Cardiology Associates of Green Bay
INTERFACE
Interfacing the Subspecialty of Cardiology with Primary Care Medicine

Cardiac CT a new imaging modality

Conventional invasive coronary angiography has long been the gold standard in visualizing coronary anatomy. Several imaging methods, including MRI, have been developed over many years in an attempt to achieve this goal noninvasively and CT angiography has now come close to reaching it. CT is one of the fastest and most popular diagnostic imaging methods currently available. Cardiac CT angiography has added a new dimension to the technique, allowing the image of a beating heart and its associated coronary vessels to be captured. Cardiac CT angiography is able to consistently provide diagnostically useful information of coronary arteries without the potential risks associated with conventional cardiac catheterization. From a hardware development point of view, CT scanners have gone through several technological advances in the past few years in order to meet the very high technical demand required by cardiac imaging. The smallest spatial resolution achievable by the current, most-advanced multidetector row CT (MDCT) scanner is 0.4 mm, and is fast approaching the 0.2 mm resolution typically seen by conventional diagnostic radiographic angiography; this resolution is far superior to that of 6-15 mm achieved by conventional nuclear perfusion imaging.[4] According to published reports, the accuracy of MDCT that uses 16-row technology in the identification of coronary stenosis is high compared with that of a conventional radiographic angiogram. Although there is a paucity of outcome data on the use of MDCT in the management of coronary artery disease, most cardiac imaging experts would agree that the negative value of a normal coronary CT angiography on 64-row MDCT is extremely high (see graph 1); an individual with a normal coronary CT angiography is highly unlikely to have significant coronary artery disease. Because of improved gantry design and increased rotation speed, the temporal resolution of cardiac CT scanners continues to improve.

Graph 1

THE TECHNOLOGY OF MULTIDETECTOR ROW CT

Cardiac CT angiography can be obtained by use of two different scanning technologies. Electron-beam CT, also known as ultrafast CT, uses a powerful electron emitter to produce an electron beam that is steered electromagnetically to encircle the heart. Electron-beam CT involves no moving mechanical parts and, therefore, offers a very rapid scanning speed (or high temporal resolution) when imaging the heart, but the overall area of coverage is limited. Electron-beam CT is lagging behind MDCT, however, in spatial resolution and cannot currently generate submillimeter image resolution. Electron-beam CT is now relegated mainly to calcium scoring. By contrast, helical CT, also referred to as spiral CT or MDCT, uses an X-ray source housed in a rotating gantry that also contains an array of multiple X-ray detectors. The latest MDCT scanners can rotate at a speed of 0.33 seconds per revolution and the image data is generated in a continuous spiral fashion as the person lying on the scanner table is transported automatically through the rapidly rotating gantry. As the gantry speed and the number of detector rows increase, the scan time shortens. With 64-slice MDCT, the scan time of a typical cardiac scan is usually 9-12 seconds a reasonable breath-hold time for a normal healthy person. In addition, it provides submillimeter spatial resolution, which enables the presence of significant coronary artery disease to be ruled out. Even with the fastest gantry speed of 330 ms per rotation in currently available MDCT scanners, the motion of a beating heart cannot be captured consistently in most people unless medication is taken to lower the heart rate. Thus, in the majority of the cases the use of oral or intravenous ß-adrenergic-blocking agents is commonly required before cardiac scanning to slow the heart rate to lower than 70 beats/min. Calcium-channel blockers may be used as an alternative in individuals who cannot tolerate ß-blockade because of labile bronchospasm. Meticulous care in heart rate and rhythm control is key to the success in obtaining consistently good overall image quality. Electrocardiographic gated scanning and retrospective reconstruction are two main features of cardiac CT imaging that enable imagers to sort out the best images with the least motion artifact from different parts of the entire cardiac cycle.

Radiation exposure and other potential associated risks

CT is an X-ray-based imaging method and radiation safety for patients and clinical practitioners is of great importance. Currently the average effective radiation exposures experienced with the latest 64-slide MDCT scanner with current modulation are 7.45 mSv for men and 10.25 mSv for women. By comparison, conventional radiographic coronary angiography is associated with effective doses of 2.1 and 2.5 mSv for male and female patients, respectively. The effective dose of X-ray in radiographic coronary angiography can be significantly higher, depending on the operator and the nature of the diagnostic procedure. To minimize the total amount of X-ray exposure, electrocardiography-controlled dose modulation technique should be employed in patients with slow heart rates and regular cardiac rhythms. Radiation dose can be greatly reduced by 30-50% by this method. In general, the radiation dose increases as the slices become thinner and the number of overlapping images rise. In MDCT the dose can be increased or decreased, and is frequently based upon the build of the patient, the coverage area, and the slice thickness of the image.

Besides radiation exposure, coronary CT angiography, in a way is similar to conventional diagnostic angiography, requires the use of potential nephrotoxic contrast agents to enhance the visualization of the vessel lumen and the vessel wall. The total amount of contrast needed can vary dependent on the scanning protocol and the scan time. The typical amount needed for a cardiac CT angiographic study with a 64-slice MDCT is about 85-100 ml. Patients with borderline renal insufficiency such as those with creatinine levels of at least 132.6 μmol/l (≥1.5 mg/dl), may be premedicated with a 2-day regimen of oral acetylcysteine, starting from one day before the examination. The usual dose of acetylcysteine is 600 mg taken orally twice daily. Patients with a history of allergy to contrast agents might need additional administration of an oral glucocorticoid together with an oral antihistamine agent depending on the nature and severity of the previous dye allergy.

