Comparison of 16 slice multi-detector computed tomography and breath hold 3D magnetic resonance angiography in the detection of coronary stenosis

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Objective To compare 16 slice multi-detector spiral computed tomography (MDCT) and breathhold 3D magnetic resonance (MR) coronary angiography in the visualization of coronary arteries and the accuracy of detecting significant (> 50%) coronary stenoses in patients with suspected coronary artery disease. Methods Forty patients were examined by 16 slice CT (GE, Lightspeed 16) and MR (GE, Twinspeed) within 3 days; 31 of them underwent conventional coronary angiography (CAG) within 2 weeks after CT and MR scan. CT was performed with 16x1.25 mm detector collimation, 0.5 s rotation time and images were reconstructed at 60%-75% of the cardiac cycle. MR was performed with breath hold 3D FIESTA (TR=4.0 ms, TE=1.7 ms, flip angle 65, slice thickness 3 mm, FOV 280 mm, matrix 256x192). Mean heart rate was 63 ± 5.8 bpm and β-blocker was used in 24 patients. MR and CT image quality was evaluated in 9 coronary segments (RCA1, RCA2, RCA3, LM, LAD1, LAD2, LAD3, LCX1, LCX2) using a four-point grading scale. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy were calculated for detection of significant stenosis using CAG as the gold standard. Results 16 slice CT showed higher image quality in most coronary segments except RCA2. Forty-three segments were diagnosed as significant stenosis by CAG, 36 and 27 of these were correctly detected by CT and MR respectively. Conclusion 16 slice CT showed higher image quality in most coronary segments excepted for middle RCA. 16 slice CT had higher sensitivity than MR for detection of coronary significant stenosis, whereas MR had higher specificity than CT. Both CT and MR showed high negative predictive value, which is useful for excluding coronary stenosis in symptomatic patients. (J Geriatr Cardiol 2006; 3(1): 24-28)

Key Words: computed tomography; magnetic resonance imaging; coronary artery disease; angiography

Patients and methods

Patients

The study included 40 patients (35 males and 5 females; mean age, 51.3 years; age range, 35-77 years) who were referred to the Chinese PLA General Hospital between May 2004 and December 2004, for further diagnostic evaluation because of suspected CAD. All patients gave written informed consent to the study protocol, which had been approved by our local ethics committee. Exclusion criteria were: irregular heart rate, allergy to iodine-containing contrast medium, renal dysfunction (serum creatinine level of more than 120 μmol/L), pronounced cardiac failure, and patients with difficulty to hold breath.

Study protocol

All patients underwent coronary CTA and MRA in random order, and the 2 examinations were performed within 3 days. Conventional coronary angiography (CAG) was performed within 2 weeks in 31 patients and with 1 month in the
other 9 patients after CTA or MRA examinations were performed. All patients had a sinus rhythm, the mean heart rate was 63 bpm (range, 48-72 bpm) during CTA examination and 62 bpm during MRA examination. In 26 patients with a prescan heart rate of more than 70 bpm and without a contraindication, 50 mg metoprolol was given orally 30-60 minutes before the examinations to reduce the heart rate to less than 70 bpm.

MDCT coronary angiography
MDCT coronary angiography was performed by using a 16 rows multi-slice spiral CT (GE, LightSpeed 16), with a 0.5-sec rotation time, 16×1.25 mm detector collimation, 5.5 mm/sec table feed, 120-kV tube voltage and a 380-mA tube current, covering the distance from the carina to the diaphragmatic surface of the heart. A bolus of nonionic contrast medium (90-100 ml) was injected intravenously during, covering the distance from the carina to the diaphragm. The image reconstruction window was at 60% to 75% of the R-R intervals. We used volume rendering (VR), curve planar reformat (CPR) and maximum intensity projection (MIP) for the image reconstruction.

MR imaging
Magnetic resonance imaging was performed on a 1.5-T magnet (GE, Signa TwinSpeed) with a gradient of 40 mT/m and 150 T/m/sec rise time, an 8-channel cardiac coil. Coronary images were acquired using 3D breathhold fast imaging employing steady state acquisition sequence (FIESTA). The scan parameters were: repetition time 4.1ms; echo time 1.9ms; flip angle 65°; field of view 260-mm, matrix 256×192, slice thickness 3mm, number of excitation (NEX) 0.5.

Conventional coronary angiography
Selective biplane coronary angiography (GE, INNOVA 2000) was performed in 31 patients within 2 weeks after the CTA or MRA examinations, with standard techniques. The angiograms were quantitatively assessed by 2 interventional cardiologists.

