Coronary MRA
Can it be compete with cardiac CT?

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Department of Radiology, Mie University

I have nothing to disclose related to the contents of this presentation
60-year-old man, chest pain
1.5T whole heart coronary MRA

RCA

LAD

Sliding thin slab MIP
60-year-old man
Coronary angiography

Pre PCI
Post PCI
## Coronary CTA and MRA

<table>
<thead>
<tr>
<th></th>
<th>Coronary CTA</th>
<th>Coronary MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ionizing radiation</strong></td>
<td>10mSv (0.5-20)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Contrast medium</strong></td>
<td>required</td>
<td>Non-contrast study feasible</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td>75 -200ms</td>
<td>flexible (~30ms)</td>
</tr>
<tr>
<td><strong>Heavy calcification</strong></td>
<td>reduced accuracy</td>
<td>not influenced</td>
</tr>
<tr>
<td><strong>Spatial resolution</strong></td>
<td>0.5mm</td>
<td>1mm</td>
</tr>
<tr>
<td><strong>Imaging time</strong></td>
<td>&lt;10sec (0.2-10)</td>
<td>&gt;5min</td>
</tr>
<tr>
<td><strong>Operator dependency</strong></td>
<td>low</td>
<td>high</td>
</tr>
</tbody>
</table>
Coronary artery aneurysm in a patient with Kawasaki disease

RCA aneurysms

LAD aneurysm with thrombus

Mie University Hospital
Assessment of anomalous origin of coronary arteries

31-year-old man, VT after exercise

Anomalous origin of RCA
Radiation dose of cardiac CT

Mean radiation dose 12mSv (8 - 18mSv)
Median dose per site 4.6 - 30mSv

Hausleiter J, et al. JAMA 2009;301:500
Ultra low-dose coronary CTA

- ECG triggered high-pitch spiral
  - 100kV, 258mAs, 0.28sec/rotation
- Iterative reconstruction (SAFIRE)

Radiation dose = 0.6mSv

Dual-source CT
Mie University hospital
Can coronary MRA be complete with coronary CTA for the detection of CAD?
Diagnostic accuracy of coronary CTA and coronary MRA: Meta analysis

<table>
<thead>
<tr>
<th></th>
<th>CTA</th>
<th>MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>97% (96.2, 98.0)</td>
<td>87% (83.0, 90.3)</td>
</tr>
<tr>
<td>Specificity</td>
<td>87% (84.5, 89.9)</td>
<td>70% (58.5, 79.7)</td>
</tr>
</tbody>
</table>

89 CT studies, 7516 patients
>50% of CT studies were published in 2007 and 2008.
20 MRA studies, 989 patients
Averaged year of 20 MRA publications was 2004
Only 7 of 20 MR studies used a whole-heart approach

Dewey M, Radiology 2011;258:329
Georg M, Ann Int Med 2010;152:167
1.5T coronary MRA using 32-ch coils

<table>
<thead>
<tr>
<th></th>
<th>Per patient (n=67)</th>
<th>Per vessel (n=201)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>87%</td>
<td>86%</td>
</tr>
<tr>
<td>Specificity</td>
<td>86%</td>
<td>93%</td>
</tr>
<tr>
<td>PPV</td>
<td>89%</td>
<td>86%</td>
</tr>
<tr>
<td>NPV</td>
<td>83%</td>
<td>93%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>87%</td>
<td>91%</td>
</tr>
</tbody>
</table>

Study success rate; 100% (67/67), Prevalence of CAD; 58%
Imaging time; 6.3 ± 2.2 min.

Mie University Hospital
Diagnostic performance of whole heart coronary MRA and 64-slice MDCT - vessel based analysis

Multi-center study on coronary MRA
J Am Coll Cardiol 2010 56:983

CorE-64 (64-slice MDCT)
Miller J, et al
Comparison of three-dimensional volume-targeted thin-slab FIESTA magnetic resonance angiography and 64-multidetector computed tomographic angiography for the identification of proximal coronary stenosis

Liuquan Cheng\textsuperscript{a,}\textsuperscript{*}, Lin Ma\textsuperscript{a}, Paul Schoenhagen\textsuperscript{b}, Huiyi Ye\textsuperscript{a}, Xin Lou\textsuperscript{a}, Yuangui Gao\textsuperscript{a}, Xihai Zhao\textsuperscript{a}, Xinjiang Wang\textsuperscript{a}, Wei Dong\textsuperscript{c}

\textsuperscript{a}Department of Radiology, Chinese PLA General Hospital, Beijing, China

Efficacy of MRA, CTA, and CTA plus MRA in grading coronary stenosis, taking CA as the standard of reference.

