Noninvasive Coronary Angiography Using Multislice Computerized Tomography

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Multislice computerized tomography (MSCT) is a relatively new, noninvasive method for evaluating coronary stenosis. In symptomatic patients, the use of MSCT has been shown to be effective in identifying coronary lesions with comparable accuracy to the traditional, catheter-based invasive angiography. With the 64-slice MSCT scanner, units are acquired faster and the slices are thinner, resulting in improved temporal and spatial resolution and coronary artery imaging. Additional benefits of the 64-slice MSCT scanner as compared with the older generation scanners include a shorter period during which the patient must hold his or her breath, a wider range of acceptable heart rates, and the ability to image very obese patients and those with moderate coronary calcium with lower volumes of contrast. The 64-slice MSCT scanner has some limitations, but it demonstrates an improved image resolution that allows for a more precise evaluation. This new generation of MSCT scanners may eventually eliminate the need for invasive coronary angiography.

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In 2000, the first generation of multislice computerized tomographic (MSCT) scanners became available for noninvasive coronary imaging. Initial studies were performed with 4 detectors.[1] In 2002, image resolution improved with the 16-slice computerized tomography (CT) scanner. Several centers reported on the feasibility of performing noninvasive coronary imaging with the 16-detector MSCT. However, in order to obtain optimal images, it was necessary for the patient to hold his or her breath for 15 seconds and to have a regular heart rate in the range of 55 to 65 beats per minute (bpm), which at times necessitated the use of intravenous or oral beta-blockers. Morbid obesity and dense coronary calcium were also obstacles to adequate imaging. Nonetheless, in selected populations, the 16-slice MSCT was reported to detect significant lesions, with sensitivity in the range of 63% to 92%.[2-4]

In 2004, Siemens Medical Solutions, Inc. (Malvern, PA) introduced the first 64-slice CT scanner. In addition to the 64 slices per rotation, the units were acquired faster and the slices were thinner. These advances resulted in improved temporal and spatial resolution and allowed for improvements in coronary artery imaging. Additional benefits of the 64-slice CT scanner as compared with the older generation scanners include a shorter period during which the patient must hold his or her breath, a wider range of acceptable heart rates, and the ability to image very obese patients and those with moderate coronary calcium with lower volumes of contrast. Three recent reports on the 64-slice MSCT scanner have found promising results.

High Negative Predictive Value

Raff and colleagues[5] reported on the diagnostic accuracy of noninvasive coronary angiography using the 64-slice MSCT. They screened 84 patients and studied 70 consecutive patients who were also undergoing elective invasive coronary angiography within 30 days. Exclusion criteria included patients with acute coronary syndromes; patients in whom use of iodinated contrast posed a risk, such as those with heart failure, dye allergy, or an elevated serum creatinine ($>$ 1.5 mg/dL); patients with an irregular heart rate; and those with contraindications to beta-blocking drugs. Fourteen patients were excluded for having arrhythmias (atrial fibrillation, extrasystoles, or sinus node dysfunction) or a history of dye allergy. Patients not taking beta-blockers received 100 mg of atenolol 1 hour before MSCT imaging if their heart rate was greater than 65 bpm and 50 mg if their heart rate was between 50 bpm and 65 bpm. Sublingual nitroglycerin (0.4 mg) was given 1 minute before imaging in order to dilate the coronary arteries. All scans showed a clear diagnostic image quality. The coronary artery tree of each patient was divided into 15 segments for analysis.

Of the 1065 segments, 88% (935 segments) were evaluable, and 83% of segments could be assessed quantitatively by MSCT. Seventeen percent of patients had coronary stenoses.

The correlation between the noninvasive coronary angiography findings and the invasive quantitative coronary angiography (QCA) findings was high (correlation coefficient = 0.768; $P < .0001$). On a per segment basis, out of the 935 interpretable segments, MSCT had 86% sensitivity (79 of 92 segments) in detecting significant lesions on invasive QCA and a specificity of 95%. The positive predictive value was 66% and the negative predictive value was 98%. On an artery-by-artery basis, 279 of 280 arteries were evaluable for lesions, with MSCT demonstrating a sensitivity of 91%, a specificity of 92%, a positive predictive value of 80%, and a negative predictive value of 97%. On a per patient analysis, the MSCT correctly identified the presence of significant coronary artery disease in 38 of 40 cases, with a sensitivity of 95% and a specificity of 90%. The positive predictive value was 93% and the negative predictive value was 93%.

