Noninvasive Assessment of Coronary Artery Disease by Multislice Spiral Computed Tomography Using a New Retrospectively ECG-Gated Image Reconstruction Technique

— Comparison With Angiographic Results —

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The present study was designed to investigate the accuracy of multislice spiral computed tomography (MSCT) in detecting coronary artery disease, compared with coronary angiography (CAG), using a new retrospectively ECG-gated reconstruction method that reduced cardiac motion artifact. The study group comprised 54 consecutive patients undergoing MSCT and CAG. MSCT was performed using a SOMATOM Volume Zoom (4-detector-row, Siemens, Germany) with slice thickness 1.0 mm, pitch 1.5 (table feed: 1.5 mm per rotation) and gantry rotation time 500 ms. Metoprolol (20–60 mg) was administered orally prior to MSCT imaging. ECG-gated image reconstruction was performed with the reconstruction window (250 ms) positioned immediately before atrial contraction in order to reduce the cardiac motion artifact caused by the abrupt diastolic ventricular movement occurring during the rapid filling and atrial contraction periods. Following inspection of the volume rendering images, multiplanar reconstruction images and axial images of the left main coronary artery (LMCA), left anterior descending artery (LAD), left circumflex artery (LCx) and right coronary artery (RCA) were obtained and evaluated for luminal narrowing. The results were compared with those obtained by CAG. Of 216 coronary arteries, 206 (95.4%) were assessable; 10 arteries were excluded from the analysis because of severe calcification (n=4), stents (n=3) or insufficient contrast enhancement (n=3). The sensitivity to detect coronary stenoses ≥50% was 93.5% and the specificity to define luminal narrowing <50% was 97.2%. The positive predictive value and the negative predictive value were 93.5% and 97.2%, respectively. The sensitivity was still satisfactory (80.6%) even when non-assessable arteries were included in the analysis. The new retrospectively ECG-gated reconstruction method for MSCT has excellent diagnostic accuracy in detecting significant coronary artery stenoses. (Circ J 2003; 67: 401–405)

Key Words: Coronary angiography; Coronary artery stenosis; Multislice spiral computed tomography

There is no doubt that direct visualization of the coronary artery is the ultimate goal of noninvasive evaluation of coronary artery disease. Although the recent developments in transesophageal echocardiography, transthoracic Doppler echocardiography, electron beam computed tomography (EBCT) and magnetic resonance imaging (MRI) have enabled direct visualization of the proximal portions of the coronary arteries, these imaging modalities are not yet a substitute for coronary angiography. For example, transesophageal echocardiography and transthoracic echocardiography permit visualization of only the left main coronary artery and the proximal portion of the left anterior descending artery.1,2 EBCT provides high temporal resolution and enables quantitative assessment of the coronary artery calcium3–5 but because of limited spatial resolution as a result of the limited z axis resolution (slice thickness = 3.0 mm), it does not permit direct visualization in multi-reformation of the whole coronary artery system6–9.

Recently, 4-detector-row multislice spiral computed tomography (MSCT), which provides simultaneous acquisition of 4 sections, 0.4–0.5 s gantry rotation, has been introduced and initial reports have indicated that this technique allows visualization of the major coronary arteries in normal subjects10 and in patients with high-grade coronary artery stenoses11,12. These preliminary studies have brought substantial optimism to the quest for non-invasive diagnosis of coronary artery disease. However, the images can be affected by cardiac motion artifacts (CMA) because of the limited temporal resolution and in some patients it can be difficult to obtain images of sufficient quality for diagnostic evaluation10–12. In this study, we utilized a new retrospectively ECG-gated image reconstruction technique that substantially reduces CMA and allows artifact-free visualization of the coronary artery.13 We evaluated the results

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from a group of patients who underwent both coronary angiography and MSCT to determine the diagnostic accuracy of MSCT for the detection of significant coronary artery stenoses and occlusions.