<table>
<thead>
<tr>
<th>Index</th>
<th>CTA</th>
<th>MRA</th>
<th>CTA plus MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity (%)</td>
<td>85.1</td>
<td>83.0</td>
<td>92.1</td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>87.2</td>
<td>86.9</td>
<td>92.4</td>
</tr>
<tr>
<td>Positive predictive value (%)</td>
<td>60.0</td>
<td>58.8</td>
<td>72.9</td>
</tr>
<tr>
<td>Negative predictive value (%)</td>
<td>95.6</td>
<td>96.5</td>
<td>98.1</td>
</tr>
<tr>
<td>Accuracy (%)</td>
<td>86.8</td>
<td>86.1</td>
<td>93.7</td>
</tr>
</tbody>
</table>

Int J Cardiac Imaging 2012
Diagnstic impact of coronary calcium on the decision to perform contrast CTA in symptomatic patients

<table>
<thead>
<tr>
<th>CCS</th>
<th>&lt;100</th>
<th>100–400</th>
<th>401–1000</th>
<th>&gt;1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (8)</td>
<td>A (8)</td>
<td>U (6)</td>
<td>U (4)</td>
<td></td>
</tr>
</tbody>
</table>
Patient with heavy coronary calcification (71M)
Coronary CTA versus MRA

64-slice MDCT  Whole heart coronary MRA

X-ray coronary angiography
Patient with heavy coronary calcification (70M)
Coronary CTA versus MRA

320-slice MDCT
3T whole heart MRA
Major factors determining image quality and diagnostic accuracy of coronary MRA

1. Motion by respiration
2. Motion by cardiac contraction
Free-breathing coronary MRA

- Navigator echo
  Respiratory gating (gating windows at expiration)
  Adaptive motion correction
Abdominal belt significantly reduces the difference between end inspiratory position (EIP) and end expiratory position (EEP) of the diaphragm

<table>
<thead>
<tr>
<th></th>
<th>Without belt</th>
<th>With belt</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>14.9 ± 6.2mm</td>
<td>9.4 ± 3.8mm</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>UK</td>
<td>15.9 ± 6.0mm</td>
<td>9.7 ± 3.1mm</td>
<td>0.001</td>
</tr>
<tr>
<td>Japan</td>
<td>14.0 ± 6.4mm</td>
<td>9.1 ± 4.6mm</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Ishida M, J Cardiovas Magn Reson 2011;13:71
Abdominal belt significantly improved scan efficiency in whole heart coronary MRA: Comparison between the UK and Japan

Ishida M, J Cardiovas Magn Reson 2011;13:71
Image quality was comparable between UK and Japan patients
1.5T whole heart coronary MRA using 5-ch coils
Acquisition window in the cardiac cycle

During diastole
83/131 (63.3%) patients
HR = 65.1 /min. ± 9.4
Window = 152 ms ± 67

During systole
48/131 (36.7%) patients
HR = 83.2 /min. ± 9.5
Window = 98 ms ± 26

Sakuma H. J Am Coll Cardiol 2006;48:1946
Whole heart coronary MRA with 32ch coils

5-channel coils
SENSE factor 2
12.3 ± 4.2 min.

32-channel coils
SENSE factor 4
6.3 ± 2.2 min.