Patient factors that limited the accuracy of MSCT included a calcium score exceeding 400, obesity (body mass index $>$ 30 kg/m^2), and heart rates greater than 70 bpm. In heavily calcified coronary segments, MSCT sensitivity was 93%, and the negative predictive value remained high at 95%. However, the specificity was lower at 72%, as was the positive predictive value of 64%.

This study demonstrated that the noninvasive coronary MSCT using the 64-slice scanner provided accurate, noninvasive coronary angiograms for most of the patients studied. Unlike other studies that used the 16-slice MSCT, this study evaluated the entire coronary tree and included patients with obesity, severe coronary calcifications, and high heart rates. The findings of this study show that 64-slice MSCT has a very high negative predictive value of 98% by segment, 97% by artery, and 93% by patient. It also demonstrates the scanner's good per patient sensitivity (95%) and specificity (90%) for the detection of more than 50% of coronary artery stenosis.

Identification of Coronary Lesions

Leber and colleagues[6] performed a quantitative study of obstructive and non-obstructive coronary lesions using 64-slice MSCT in 59 consecutive patients. They studied the ability of 64-slice MSCT to evaluate coronary stenosis severity and coronary plaque dimensions. Results were compared with those from invasive QCA in all cases and from intravascular ultrasound (IVUS) in a subset of 18 patients. The exclusion criteria for the study included atrial fibrillation, previous coronary artery bypass surgery, stenting of more than 1 vessel, an unstable clinical condition, or contraindications to intravenous contrast.

The MSCT was performed within 2 days of the coronary angiography in all cases. If the patient's heart rate was more than 70 bpm, metoprolol 50 mg was given orally 1 hour before imaging. If there were contraindications to beta-blockers, the scan was performed without this premedication. In total, 21 patients received beta-blockers.

A total of 798 evaluable segments were available for comparison between the MSCT and invasive coronary angiography. (Four vessels were occluded and 14 distal segments could not be evaluated.) In the mid-proximal coronary atrial segments, the MSCT sensitivity for a stenosis greater than 50% was 75%; for a stenosis greater than 75%, it was 88%. Specificity was 97%. Eighty-nine percent of lesions and 94% of patients who later required coronary intervention (angioplasty or surgery) were identified by MSCT. Thus, this study also documented that 64-slice MSCT is a robust method for noninvasive evaluation of coronary anatomy. The authors found limited accuracy for imaging the distal of the left anterior descending artery and the distal segments of the left circumflex and its marginal branches. Fortunately, the distal segments are rarely responsible for ischemia-producing lesions that are revascularizable.

A subset of the study used IVUS to evaluate 32 coronary arteries in 18 patients. Comparing MSCT with IVUS, the correlation coefficients were good for mean lumen cross sectional area (r = 0.81) and mean plaque area (r = 0.73). For percent vessel obstruction, the correlation was less strong (r = 0.61). This factor was attributed to the trend to overestimate lumen areas and underestimate plaque size, which is thought to be the result of partial volume effects at the lumen-plaque interface caused by calcium, fibrotic hard plaques, the contrast agent itself, or the density values of opacified lumen and plaque overlapping in certain ranges. In the IVUS subset, the authors demonstrated that 64-slice MSCT is able to quantitatively assess non-obstructive coronary plaque with 84% sensitivity and 91% specificity. Thus, MSCT holds promise to not only visualize the coronary lumen, but the vessel wall and plaque as well.

Identification of Normal Arteries

Pugliese and colleagues[7] used 64-slice MSCT to study 35 patients (21 men and 14 women, average age 61 ± 10 years) with stable angina pectoris. All patients underwent conventional coronary angiography within 15 days of the CT coronary angiogram. Only patients in sinus rhythm who were able to hold their breath for 15 seconds were included. Patients with prior coronary artery bypass surgery or percutaneous coronary interventions with stent implantations were excluded. Patients with a heart rate above 70 bpm (77% of the patients) received 100 mg of oral metoprolol 1 hour before the test. To begin the CT scan, 100 mL of a contrast agent was injected at a rate of 5 mL/sec into the antecubital vein.

