

# The Role of 16-Slice Computed Tomography Angiography in the Diagnosis of Coronary Artery Disease: Large Sample Analysis

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**Key words:** multi-slice computed tomography, coronary angiography, coronary artery stenoses, bypass surgery, coronary anomaly

## Abstract

**Background:** Computed tomography angiography enables non-invasive evaluation of the coronary arteries.

**Objectives:** To evaluate the accuracy of 16-slice multi-detector CT angiography in the diagnosis of coronary artery disease, and assess coronary bypass grafts and coronary anomalies.

**Methods:** We conducted a retrospective study of 223 patients who were examined at our medical center over a period of 2 years with a 16-slice CT angiography scanner and retrospective electrocardiographic gating.

**Results:** There were no significant complications, and good visualization of the coronary arteries was achieved in all but eight patients. A high correlation with the results of the invasive angiography was noted (sensitivity 85%, specificity 93%, negative predictive value 98%). Altogether, 131 bypass conduits were examined with excellent graft visualization. Several coronary anomalies were detected, as were significant extra-cardiac findings.

**Conclusions:** Multi-slice CT angiography is a reliable non-invasive diagnostic procedure for demonstration of the coronary arteries and bypass grafts. In the future it will probably replace part of the diagnostic invasive coronary angiography and, as a result, a large proportion of coronary angiography procedures will be therapeutic.

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Coronary artery disease is the leading cause of death in the western world and the major cause of premature permanent disability. Although invasive coronary angiography is considered the diagnostic standard for establishing the presence and severity of significant coronary artery disease, interventional treatment is generally performed in no more than 50% of diagnostic procedures. More than 1 million invasive coronary angiographic procedures are performed annually in the industrialized world. Since invasive procedures have an associated mortality (0.15%) and morbidity (1.5%), there is no doubt that replacing part of the diagnostic coronary angiography with a non-invasive procedure would constitute an important advance in the care of patients with known or suspected coronary artery disease. During the past decade, considerable progress was made in the field of non-invasive coronary artery imaging, with magnetic resonance imaging, electron beam computed tomography and, most recently, multi-detector spiral CT.

MDCT systems for non-invasive detection of coronary artery disease were introduced in 1999 with the four-detector row CT scanner. Since then, impressive advances have been made with the introduction of 16-detector row scanners. The new generation of multi detector-array CT scanners was used in the present study. They operate at an increased rotation rate (0.42 seconds) and produce up to 16 slices per rotation simultaneously. These developments permit high-speed scanning of large volumes with a high in-plane resolution, as well as an improved Z-axis resolution. The decrease in rotation time allows an improvement in the temporal resolution to 210 msec or less.

Many studies have compared MDCT with invasive coronary angiography in the evaluation of coronary artery disease, and showed good accuracy [1-4]; these included the evaluation of bypass grafts [5-7] and the detection of coronary anomalies [8,9]. The first 16-slice CT angiography in Israel was introduced at the Carmel Medical Center in May 2002 and since then more than 200 examinations have been performed. We summarize our experience with this new technique.

