Coronary Computed Tomography: Choosing the Right Patient for the Right Clinical Entity

Eli Konen MD[1] and Joseph Shemesh MD[2]

[1]Department of Diagnostic Imaging and [2]Grace Ballas Research Unit of the Cardiac Rehabilitation Institute, Sheba Medical Center, Tel Hashomer, Israel
Affiliated to Sackler Faculty of Medicine, Tel Aviv University, Ramat Aviv, Israel

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In the past 3 years, immense progress has been made in the development of a new non-invasive diagnostic technique for the evaluation of coronary artery disease – coronary CT angiography. The current *IMAJ* issue includes two original studies that evaluate this new and promising imaging modality in patients with suspected CAD [1,2].

The principles of computed tomography were first investigated in the mid-1950s, but it was not until 1972 that the first generation of CT scanners was introduced. Invented by British engineer Godfrey Hounsfield of EMI Laboratories, England, the first CT scanner required several hours to acquire the raw data for a single scan or "slice," and days to reconstruct a single image from these raw data. Hounsfield was later awarded the Nobel Peace Prize for his contributions to medicine and science. The first clinical CT scanners were installed between 1974 and 1976. At that time, approximately 5 minutes were needed to acquire one tomographic image. Initial scanners were only suitable for head examinations because the opening in the gantry was small. Improvements in components of the scanners and techniques allowed scanning of any part of the body, and in 1976 whole-body scanners became available. By the early 1980s CT technology was used widely.

The last 20 years have seen the development of several generations of CT scanners. The most important was the introduction of the "spiral" technique in the early 1990s. With this technique (also known as "volumetric scanning"), the X-ray point source and the detector array are placed on opposite sides of the patient on a ring-like structure called the gantry. The patient on the table is moved continuously through the scan field in the z direction while the gantry performs multiple rotations around the patient. The X-ray thus traces a spiral around the body and produces a data volume. This large data volume is then sent to a computer that can reconstruct multiple overlapping axial slices, as much as needed, with no additional "cost" of ionizing radiation exposure to the patient. Overlapping axial images enable the reformation of various types of high quality three-dimensional images on a post-processing station. The introduction of spiral CT also enabled the faster acquisition of larger body parts. When coupled with a bolus of intravenous contrast injection, the enhanced arteries could be scanned in a short time, thus allowing the introduction of CTA.

Image post-processing continued to improve with the advance in computer technology, allowing enhanced display of various vascular pathologies, such as dissections or emboli throughout the entire vascular system, including small branches. During the mid-1990s, CTA gained popularity as a reliable non-invasive alternative for angiography of the aorta and its main branches (including the carotid arteries, renal, mesenteric, and iliac arteries) as well as the pulmonary arteries – becoming an important daily examination for patients with suspected pulmonary emboli.

In the late 1990s, CT was still not suitable for cardiac imaging. Its temporal resolution was too low for such a fast moving structure, and its spatial resolution was insufficient for the small caliber of the coronary arteries. The introduction of the multi-row detector scanners in the early 2000s – known also as "multi-detector" or "multislice" scanners – was a major technological breakthrough for cardiac imaging. These scanners use several parallel rows of detectors that enable significant reduction in scan time and reduction in slice width (down to 0.625 mm), resulting in improved spatial resolution – a crucial factor for imaging small vessels such as the coronary arteries. An additional important advance is the shorter rotation time of ~0.4 sec (the time interval needed for a complete 360° rotation of the tube-detector system around the patient), resulting in an improved temporal resolution. A computerized coupling of the acquired scanning data with electrocardiographic tracing enables "freezing" of heart motion in different phases of the R-R interval. Cardiac imaging began to be used in the early 2000s with 4, 8, and 16-slice scanners, but in 2005 all companies pro-

CAD = coronary artery disease
CTA = coronary CT angiography

ducing multi-detector CT machines (General Electric, Phillips, Siemens, and Toshiba) are expected to complete the development of 64-slice scanners, which are expected to become the standard CT scanner for coronary angiography in the coming years.

Although there are several clinical indications for performing cardiac CTA, coronary imaging is expected to be the most common by far. The exact roles of CTA for atherosclerotic heart disease and patient selection criteria for coronary CTA are under investigation. Unfortunately, the current number and size of published series comparing MDCT with catheter angiography for the evaluation of coronary artery stenosis is limited. Also, most of them are methodologically poor, using different inclusion criteria and various methods of analysis, making any comparison between them difficult. Initial studies have been performed using four-slice MDCT [3–6]. Sensitivity and specificity for the detection of coronary artery stenosis exceeding 50% were in the range of 73–85% and 76–93% respectively; however, as many as 30% of coronary artery segments have been excluded because of motion artifacts. More recent reports using the 16-slice scanner showed that in most series better results were achieved, with sensitivity, specificity, positive and negative predictive values in the range of 59–95%, 86–97%, 61–80%, 87–97% respectively [7–10]. Both series in the current *IMAJ* issue, presented by Blinder and Gaspar and their teams [1,2], are encouraging and demonstrate comparable results.

