Introduction
Coronary artery disease is a common cause of death in adults in this country. Coronary artery disease is secondary to narrowing of the coronary vessels from atherosclerosis. Injury to the endothelium leads to an inflammatory reaction, and there is accumulation of inflammatory cells, smooth muscle cells, and fat deposits in the vessel wall. These lead to formation of an atherosclerotic plaque that narrows the lumen. Risk factors are well known and include age, male gender, lack of exercise, obesity, high blood pressure, elevated blood lipid levels, smoking, and diabetes.

Invasive coronary angiography (ICA) remains the gold standard for the diagnosis and then assessment of severity of coronary artery stenoses. It also has the advantage of carrying out therapeutic intervention at the same time. However, it carries with it the complications of the invasive procedure and the inconvenience for the patient. Introduction of multidetector technology made it possible to see coronaries noninvasively, however the results were not very acceptable. With further improvements in CT technology and introduction of 64 slice CT which provides increased spatial and temporal resolution the results have been very encouraging and presently it can be and is being used for coronary evaluation with satisfying results.

The main applications of coronary angiography with multi-detector row CT are diagnosis of anomalous origin of coronary, noncalcified plaques, detection, quantification of coronary artery stenoses, and follow-up after surgical bypass therapy. Additional applications include evaluation of myocardial perfusion, scarring, and contractility. The key advantages of this technique are the noninvasiveness of the study and the ability to evaluate both the coronary artery lumen and the vessel wall.

Challenges in evaluating the coronary arteries at CT are the small size of the vessels and the location adjacent to the moving heart. The vessels are typically 2–4 mm in diameter and are parallel, oblique, or perpendicular to the axial plane in portions. In addition, they are adjacent to both the atria and ventricles and therefore may be affected by cardiac motion in different phases of the cardiac cycle. Possible solutions are imaging on scanners with an increasing number of rows and faster rotation speeds and reconstructing multiple sets of images obtained in different phases of the cardiac cycle from a volume acquisition.

The role of imaging is progressing from simple determination of the presence of arterial calcifications on nonenhanced scans to demonstration of vascular stenoses on coronary CT angiograms. Optimization of the imaging technique and knowledge of coronary artery anatomy are both important for the development of CT of the heart. Technical factors such as a slow heart rate, a short scanning time, subcentimeter spatial resolution, high temporal resolution, and reconstruction of multiple image data sets at various intervals in the cardiac cycle result in optimal visualization of the coronary arteries. Axial, thin-slab maximum intensity projection, and volume-rendered images are used to display the normal anatomy and anomalies of the coronary arteries.

Indication and contraindication
The main indications for coronary CT today are: (1) Non specific chest pain to exclude the cardiac cause (2) Screening for high risk patients – patients with diabetes / hypertension / deranged lipid profile / strong family history (3) Screening for anomalous origin of coronary artery.

Conventional angiography remains the standard in patients suspected of having acute coronary syndromes, for which intervention is anticipated. The confidence in predicting unstable plaque and coronary events falls with increasing atherosclerotic disease burden. Coronary CT angiography is not performed in patients with a heavy burden of calcified plaque because estimating the degree of stenosis at the site of calcified plaque will be difficult due to blooming artifact and because a catheter angiogram will
still be necessary. Patients with a heart rate of more than 70 beats per minute (bpm) or with significant arrhythmia are considered unsuitable because the resulting images are poor. Breath-hold difficulties and the inability to remain supine and motionless are relative contraindications.

Patients with arrhythmia, allergy to iodinated contrast media, and renal insufficiency (serum creatinine > 120 mmol/l) are not suitable for the study.

Patient Preparation
The main preparation involves slowing the patient’s heart rate to approximately 60 bpm because this lower heart rate increases the relative proportion of the cardiac cycle spent in diastole and limits motion artifact. Generally oral ß-blockers are prescribed by the referring doctor 2–3 days before scanning and organized at the time of scheduling. Some sites also give ß-blockers at the time of the study as well.

Sample ß-blocker protocols include giving 50 mg of metoprolol orally 1 hr before scanning or 5 mg of metoprolol IV a few minutes before the study. Calcium channel blockers are used if ß-blockers are contraindicated. Contraindications for ß-blocker therapy include asthma, atrioventricular conduction block, heart failure, diabetes, and Raynaud syndrome. Three ECG leads are placed over the patient as specified by the manufacturer of the scanner to obtain an ECG tracing on the scanner console.

Technique Summary
A 80-120-ml dose of nonionic iodinated contrast material is injected intravenously at approximately 4 – 5 mL / sec for CT angiography. A saline solution bolus is also given following contrast material injection to decrease artifact from contrast material in the right heart. 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 study are 10–18 seconds. Detector collimation, kilovolt peak, pitch factor and matrix size optimisation is also crucial. The images are reconstructed by using a medium soft-tissue kernel with retrospective ECG gating. Multiple image sets are reconstructed in diastole at variable relative delay. In general, reconstruction is avoided at 10%–30% or greater than 80% of the R-R interval, as these times are particularly susceptible to motion artifacts.