## Patients and Methods

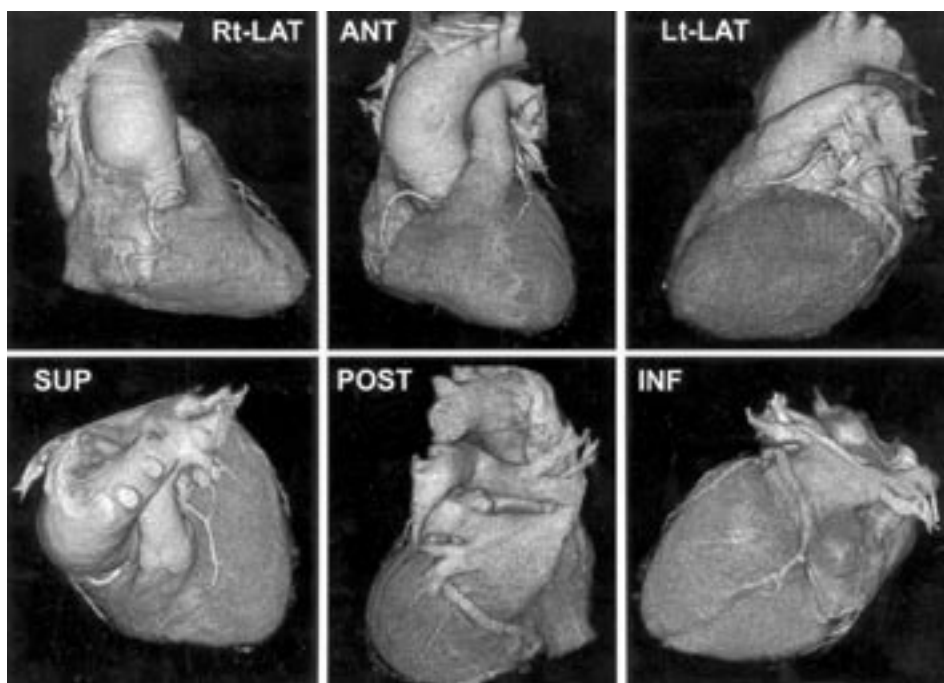
### Study population

The study population consisted of 223 patients, 73% male, age 21-88 years, who underwent contrast enhanced CT angiography of the coronary arteries from May 2002 to March 2004. Exclusion criteria included known allergy to contrast media and impaired renal function. Fifty-one percent of the patients underwent coronary catheterization prior to or after CT; 20% were totally asymptomatic. Forty-three percent of the female patients had diabetes mellitus

### Examination technique

During the examination the patient was placed in a supine position within the gantry of a newly released 16-slice CT scanner (Mx8000IDT, Philips, Cleveland, OH, USA). Leads were attached for simultaneous electroencephalograph and image recording necessary for inter-related image reconstruction. According to the expected location of the coronary arteries and bypass grafts obtained from the coronal scout view, the scan volume was de-

MDCT = multi-detector spiral CT



**Figure 1.** CT images of a heart and its coronary arteries from different angles.

fined. A retrospective ECG gating was used, which allows post-scan acquisition window selection and optimal gating. This approach improves the image quality and reduces the sensitivity to arrhythmia and ECG noise. Fixed scanning variables included 0.42 sec rotation time, tube voltage of 140 kV, and 400 mAs. We used 16 slices of 0.75 mm thickness collimation. The effective slice thickness was 0.8 mm with an increment of 0.4 mm. The pitch (table feed per rotation divided by the single collimation slice thickness) was set between 0.2 and 0.3 according to the heart rate. To facilitate adequate breath hold, the patients were connected to an oxygen mask and were asked to hyperventilate prior to the actual scan. To determine the exact transit time of the contrast material from injection site in an antecubital vein to the aortic root and coronary arteries, a test bolus of 20 ml non-ionic contrast agent with a high iodine content (Iohexol 350 mg L/ml; Omnipaque®, Nycomed, Ireland) was injected at a rate of 4.0 ml/sec. Good contrast between blood and surrounding tissues was achieved by the injection of 100–120 ml contrast material at a rate of 3.5–4.0 ml/sec. The acquired CT and ECG axial slices were reconstructed from the acquired volumetric CT data during mid- to late diastolic phase (usually 70–80% of the cardiac cycle) to minimize motion artifacts. The images were further processed on a separate workstation (NT, Philips) and three-dimensional volume rendering reconstructions of the heart and coronary arteries were performed as well as two-dimensional reconstructions (curved multiplanar reformation) in several planes.