Owing to the lack of large outcome study results, a consensus statement on the role of CTA in the current cardiac evaluation algorithm is not yet available. There are no universally accepted absolute indications for cardiac CTA, but the high negative predictive value found by most studies suggests that this examination might be most helpful for patients with a low-intermediate pretest probability of obstructive coronary artery disease. It is widely accepted that coronary CTA is clinically indicated in cases where coronary catheterization cannot be performed due to technical limitations, or when the resulting information from coronary catheterization is insufficient. Others suggest that coronary CTA might be indicated whenever other non-invasive cardiac studies (such as stress test) are equivocal.

Another promising clinical application of coronary CTA is the ability to diagnose acute or subacute occlusions (generally of thrombotic origin) and to reliably differentiate them from normal arteries. These occlusions clinically manifest as acute coronary syndrome, sudden death, acute myocardial infarction, or unstable angina. This syndrome is related to fissure or rupture of one or more vulnerable plaques generally characterized by a lipid-rich core and thin fibrous cup. The resultant thrombotic occlusion determines the clinical consequence by the degree of lumen obstruction. Most of these occlusions are minor and the patient remains asymptomatic. Subtotal occlusion manifests as unstable angina, and total thrombotic occlusion results in acute myocardial infarction or sudden death. The patients who may benefit from coronary CTA for this indication are those who presented to the emergency room, internal departments or intensive care unit with acute or subacute chest pain and/or ECG changes suggesting an acute or recent coronary event, but with equivocal clinical presentation and uncertain indication for invasive (therapeutic) coronary catheterization.

Less common indications for obtaining cardiac CTA include the evaluation of patients with a suspected aberrant coronary pathway, evaluation of left atrial anatomy in patients before ablation of pulmonary vein orifices (for atrial fibrillation), evaluation of pericardial disease, post-surgical complications, and congenital malformations. Although coronary CTA may demonstrate myocardial perfusion defects, infarcts and tumors, cardiac magnetic resonance imaging is a superior technique for demonstrating these abnormalities.

There is considerable debate regarding the role of coronary CTA as a primary screening test in asymptomatic patients. The main goal of screening asymptomatic populations for the presence of CAD is to diagnose the subclinical stage of the disease in order to initiate early treatment and to avoid the morbidity and mortality associated with the advanced stages. Thus, the target for CAD screening should be the early stages of atherosclerosis. These early plaques are located within the wall of the arteries in the form of lipid-rich fibroplaque, and they can be identified by coronary CTA. However, adequate methods to measure soft plaques have not yet been established and are still under investigation. In general, coronary CTA has to fulfill several universal criteria that are required to justify it as a screening test. It requires high sensitivity, specificity and positive predictive values, a low complication rate, a low risk/benefit ratio, and a reasonable cost. Unfortunately, the clinical value of coronary CTA (especially with the new MDCT scanners) is not well established. In addition, the risk and complication rate of coronary CT cannot be underestimated: it exposes the patients to ionizing radiation that is at least as high as an average diagnostic cardiac catheterization, and it requires intravenous injection of iodinated contrast material. Moreover, the present cost of coronary CTA is relatively high, ranging between 3,000 and 4,500 shekels ($680–$1,000) in most centers in Israel that currently offer the examination.

Referring physicians should be aware of the limitations of cardiac CTA. Heavy calcified plaques, which are frequent in patients with chronic CAD, might not allow accurate estimation of the degree of stenosis due to the blooming artifact. Heart rate of more than 60 beats per minute or significant arrhythmia might reduce image quality. These limitations are well emphasized in Blinder's study that used a four-slice scanner, but are still very relevant when using the latest MDCT generations. Patients should be prepared with beta blockers if no contraindications exist. Breath-hold difficulties and the inability to remain supine and motionless are relative contraindications. It is anticipated that in the near future many of these limitations will be improved due to the rapidly evolving technology.

In summary, coronary CTA is an additional new diagnostic modality that can contribute to the clinical evaluation of

MDCT = multi-detector CT

patients with suspected CAD. Despite the current limitations, MDCT can provide adequate and useful information as long as referring physicians will select the right patient for the right clinical entity.

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Correspondence: Dr. E. Konen, Dept. of Diagnostic Imaging, Sheba Medical Center, Tel Hashomer 52621, Israel.
Phone: (972-3) 530-2530
Fax: (972-3) 535-7315
email: konen@post.tau.ac.il, eli.konen@sheba.health.gov.il