**Methods**

**Patient Population**

Fifty-four consecutive patients who underwent coronary CT angiography entered the study: patients in the acute (n=8) or chronic (n=11) phase of acute myocardial infarction (AMI), stable angina pectoris (n=24), coronary vasospasm (n=3) and patients being followed up after percutaneous coronary interventions (n=8). The patients’ characteristics are shown in Table 1. Exclusion criteria included (1) chronic atrial fibrillation, (2) deteriorated renal function (serum creatinine >1.5 mg/dl), (3) pregnancy, hyperthyroidism or a known allergic reaction to contrast media, (4) severe left ventricular dysfunction (left ventricular ejection fraction <30%) and (5) known history of bronchial asthma in whom the use of β-blocker was contraindicated. The study was approved by the hospital’s ethical committee and informed consent was obtained from all patients.

**MSCT**

MSCT (4-detector-row) was performed within 4 weeks prior to the angiographic study using a SOMATOM Volume Zoom (Siemens AG, Germany). Medications were not discontinued throughout the angiographic and MSCT studies. Metoprolol (20–60 mg) was administered orally 90–120 min prior to the MSCT scan to reduce the heart rate so that a single-phase algorithm (reconstructing one image by single cardiac cycle) could be performed. Sublingual nitroglycerin (6 mg) was also administered 5 min prior to the scan. Image acquisition was performed during an inspiratory breathhold preceded by inhalation of oxygen (4 L/min) for 5 min. First, a non-contrast localization scan was performed that yielded an anteroposterior view of the chest in order to position the imaging volume for coronary artery imaging. After imaging at the level of the carina and positioning the region of interest (ROI) in the center of the ascending aorta, a bolus of 15 ml of the contrast medium (Iomeron 350 syringe, Eisai, Tokyo, Japan) was injected intravenously at 3.3 ml/s via a 20 g catheter placed in the cubital vein and the time interval between contrast agent injection and the maximum enhancement within the ROI was measured (collimation 2.5 mm, 140 kV, 60 mA, rotation time 500 ms). The remainder of the contrast medium (85 ml) was then injected and the scan was started with a delay according to the previously determined contrast transit time. The volume data set for coronary artery imaging was acquired in spiral mode, with simultaneous acquisition of 4 parallel slices (slice thickness 1.0 mm, pitch 1.5, table feed 1.5 mm per rotation, 140 kV, 320 mA and the gantry rotation time 500 ms), which allowed temporal resolution of 250 ms.

**Image Reconstruction**

The raw data of the scans were reconstructed using a SOMATOM Volume Zoom (Siemens AG, Germany). Medications were not discontinued throughout the angiographic and MSCT studies. Metoprolol (20–60 mg) was administered orally 90–120 min prior to the MSCT scan to reduce the heart rate so that a single-phase algorithm (reconstructing one image by single cardiac cycle) could be performed. Sublingual nitroglycerin (6 mg) was also administered 5 min prior to the scan. Image acquisition was performed during an inspiratory breathhold preceded by inhalation of oxygen (4 L/min) for 5 min. First, a non-contrast localization scan was performed that yielded an anteroposterior view of the chest in order to position the imaging volume for coronary artery imaging. After imaging at the level of the carina and positioning the region of interest (ROI) in the center of the ascending aorta, a bolus of 15 ml of the contrast medium (Iomeron 350 syringe, Eisai, Tokyo, Japan) was injected intravenously at 3.3 ml/s via a 20 g catheter placed in the cubital vein and the time interval between contrast agent injection and the maximum enhancement within the ROI was measured (collimation 2.5 mm, 140 kV, 60 mA, rotation time 500 ms). The remainder of the contrast medium (85 ml) was then injected and the scan was started with a delay according to the previously determined contrast transit time. The volume data set for coronary artery imaging was acquired in spiral mode, with simultaneous acquisition of 4 parallel slices (slice thickness 1.0 mm, pitch 1.5, table feed 1.5 mm per rotation, 140 kV, 320 mA and the gantry rotation time 500 ms), which allowed temporal resolution of 250 ms.
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Coronary angiography was performed in all patients within 4 weeks after the MSCT study using the transfemoral Judkin’s technique. The angiograms were documented on cine film and evaluated by at least 2 skilled cardiologists who were independent of the MSCT team. The severity of coronary artery stenosis was graded using the same categories as for the MSCT analysis.