#### Vascular analysis

The purpose of the analysis was to detect coronary lesions. An artery without a significant obstruction was defined when con-

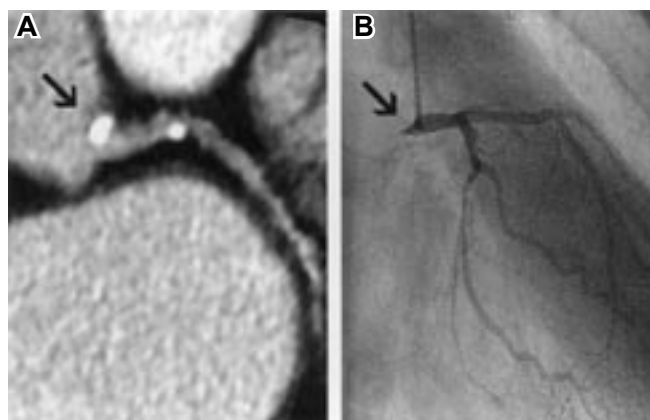
trast material appeared throughout the artery without any signs of plaques causing more than 30% stenosis of the vessel diameter. Graft patency was defined as the presence of contrast material continuously throughout the artery.

#### Results

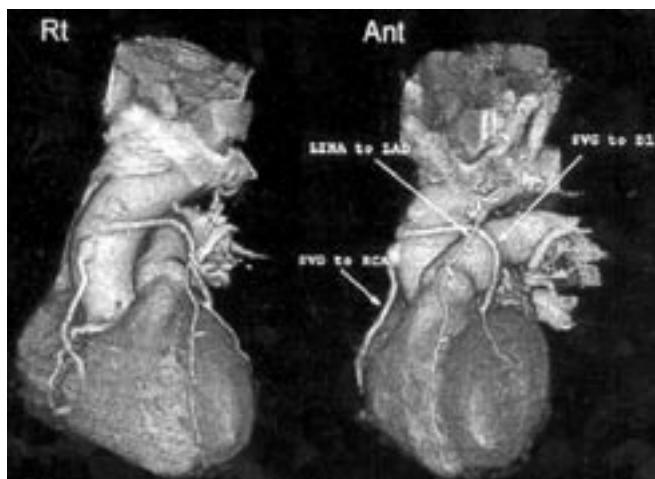
There were no significant complications. Good visualization of the coronary arteries was achieved in all but eight patients [Figure 1]. The average time needed for the investigation was less than 20 minutes, including preparations and scanning. Reconstruction of the images and evaluation took up to 3 hours per patient, but decreased significantly after a learning curve. The average heart rate during the scan was 82 beats/minute (range 54–97) and all patients were able to hold their breath for the required time.

#### Correlation with angiography

Of the 223 patients 114 underwent conventional coronary angiography prior to or after the CT examination. Altogether, 1,314 segments were correlated (132 coronary segments were excluded because of reduced image quality). On invasive angiography, 225 of the 1,314 segments had high grade stenoses or occlusion. Among the segments with occlusions, 209/225 were identified on CT examination, while among the segments without occlusions 926/1,089 were detected (sensitivity 85%, specificity 93%). The negative predictive value was 98%. There were three cases in which ostial lesions were not detected in the first conventional coronary angiography but were obvious on the CT examination and confirmed on the second conventional coronary angiography [Figure 2].



**Figure 2.** CT angiography [A] and invasive angiography [B] images of a significant lesion in the proximal left main artery.



**Figure 3.** CT images of bypass grafts from different angles.

### Bypass graft assessment

Of the 223 patients, 61 had previous coronary bypass surgery and 36% of them underwent CT scanning 1 week following the surgery. Five patients underwent a minimally invasive direct operation and three had a redo operation before the CT examination. A total of 131 conduits were examined. Excellent graft visualization, including the anastomoses, was achieved in all patients [Figure 3]. Of the 131 grafts, 112 were patent according to the CT scan. In three cases, three-dimensional images of the heart enabled the surgeons to evaluate the actual anatomy of the conduits when a redo operation was planned.