1.5T whole heart coronary MRA using 32-ch coils

Acquisition window in the cardiac cycle

- During diastole (n=49)
  - Heart rate: 70 ± 10 beats/min
  - Window: 84 ± 57ms

- During systole (n=18)
  - Heart rate: 79 ± 9 beats/min
  - Window: 48 ± 18ms

3T Coronary MRA
Whole heart coronary MRA at 1.5T and 3.0T in the same subject

1.5T, 32ch coils
SSFP, T2 prep and SPIR

3.0T, 32ch coils
TFE, T2 prep and SPIR

Mie University Hospital
3.0T whole heart coronary MRA
T2 prep and SPIR, 32-ch coils, MultiTransmit
MRA acquired after LGE MRI (0.15mmol/kg)
## 3T whole heart coronary MRA

T2 prep and SPIR, 32-ch coils, MultiTransmit
MRA acquired after LGE MRI (0.15mmol/kg)

<table>
<thead>
<tr>
<th></th>
<th>Per patient (n=42)</th>
<th>Per vessel (n=236)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>89%</td>
<td>83%</td>
</tr>
<tr>
<td>Specificity</td>
<td>92%</td>
<td>97%</td>
</tr>
<tr>
<td>PPV</td>
<td>89%</td>
<td>87%</td>
</tr>
<tr>
<td>NPV</td>
<td>92%</td>
<td>96%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>91%</td>
<td>94%</td>
</tr>
</tbody>
</table>

Nagata M, Mie University Hospital  
AHA 2009
Vessel sharpness (%) in proximal 4cm (n=15)

<table>
<thead>
<tr>
<th>Field strength and sequence</th>
<th>1.5T Achieva bTFE</th>
<th>3.0T Achieva Tx TFE</th>
<th>3.0T Ingenia TFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMT+LAD</td>
<td>46.5±7.4</td>
<td>52.8±7.8</td>
<td>54.3±6.2</td>
</tr>
<tr>
<td>LCx</td>
<td>53.7±6.1</td>
<td>60.5±7.0</td>
<td>60.3±6.3</td>
</tr>
<tr>
<td>RCA</td>
<td>53.2±10.5</td>
<td>62.4±7.7</td>
<td>66.1±6.8</td>
</tr>
</tbody>
</table>

Non-contrast enhanced studies
Use of stable contrast medium is important for 3.0T whole heart coronary MRA.
3.0T Whole-Heart Coronary Magnetic Resonance Angiography Performed With 32-Channel Cardiac Coils
A Single-Center Experience

Qi Yang, MD, PhD; Kuncheng Li, MD, PhD; Xin Liu, MD; Xiangying Du, MD; Xiaoming Bi, PhD; Feng Huang, PhD; Renate Jerecic, PhD; Zhi Liu, MD; Jing An, PhD; Dong Xu, MD; Hairong Zheng, PhD; Zhaoyang Fan, PhD; Debiao Li, PhD

Table 3. Accuracy of WH-CMRA Using 32-Channel Cardiac Coils for Detection of Coronary Stenosis

<table>
<thead>
<tr>
<th></th>
<th>Patient Based n=101</th>
<th>Vessel Based n=403</th>
<th>Segment Based n=1181</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity, % (95% CI)</td>
<td>95.9 (86.0–99.4)</td>
<td>88.7 (80.3–94.5)</td>
<td>85.1 (76.9–91.2)</td>
</tr>
<tr>
<td>Specificity, % (95% CI)</td>
<td>86.5 (74.2–94.4)</td>
<td>91.1 (87.9–93.4)</td>
<td>91.8 (90.0–93.4)</td>
</tr>
<tr>
<td>Positive predictive value, % (95% CI)</td>
<td>87.0 (75.1–94.6)</td>
<td>68.7 (59.4–77.0)</td>
<td>50.8 (43.3–58.4)</td>
</tr>
<tr>
<td>Negative predictive value, % (95% CI)</td>
<td>95.7 (85.4–99.4)</td>
<td>97.4 (95.2–98.7)</td>
<td>98.4 (97.4–99.1)</td>
</tr>
</tbody>
</table>

WH-CMRA indicates whole-heart coronary magnetic resonance angiography.
Comparison of 32-channel 3T coronary MRA and 64-slice CT for detecting coronary artery stenosis
Hamdan A, et al. JACC Cardiovasc Imaging 2011;4;50

Table 3. Diagnostic Accuracy of 32-Channel MRI and 64-Slice CT Angiography for Patient- and Vessel-Based Detection of Coronary Stenosis ≥50%

