 ms) and offer not only a shorter scan time and a higher spatial resolution but also a higher temporal resolution compared with previous scanner generations. Multislice CT coronary angiography of the clinically relevant coronary segments, as designated by the AHA classification, is now possible. Significant coronary stenoses were detected with the latest 64-slice CT scanner with a sensitivity of 99% and a specificity of 95% compared with conventional invasive diagnostic coronary angiography.

### Comparison with EBCT/ MRI

At electron-beam CT, a compromise has to be made between z-axis resolutions and scan coverage, so the distal coronary arteries may not be included in the acquisition. In addition, spatial resolution and signal-to-noise ratio are lower with electron-beam CT, whereas scanning time is higher. Therefore, evaluation with electron beam CT and MR imaging is usually limited to the proximal and middle vessel segments. With multi-detector row CT, the entire heart can be covered, so both proximal and distal vessel segments can be visualized.

### Plaque Morphology

Early work characterizing atherosclerotic plaques suggests that lipid plaques have an attenuation of less than 50 HU, intermediate plaques have an attenuation of 50-119 HU, and calcified plaques have an attenuation of greater than 120 HU. The effect of partial volume averaging on attenuation measurements is reduced with thin sections. Lipid plaques are not as stenotic but are prone to rupture, which can lead to acute occlusive thrombosis.

### Artifacts

Following types of artifacts are usually encountered while reconstructing images:

a. Motion-related artifacts caused by cardiac, pulmonary, or other body motion
b. Beam-hardening effects caused by metallic implants, severe calcifications, or air bubbles in the pulmonary artery that obscured the underlying coronary vessel lumen
c. Structural artifacts produced by adjacent contrast material-filled structures and overlying vessels
d. Artifacts that resulted from technical errors or limitations.

The most frequently observed artifacts were those related to cardiac motion. The most effective methods for minimizing cardiac motion artifacts are:

a. Premedication with β-blockers to maintain optimal heart rate during scanning

b. Optimal selection of the reconstruction window.

## FURTHER READING


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