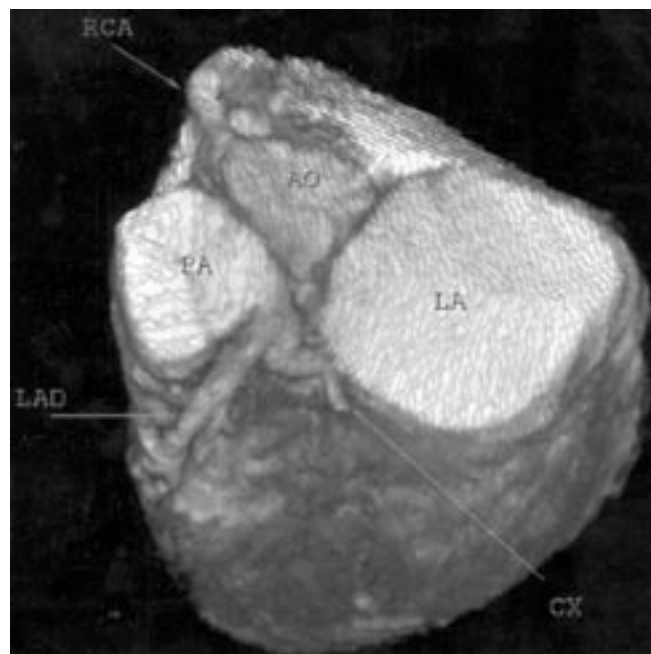
### Congenital anomalies

Anomalous origin and course of the coronary arteries was observed in four patients. In a representative case, a 30 year old woman had symptoms of ischemic heart disease. Coronary angiography failed to demonstrate the left coronary system, but CT angiography indicated the anomalous origin of the left main coronary artery arising from the pulmonary artery [Figure 4]. Corrective surgery was performed.

Intramyocardial segment, an anomaly in which an epicardial coronary segment dips into the myocardium, was present in 19% of the patients. Sixty percent of the segments were of the left anterior descending artery. None of these segments had atherosclerotic lesion, but two patients had ischemic symptoms that were secondary to non-atherosclerotic narrowing of these segments during systole.

### Extra-cardiac findings

The most common findings were cholelithiasis and hepatic cysts (18%). Numerous other findings were located inside and outside the mediastinum. Pulmonary nodules were evident in 35 patients (15.6%), who were subsequently referred to the pulmonary clinic for further evaluation. Two of these patients (5.7%) were finally diagnosed with pulmonary malignancy.



**Figure 4.** Anomalous origin of the left main coronary artery from the pulmonary artery.

### Discussion

CT angiography is a non-invasive diagnostic imaging modality of the coronary arteries that can be performed in outpatients and inpatients almost without complication [10,11]. It is less expensive and has the potential to be more available than catheterization due to the large number of CT scanners and the relative ease of performing the examination. It provides information about the vessel wall, its surrounding structures as well as its lumen, thus allowing an earlier diagnosis of atherosclerotic changes in the vessel wall as compared to invasive angiography.

Our study and several previous studies [1–4] have documented the high accuracy of CT angiography in detecting coronary artery disease in relation to conventional invasive coronary angiography and intravascular ultrasound. The very high negative predictive value of this examination allows screening of patients before referral to coronary catheterization.

CT can serve as a triage tool for patients with chest pain since it enables evaluation of the entire chest, including the chest wall, pleura, lungs, pulmonary arteries, aorta, coronary arteries, and other mediastinal structures. The ability of CT to evaluate extra-cardiac organs is another very important advantage over conventional coronary angiography; for example, in the current study the use of CT led to the diagnosis of early pulmonary malignancy in two patients.

### Conclusion

Our results indicate that multi-slice CT angiography is a reliable non-invasive diagnostic procedure for demonstration of the coronary arteries and bypass grafts. In view of the rapid evolution of this modality, we believe that CT will gradually replace con-

ventional coronary angiography as the primary imaging modality for the evaluation of coronary arteries.

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