Analysis of technical image qualities
CTA and MRA images were analyzed by 2 experienced radiologists who were blinded to the patient’s other clinical data and results of CAG. Image quality were scored on 9 coronary segments: proximal, middle and distal right coronary artery (RCA1, RCA2, RCA3), left main (LM) artery, proximal, middle and distal left descending (LAD1, LAD2, LAD3), proximal and distal circumflex artery (LCX1, LCX2). Scoring was using a four-point grading scale. The scores were defined as shown in Table 1. Discordant scoring between the two observers was resolved by consensus reading. Significant coronary stenosis was defined as more than 50% diameter reduction.

Statistics
Statistical analyses were performed by using Chinese High Intellectualized Statistical Software (CHISS, Tsinghua University, China). Values were expressed as mean ± SD. Comparison of graded image quality between CTA and MRA were tested with two tailed t test. The diagnostic accuracies of the two examinations (sensitivity, specificity, positive predictive value and negative predictive value, using the results of CAG as reference) were compared by using χ² test. A P value <0.05 was considered to indicate statistical significance.

Results
Image quality
CTA and MRA were successfully performed in all 40 patients after heart rate control and breathe instruction and excise. The mean duration of CT scanning was 11.5(10.5-12.8) seconds. The mean duration of MR imaging (including examination of cardiac function) was 23 (18-32) minutes. Of all the 360 coronary segments, 327(91%) were evaluabe with CTA; 33 (9%) segments could not be analyzed diagnostically (18 segments were not shown, and 15 because of significant motion artifacts). With MRA, 300 (83%) of the 360 segments were evaluabe; 60 (17%) segments could not be analyzed diagnostically (49 were not shown, 11 due to significant motion artifacts). The mean image quality scores of CTA and MRA in each of the 9 coronary segments were shown in Table 2.

Coronary stenosis at CAG
Of the 31 patients undergoing CAG, significant coronary stenosis (>50% diameter narrowing) was found in 26 patients. Fifteen patients had single-vessel disease, 7 had two-vessel disease and 4 had three-vessel disease. Of all 279 segments, 43 (15.4%) were shown to have significant stenosis at CAG. Seventeen of them were in RCA, 19 in LAD and 7 in LCX.

Diagnostic accuracy of CTA and MRA
The diagnostic accuracy of MRA and CTA in 31 patients who underwent conventional selective coronary angiography, for detection of >50% diameter stenosis on a segmental basis was shown in Table 3.

Table 1. Scoring of image quality

<table>
<thead>
<tr>
<th>Score</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Severe motion artifacts or segment not shown, not assessable</td>
</tr>
<tr>
<td>2</td>
<td>Ill-defined vessel contour, but diagnostically assessable</td>
</tr>
<tr>
<td>3</td>
<td>Minor artifacts, sub optimal vessel delineation</td>
</tr>
<tr>
<td>4</td>
<td>No artifacts, excellent vessel delineation</td>
</tr>
</tbody>
</table>
CTA correctly identified significant stenosis in 36 (83%) of the 43 segments, whereas MRA identified 27 (63%) segments (P=0.03). However, compared with CTA, MRA had a higher specificity (90% vs 84%, P=0.03). CTA incorrectly diagnosed 37 significant stenoses in 37 segments, the underlying reasons of false-positive included: severe calcification in 23 segments, motion-artifact in 8 segments and overestimation of stenosis in 6 segments. MRA overestimated 22 significant stenoses in 22 segments, the underlying cause of false-positive were motion artifacts and lower spatial resolution.

Table 2. Image quality scores of CTA and MRA in 9 coronary segments

<table>
<thead>
<tr>
<th></th>
<th>RCA1</th>
<th>RCA2</th>
<th>RCA3</th>
<th>LM</th>
<th>LAD1</th>
<th>LAD2</th>
<th>LAD3</th>
<th>LCX1</th>
<th>LCX2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>3.4±0.7</td>
<td>2.6±1.1</td>
<td>3.1±1.2</td>
<td>3.8±0.4</td>
<td>3.6±0.7</td>
<td>3.6±0.6</td>
<td>3.1±1.3</td>
<td>3.2±0.8</td>
<td>2.5±1.4</td>
</tr>
<tr>
<td>MR</td>
<td>3.5±0.6</td>
<td>3.1±0.8</td>
<td>2.3±1.2</td>
<td>3.5±0.6</td>
<td>3.1±0.6</td>
<td>2.7±0.8</td>
<td>2.1±1.6</td>
<td>2.8±0.8</td>
<td>0.7±1.2</td>
</tr>
<tr>
<td>P value</td>
<td>0.51</td>
<td>0.02</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 3. Diagnostic accuracy of MRA and CTA in 31 patients for detection of >50% diameter stenosis on a segmental basis