CT ANGIOGRAPHY SCANNING PROTOCOL

Many studies from different parts of the world, in which 16-slice MDCT scanners made by different vendors have been assessed, have reported a close to 95% success rate in achieving reliably diagnostic images. Obtaining the best results relies on the physician or nonphysician practitioner applying meticulous care in maintaining the heart rate at or lower than 65 beats/min and with a regular cardiac rhythm during the scanning by use of a combination of oral and intravenous ß-blockers, or calcium-channel blockers if ß-blockers are contraindicated. In addition to the decreasing heat rate due to elevated sympathetic tone, ß-blockade might also reduce the number of atrial and ventricular premature beats, which could severely hamper the overall quality of the images. The protocol at Bellin Hospital includes the use of an oral ß-blocker, metoprolol, 12 hours prior and 3-4 hours before the procedure and an additional intravenous ß-blocker, such as 5-20 mg metoprolol immediately before scanning, according to the heart rate. We do not use sublingual nitroglycerin although some investigators use this regularly before scanning to achieve maximum coronary vasodilatation at the time of the contrast study. All patients are required to have an EKG or a rhythm strip to exclude any arrhythmias, particularly uncontrolled atrial fibrillation, prior to the procedure. Serum creatinine is also obtained as a routine.

The two common methods used to achieve optimum contrast enhancement of the coronary vessels are test bolus and tracking bolus. Tracking bolus is an automatic way to trigger scanning based on a preset HouseField unit at a certain anatomic landmark, such as the ascending aorta. A typical tracking bolus protocol for performing coronary CT angiography triggers scanning when the contrast enhancement at a predetermined level in the ascending or descending aorta reaches 100 HU or above. Test bolus method is helpful in eliminating frequent problems with improper placement of an intravenous catheter and also allows additional breathing instruction to be given to lessen anxiety and potential motion artifacts. We normally use Tracking bolus method using about 85 ml contrast for native coronary studies and 100 ml for studies done with a 16 MDCT scanner involving bypass grafts. The infusion rate is normally 4.5-5 ml/s provided that a 20-gauge angiocatheter is used for the contrast infusion and that this catheter is securely placed in the antecubital vein.

CURRENT CLINICAL INDICATIONS

Assessment of nonacute coronary artery disease.

64-slice MDCT angiography, if performed well, can reliably rule out the presence of significant coronary artery disease (CAD) in patients with low to intermediate probability of having coronary artery disease. Many experts in the field of coronary imaging have agreed that coronary CT angiography is particularly useful because of its extremely high negative predicative value in ruling out significant coronary artery disease in patients who have symptoms suggestive of obstructive disease and equivocal stress myocardial perfusion test results. Approximately 30% of all the diagnostic radiographic angiograms being performed currently do not lead to further coronary intervention. Coronary CT angiography might therefore potentially decrease the number of unnecessary cardiac catheterizations.

Another important indication being promoted is the detection of coronary artery disease in individuals who are asymptomatic but have multiple risk factors for CAD. Detection of disease early may thwart a potentially fatal primary coronary event. Demonstration of disease to a patient may also serve as a powerful tool in lifestyle changes.

Assessment of graft patency after CABG

In properly selected cases, MDCT can also provide important clinical information on the status of bypass grafts. Extensive coronary artery calcification, surgical clips can sometimes interfere with proper interpretation. Cardiac CT angiography has high sensitivity and specificity for the evaluation of bypass graft patency. Three prospective studies examined the diagnostic accuracy of 16-slice MDCT in 171 patients who had previously received coronary artery bypass grafts and who were scheduled for radiographic coronary angiography.[21-23] The sensitivity and specificity for graft occlusion were 100% and 98-100%, respectively, and for graft stenosis were 60-90% and 88-100%, respectively. The maximum proportion of non-evaluable grafts was 12%.

Assessment of congenital anomalies of the coronary or great vessels.

Many experts in the field of cardiac imaging now consider cardiac CT angiography to be an imaging method of choice for congenital anomalies of coronary or great vessels.

Assessment of cardiac morphology and function.

Cardiac CT angiography can also be used to assess cardiac morphology and function. Published data for 4-slice and 16-slide MCDT support the use of cardiac CT angiography for evaluation of cardiac chamber morphology, wall motion, systolic thickening, and ejection fraction. The results of cardiac function evaluated by MDCT are also comparable to those obtained with cardiac MRI, the current gold standard for the quantitative assessment of cardiac mass and function. With advanced electrocardiography gating and improved temporal resolution of MDCT scanners, cardiac CT angiography can be a valuable noninvasive method for the assessment of cardiac structural and morphologic abnormalities. Cardiac CT angiography has become an important part of the evaluation of the pulmonary veins and the left atrium before and after radiofrequency ablation of atrial fibrillation.

FUTURE DIRECTIONS AND CONCLUSIONS

Cardiac CT angiography is likely to become an important part of noninvasive cardiac imaging for cardiologists and radiologists. Results from further outcome studies will be needed in order to gain widespread acceptance for reimbursement of this imaging procedure by third-party payers in the US. Medicare has already started looking at this reimbursement issue and trial billing codes have been introduced. Improvement in temporal resolution through advances in gantry design and rotating speed will eliminate the need for routine ß-blockade in the near future and will further enhance the usefulness of cardiac CT in the emergency department for the evaluation of acute chest pain. Further improvement in spatial resolution, approaching that of conventional radiographic diagnostic angiography, will be appealing only if individuals will not be exposed to unsafe levels of ionizing radiation. Future research and development in gantry and detector design needs to take into consideration the importance of more-reliable tissue and plaque characterization, and issues related to the calcium blooming effect. Early data on the detection of myocardial viability and perfusion using first-pass CT angiography would further expand the potential clinical utility of this imaging technique.

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Technology Insight: cardiac CT angiography Nature POON MAY 2006 VOL 3 No 5
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