Results

MSCT was performed without major complications in all 54 patients. Scan parameters are shown in Table 1. The examination was generally completed within 10 min, and the post processing and data evaluation required 10–20 min, depending on the complexity of the coronary artery status. The heart rate increased during breathhold from 51.5±5.6 beats/min to 56.9±6.6 beats/min. The average contrast transit time was 23.0±3.4 s, but it varied greatly among the patients (15–31 s). The z axis coverage ranged from 90 to 115 mm, which corresponded to a duration of breathhold of 30–38 s. Of the 216 coronary arteries, 206 (95.4%) were available for assessment; 10 arteries (2 LMCA, 3 LAD 3, LCx, 2 RCA) were excluded from the analysis because of severe and diffuse calcification more than 20 mm in length (n=4), stents (n=3) or insufficient contrast enhancement (n=3) (Table 2). For the assessable arteries, the interobserver and intraobserver variations expressed by the kappa values were 0.82 and 0.94, respectively. The sensitivity and specificity to detect significant coronary stenoses were 93.5% and 97.2%, respectively. The positive predictive value and the negative predictive value were 93.5% and 97.2%, respectively (Table 3). By including nonassessable arteries, the overall sensitivity decreased to 80.6%.

Discussion

Our study demonstrated that MSCT with our new retro-
spective ECG-gated reconstruction method can detect significant coronary artery stenoses with high sensitivity (93.5%) and specificity (97.2%) in assessable coronary arteries. The sensitivity was still fair (80.6%) even when the nonassessable arteries were included in the analysis. The diagnostic accuracy of MSCT depends largely on the image quality. For example, in the study by Achenbach et al. only 68% of the coronary arteries were assessable, and although the sensitivity and specificity to detect coronary artery stenoses in the assessable arteries were fair (91% and 84%, respectively), the overall sensitivity was low (58%) when nonassessable arteries were included. The major causes of nonassessability were CMA (39 of the 256 arteries). In our study, the morphological assessment was limited because of poor image quality resulting from CMA. Only 74% of the coronary arteries were visualized and assessable without CMA even at heart rates less than 60 beats/min. Those previous studies used the retrospectively ECG-gated reconstruction method by creating multiple (7–10 times) reconstructed image sets at different time periods during the cardiac cycle, which is an extremely time consuming technique and its accuracy depends on the observer’s experience. The concept of our ECG-gated reconstruction method stems from echocardiographic observations that the cardiac motion is the least during the late phase of the slow filling period immediately before atrial contraction. Imaging during this period avoids abrupt ventricular movement, which is the major source of CMA, occurring during the rapid filling and atrial contraction periods. In fact, CMA-free visualization was achieved in all patients in our study. The major cause of disagreement between MSCT and angiographic results was focal calcification, which hampered assessment and caused misinterpretations in 7 arteries. The partial volume effect is likely to decrease in the future with improvements in the spatial resolution and therefore misinterpretations because of calcification will be less.

Study Limitations

Visualization of the coronary artery using the current temporal resolution of 250ms is only available at low heart rates, so the use of ß-blockers is essential at present for artifact-free visualization of the coronary artery. To improve temporal resolution at higher heart rates, multisegment reconstruction algorithms have to be used, but spatial resolution decreases and the accuracy of the morphological assessment may be sacrificed. With the use of currently available 16-detector-row MSCT, which provides temporal resolution of 210 ms, artifact-free visualization can be achieved at higher heart rates and the dosage of ß-blockers can be reduced.

In our study, the morphological assessment was limited to the vessels greater than 2.0 mm in diameter, so the distal portions and side branches, such as segments #4, #8, #9, #12 and #14, were not evaluated. Vessels with a diameter greater than 1.0 mm could be evaluated by MSCT with a spatial resolution of 0.5 mm. However, we believe our approach is reasonable for screening purposes and for assessment of coronary stenoses that would be potential targets of revascularization therapy.

In conclusion, our results indicate that assessment of coronary artery stenoses and occlusions, which is at present the domain of coronary angiography, might be accurately performed noninvasively by MSCT. Further studies in larger patient cohorts are needed to validate the presented data.

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