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value</th>
<th>Negative predictive value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>83% (36/43)</td>
<td>84% (199/236)</td>
<td>49% (36/73)</td>
<td>97% (199/206)</td>
</tr>
<tr>
<td>MR</td>
<td>63% (27/43)</td>
<td>90% (214/236)</td>
<td>55% (27/49)</td>
<td>93% (214/230)</td>
</tr>
<tr>
<td>χ²</td>
<td>4.81</td>
<td>4.50</td>
<td>0.39</td>
<td>6.94</td>
</tr>
<tr>
<td>P</td>
<td>0.03</td>
<td>0.03</td>
<td>0.53</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Fig. 1. Artifact caused by cardiac motion. Motion-related artifact at the proximal LAD in a 54 year old man with a heart rate of 68 bpm, would be easily misinterpreted to be a significant stenosis on the axial image of CTA (A). MRA (B) and CGA (C) showed normal lumen at the same segment.

Fig. 2. A 50% stenosis at middle RCA (C) was poorly delineated on CTA due to motion artifact (A) and under-estimated on MRA.
Discussion

Principles of CTA and MRA

Owing to the small size, the tortuosity and the complex motion of the coronary arteries, high quality of coronary imaging requires high temporal and spatial resolutions. Conventional coronary angiography, that is, selective X-ray coronary angiography, with its excellent spatial and temporal resolution (about 0.13-0.1mm and 20 ms, respectively), is still the gold standard of coronary anatomic imaging. Unfortunately, in the end-systolic phase and mid-diastolic phase, magnetic resonance imaging, for their limited temporal resolutions, could not acquire the image of coronary artery when it is in motion. Fortunately, in the end-systolic phase and mid-diastolic phase, there are short periods at which minimal coronary motion occurred. The duration of these motion-free intervals is inversely related to heart rate. Both CTA and MRA use data collected during these periods for coronary image construction. However, magnetic resonance and MDCT differ not only in their physical principles but also in the strategies they employ to correct for coronary artery motion. Correction for cardiac motion by MR was performed by prospective vectorcardiographic gating while by MDCT, it was obtained by retrospective re-alignment of multislice partial scan data relative to an ECG signal that is recorded during image acquisition.

Diagnostic accuracy of CTA and MRA

Our results showed that in the detection of significant stenosis, CTA had a higher sensitivity whereas MRA had a higher specificity. The higher sensitivity of CTA was related to the better spatial resolution. It also reflected the greater capability of CT to depict calcified plaques, which usually generate a strong signal on MDCT images and are therefore quite easily identified. However, severe calcification will lead to overestimation of stenosis and hence a reduced specificity. Several studies with four-slice or 16-slice MDCT have showed plaque calcification as the major reason of false-positive findings in detection of coronary stenosis. MRA has advantages over CTA in the detection of calcified coronary plaques. Coronary MRA depict artery by using the blood flow as a bright signal, so it is not affected by calcification.

To our knowledge, only one previous study has directly compared the accuracy of MRA and 16-slice MDCT angiography. In that study of 53 patients by Keffler et al, MRA and CTA had similar sensitivity (75% vs 82%), specificity (77% vs 79%) and diagnostic accuracy (77% vs 80%) for detection of significant coronary stenosis. The difference between our findings and Keffler’s study may be in part due to the different study populations.

Comparison of image quality

In our study with a 16-slice MDCT, image quality of CTA was better than MRA at most coronary segments. Although the temporal resolution of 16-slice MDCT and MR are approximately similar, MDCT has a higher spatial resolution than MR, which might explain the better image quality of CTA. We also noted that at RCA2 the image quality of CTA was poorer than that of MRA. Motion artifacts were the major reason for the relative poor quality of RCA. Several factors contribute to the fact that RCA is often affected by motion artifacts. First, the 16-slice MDCT such as that used in this study still has a limited temporal resolution of about 125 ms to 250 ms; Second, RCA has an extensive motion radius and short motion free period. Our study also showed that image quality in distal LCX and RCA by MRA was especially poor, perhaps because of the poor spatial resolution of MR.

Study limitations

The major limitation of the present study was the relatively small number of patients. Also, in the present study, we used 16-slice MDCT, which represented the state of the art in MDCT technology at the time the study was carried out. More recently introduced MDCT with 64 detector scanner, which yields higher temporal and spatial resolutions, might provide better diagnostic accuracy for the detection of CAD. On the other hand, the whole heart axial MR imaging techniques introduced recently might allow for a better visualization of small and curved coronary segments and, thus, for an improved diagnostic accuracy of coronary MR. Since the field of noninvasive coronary imaging is rapidly evolving, we anticipate that upcoming improvements will result in additional increases in the
diagnostic accuracy of both imaging techniques. References