<table>
<thead>
<tr>
<th></th>
<th>Non-contrast enhanced</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32-Channel MRI</td>
<td>64-Slice CT</td>
<td>p Value</td>
<td></td>
</tr>
<tr>
<td>Patient-based analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>54/62 (87 [76–93])</td>
<td>56/62 (90 [80–95])</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>37/48 (77 [63–87])</td>
<td>40/48 (83 [70–91])</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>54/65 (83 [72–90])</td>
<td>56/64 (88 [77–93])</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>37/45 (82 [69–91])</td>
<td>40/46 (87 [74–94])</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>Diagnostic accuracy</td>
<td>91/110 (83 [75–87])</td>
<td>96/110 (87 [80–92])</td>
<td>0.38</td>
<td></td>
</tr>
</tbody>
</table>
Prognostic value of coronary MRA
Prognostic Value of Coronary Magnetic Resonance Angiography for Prediction of Cardiac Events in Patients With Suspected Coronary Artery Disease

Yeonyee E. Yoon, MD,* Kakuya Kitagawa, MD,* Shingo Kato, MD,* Masaki Ishida, MD,* Hiroshi Nakajima, MD,† Tairo Kurita, MD,‡ Masaaki Ito, MD,‡ Hajime Sakuma, MD*

Mie, Japan

J Am Coll Cardiol 2012 (in press)

- Whole-heart CMRA is useful for predicting the future risk for cardiac events in patients with suspected coronary artery disease
- The absence of significant stenosis on whole-heart CMRA is associated with a very low risk of cardiac events
Study population and follow-up

278 patients with CMRA

226 patients eligible

52 patients with known CAD

19 patients lost on follow-up

207 patients included

123 patients without significant stenosis

84 patients with significant stenosis

Yoon Y. Mie University Hospital
Cardiac death, myocardial infarction, unstable angina

Cardiac death, myocardial infarction, unstable angina and revascularization >90 days after CMRA

**Figure 3** Kaplan-Meier Event-Free Survival Curves

Curves for (A) severe cardiac events and (B) all cardiac events.
Univariate and multivariate analyses

After adjusting smoking and family history of CAD, the presence of significant stenosis remains >17 folds adjusted hazard increase for all cardiac events (p=0.006).

Yoon Y. Mie University Hospital

Table 3: Univariate Analysis of Factors Associated With All Cardiac Events

<table>
<thead>
<tr>
<th>Factor</th>
<th>HR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>1.05 (0.98-1.12)</td>
<td>0.189</td>
</tr>
<tr>
<td>Male sex</td>
<td>3.12 (0.67-14.47)</td>
<td>0.145</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.64 (0.19-2.19)</td>
<td>0.478</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.66 (0.18-2.50)</td>
<td>0.544</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>2.08 (0.55-7.83)</td>
<td>0.281</td>
</tr>
<tr>
<td>Current smoking</td>
<td>4.88 (1.43-16.67)</td>
<td>0.011</td>
</tr>
<tr>
<td>Family history of CAD</td>
<td>3.95 (1.04-14.99)</td>
<td>0.044</td>
</tr>
<tr>
<td>BMI &gt;25kg/m²</td>
<td>0.99 (0.26-3.72)</td>
<td>0.983</td>
</tr>
<tr>
<td>Presence of significant stenosis</td>
<td>20.78 (2.65-162.70)</td>
<td>0.004</td>
</tr>
<tr>
<td>1-vessel disease (as compared with no significant stenosis)</td>
<td>18.80 (2.19-161.37)</td>
<td>0.007</td>
</tr>
<tr>
<td>2- or 3-vessel disease (as compared with no significant stenosis)</td>
<td>23.22 (2.71-199.28)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

CI = confidence interval(s); HR = hazard ratio(s); other abbreviations as in Table 1.
Conclusions

- Coronary MRA has been categorized as an “inappropriate” for excluding CAD.
- Coronary MRA has been substantially improved during recent several years, by using multi-channel coils and 3T system.
- In single center studies, the accuracy of coronary MRA is comparable to that of CTA, especially in subjects with high CAC scores.
- Standardization of protocols and training for technologists are important for the widespread clinical use of coronary MRA.
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- Shiro Nakamori, MD
- Masaaki Ito, MD

Matsusaka Central Hospital
- Yasutaka Ichikawa, MD

Seoul National University Hospital
- Yeonyee Yoon, MD