Display of Multi–Detector Row CT Coronary Angiograms
Three-dimensional and multiplanar views are used to supplement the axial CT images. Portions of all vessels, in particular the left main artery and LAD artery, can be evaluated on the axial images. Longer vessel segments are demonstrated on curved multiplanar reformatted and three-dimensional volume-rendered images. Calculifications and noncalcified plaques are assessed on thin-slab maximum intensity projection and volume-rendered images. Virtual angioscopic views are also possible. In a study that compared axial, virtual angioscopic, volume-rendered, and multiplanar reformatted images, the most stenoses were seen on axial images followed by virtual angioscopic, volume-rendered, and multiplanar reformatted images. Use of all four techniques gave the highest sensitivity. A combination of various viewing methods has been used in most studies. The most effective method for reformation has still to be determined, but thin-slab maximum intensity projection seems to be most widely used.

Detection of coronary artery stenoses
The opportunity to non-invasively visualize coronary anatomy is the major reason for the current interest in cardiac MDCT. With the introduction of 64-slice MDCT systems, improved temporal and spatial resolution as well as substantially shorter scan times led to improved image quality throughout the entire coronary tree. Importantly, the technique may be most suitable as a non-invasive tool to rule out significant CAD and avoid further imaging or invasive angiography.

There is a tendency to overestimate the degree of luminal narrowing by CT when compared with invasive angiography, and pronounced calcification of a vessel segment can make lesion assessment particularly difficult. Usually, calcification will lead to overestimation, rather than underestimation of lesion severity. Furthermore, coronary CT angiography is limited to the anatomic visualization of stenoses and does not provide information as to the functional relevance of a lesion. For this reason, although 64-slice MDCT is a reliable tool to rule out functionally relevant CAD in a non-selected population with an intermediate pre-test likelihood of disease, an abnormal coronary CT angiogram does not necessarily predict ischemia.

The use of coronary CT angiography should be restricted to patients in whom diagnostic image quality is achievable (e.g. absence of arrhythmias), and scans need to be expertly performed and interpreted.

Evaluation of Bypass Graft and Native Postanastomotic Coronary Artery Patency
Conventional selective angiography is the standard for assessing bypass graft patency after coronary artery bypass grafting (CABG). It is an invasive and potentially harmful procedure with a low risk of serious complications, such as conduit dissection, spasm, embolization and myocardial infarction, arrhythmia, stroke, and death.

Cardiac CT is a promising noninvasive measure to evaluate patency of bypass conduits, including the gastroepiploic artery where catheterization is usually difficult. The ability to display the vessel wall as well as its lumen might distinguish radial artery spasm from intimal hyperplasia. Knowledge about the patency rate of various bypass grafts is valuable in the care of patients undergoing surgical revascularization. The demonstrated improved patency rate of internal mammary artery (IMA) grafts over saphenous vein grafts, for example, changed the surgical approach in the late 1980s, and many surgeons currently perform multiple arterial grafting in daily practice.
Coronary Artery Anomalies

Although coronary anomalies are rare conditions, possible consequences include myocardial infarction and sudden death. In young athletes, coronary artery anomalies are the second most common cause of sudden death due to structural heart disease. The identification of the origin and course of aberrant coronary arteries by invasive angiography can be difficult. Because of the three-dimensional nature of the data set, MDCT is very well suited to detect and define the anatomic course of coronary artery anomalies and their relationship to other cardiac and non-cardiac structures. CT analysis of coronary anatomy is straightforward and very reliable with accuracy close to 100%.

The robust visualization and classification of anomalous coronary arteries make CT angiography a first-choice imaging modality for the investigation of known or suspected coronary artery anomalies. Radiation dose must be considered often in the young patients, and measures to keep dose as low as possible must be employed.

Calcium scoring

Coronary calcium is a surrogate marker for the presence and amount of coronary atherosclerotic plaque. Both EBCT and MDCT permit accurate detection and quantification of coronary artery calcium. The so-called ‘Agatston Score’, which takes into account the area and the CT density of calcified lesions, is most frequently used to quantify the amount of coronary calcium in CT, and large population reference databases are available. Even the detection of large amounts of calcium does not indicate the presence of significant stenoses and it should not prompt invasive coronary angiography in otherwise asymptomatic individuals.

Non-calcified plaque

There is growing interest concerning the ability of contrast-enhanced CT coronary angiography to detect (and possibly to quantify and to further characterize) non-calcified coronary atherosclerotic plaque. The tremendous potential of CT angiography for visualization and characterization of coronary plaques must be recognized and further research is strongly supported.

Conclusions

64-slice CT due to its high spatial and temporal resolution is an excellent modality to evaluate coronaries non invasively. Still existing limitations are the exclusion of patients with arrhythmia and limiting factors such as strong vessel wall calcifications and motion artifacts which all can cause a restricted image interpretation. With further developments in the CT technology and introduction of 256-slice the results are bound to improve further. The present day indications of coronary CT are as follows:

1. Patients with atypical or unclear thoracic symptoms
2. Screening for high risk patients
3. Preoperative planning: Exact localization of coronary arteries in relation to surrounding structures and identification of significant stenosis or vessel wall calcifications, as well as an intramyocardial course of the arteries to plan and conduct the surgical procedure. Similar to the coronary arteries, evaluation of internal mammary arteries and ascending aorta for planning the operation in terms of graft harvesting and cannulation site can be performed in the same CT examination.
4. Followup of patients with CABG / stent.
References


7. MDCT Evaluation of the Coronary Arteries, 2004: How We Do It—Data Acquisition, Postprocessing, Display, and Interpretation Leo F Lawler1, Harpreet K. Fannu and Elliot K. Fishman. All authors: Department of Radiology and Radiological Science, Johns Hopkins University, 601 N Caroline St., Rm. 3254, Baltimore, MD 21287-0801. Received February 12, 2004; accepted after revision September 15, 2004.