A total of 494 coronary segments were available for comparison between coronary angiography and MSCT. Coronary angiography showed 67 significant lesions (> 50% diameter stenosis). MSCT correctly identified 66 of these segments. The 1 lesion missed by the MSCT was in the mid-portion of the left anterior descending artery; it had a diameter stenosis of 52% by angiography and was affected by calcification and motion artifact. Out of 10 patients (29%) who showed no significant coronary narrowing by conventional angiography, 9 were correctly identified by the MSCT. Analysis per segment showed that MSCT detected luminal diameter stenosis of 50% or more with a 99% sensitivity and a 96% specificity, with positive and negative predictive values of 78% and 99%, respectively. Analysis per patient showed a sensitivity of 100%, specificity of 90%, positive predictive value of 96%, and negative predictive value of 100%. The investigators concluded that when referral to conventional coronary angiography is questionable, MSCT may help in identifying patients with normal coronary arteries, thereby decreasing the number of unnecessary invasive procedures.

Assessment of Coronary Bypass Graft Patency

Coronary bypass grafts are relatively immobile during the cardiac cycle and are large in diameter. Seven studies with a total of 257 patients compared MSCT to conventional angiography in assessing graft patency.[8] Pooled analysis showed that MSCT detected graft occlusion with a sensitivity of 88% and a specificity of 98%. Five studies with a total of 267 patients assessed graft stenosis. A total of 80% of the grafts were evaluable. The pooled sensitivity and specificity of MSCT were 84% and 95%, respectively.[8] However, artifacts from the metal surgical clips are a major limitation of this technique.

With the newer generation of MSCT scanners, assessment of coronary stents is becoming feasible. Patency as well as in-stent restenosis and occlusion can all be detected using the 64-slice MSCT scanner. However, overestimation of narrowing of the stent lumen has been reported to be a major problem.[8,9]

Limitations

Limitations of MSCT include the need for relative bradycardia and a regular heart rhythm for optional imaging, the use of dye load, and the radiation exposure.

Heart rates above 65 bpm affect image quality; patients with a heart rate at or above 65 bpm should receive beta-blockers, unless contraindicated. Currently, patients with arrhythmia should not undergo MSCT. However, recent studies have reported advances in using electrocardiogram gating and performing MSCT in patients with mild heart rhythm irregularities,[10] and even with atrial fibrillation.[11] Artifacts can be related to motion (caused by a high or irregular heart rate, breathing, patient movement, suboptimal selection of the temporal window, etc), poor image contrast to noise ratio due to insufficient vascular enhancement, beam hardening due to extensive calcifications, metal stents, and arterial clips.

MSCT requires a relatively large amount of contrast dye (~100 mL).[8] In addition, CT coronary angiography is associated with a substantial radiation exposure—950 to 1150 millirems—which is equivalent to the exposure received from a stress myocardial nuclear perfusion examination. A regular 2-view chest x-ray is 6 millirems. Such large doses of radiation (500 to 2000 millirems) have been associated with a small but relative increase in cancer in Japanese atomic bomb survivors.

Conclusion

Noninvasive coronary angiography using MSCT is a rapidly emerging technique that is having a major effect on clinical practice. In selected populations, it has been shown to be feasible and accurate in assessing the native coronary anatomy as well as bypass graft patency. Its use appears to alleviate the need for performing invasive coronary angiography in many patients. Although the spatial and temporal resolution of the 64-slice MSCT scanner is still inferior to that of conventional invasive angiography, it is capable of providing information regarding the vessel wall in addition to imaging the lumen. This ability has the potential to be a major advantage of MSCT over conventional angiography. Three-dimensional magnetic resonance imaging is also an emerging new modality for noninvasive coronary angiography; however, it does not require large volumes of contrast or any radiation exposure. A recent study comparing 16-slice MSCT and magnetic resonance imaging showed that MSCT produced superior image quality and diagnostic accuracy of coronary lesions.[12] ■

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Main Points

- With the 64-slice multislice computerized tomographic (MSCT) scanner, units are acquired faster and the slices are thinner, resulting in improved temporal and spatial resolution and coronary artery imaging.
- Additional benefits of the 64-slice MSCT scanner as compared with the older generation scanners include a shorter period during which the patient must hold his or her breath, a wider range of acceptable heart rates, and the ability to image very obese patients and those with moderate coronary calcium with lower volumes of contrast.
- In a study of 1065 segments, 64-slice MSCT had a very high negative predictive value of 98% by segment, 97% by artery, and 93% by patient.
- MSCT holds promise to not only visualize the coronary lumen, but the vessel wall and plaque as well.
- When referral to conventional coronary angiography is questionable, MSCT may help in identifying patients with normal coronary arteries, thereby decreasing the number of unnecessary invasive procedures.