MDCT: Noncoronary Applications

David A. Bluemke, M.D., Ph.D.
Associate Professor, Clinical Director, MRI
Departments of Radiology and Medicine
Johns Hopkins University School of Medicine
Baltimore, Maryland

Noncoronary MDCT – Topics:
LV mass
Pericardial disease
Congenital disease
Pulmonary vein anatomy
LV function
Valve analysis
Myocardial infarction, perfusion

Background – LV function
• Coronary CTA: fixed delay time after R wave is chosen to freeze motion.

Temporal Resolution Determined by Gantry Rotation Time for LV cines
• Rotation speed: 330-500 msec
• 1/2 scan: 165-250 msec temporal resolution

1 cardiac cycle, gantry = 400 sec
Single Segment Reconstruction

E.g., Heart Rate < 65 bpm, min temporal resolution 200 ms
**MDCT Temporal Resolution**

- MDCT nonsegmented: 165-250 msec,
- 2 segment MDCT @ 330 msec gantry rotation: 83 msec*
- MRI: 50 msec
- Echo, Nuclear: 25 msec or less

**LV function**

- Sophisticated segmentation algorithms are adaptive to heart rate, chosen ‘automatically’ (little user control) to optimize CT angiography.
- Higher segmentation factor beneficial for LV function evaluation.
- Raw data reconstruction available on some scanners; higher segmentation may improve temporal resolution.

**Steps for LV function analysis:**

1. Reconstruct cardiac phases: 20 images, or every 5% of cardiac cycle.
2. Corresponds to images approximately every 50 msec.
   (Compare to actual temporal resolution of 100-200 msec).
LV function: slice thickness

- Instead of 0.5 mm slices for CTA, use 5 mm slices (1000 images).
- MRI uses 6-8 mm slices at 1 cm intervals, ~250 images.

LV function – reformat

- MDCT images are acquired in the axial plane
- LV quantitative analysis usually performed in the short axis plane.

3D Volumetric Analysis of the LV

[Diagrams and images related to LV function, reformatting, and 3D analysis]
Papillary Muscles

- Papillary muscle mass accounts for 8.9% of the total LV mass in both men and women
- Correlated with LV wall mass \((r=0.81, p<0.001)*\)

J. Vogel-Claussen, JHU

Contouring: ED/ES only (50 frames)

End diastole

End systole

Rob van der Geest, Univ Leiden

Parameters computed and displayed with ED,ES:

(a) ESV, EDV
(b) EF (%)
(c) SV
(d) CO
(e) Myocardial mass
(f) Filling rates
(g) Emptying rates

LV Volume

Data courtesy of Fujita Health University, Aichi, Japan

LEFT VENTRICULAR VOLUME

RESULTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Surface Area</td>
<td>1.89 m²</td>
</tr>
<tr>
<td>ED volume</td>
<td>307.85 ml</td>
</tr>
<tr>
<td>ED volume/BSA</td>
<td>189.04 ml/m²</td>
</tr>
<tr>
<td>ES volume</td>
<td>241.32 ml</td>
</tr>
<tr>
<td>ES volume/BSA</td>
<td>127.55 ml/m²</td>
</tr>
<tr>
<td>Stroke volume</td>
<td>116.33 ml</td>
</tr>
<tr>
<td>Stroke volume/BSA</td>
<td>61.49 ml/m²</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>32.53 %</td>
</tr>
<tr>
<td>LV mass ED</td>
<td>175.24 g</td>
</tr>
<tr>
<td>LV mass ED/BSA</td>
<td>92.62 g/m²</td>
</tr>
<tr>
<td>LV mass ES</td>
<td>190.87 g</td>
</tr>
<tr>
<td>LV mass ES/BSA</td>
<td>100.78 g/m²</td>
</tr>
<tr>
<td>PER</td>
<td>281.68 m/s</td>
</tr>
<tr>
<td>PER/EDV</td>
<td>0.79 EDV/s</td>
</tr>
<tr>
<td>TPER</td>
<td>400.00 ms</td>
</tr>
<tr>
<td>TPER phase number</td>
<td>5</td>
</tr>
<tr>
<td>PFR</td>
<td>203.65 m/s</td>
</tr>
<tr>
<td>PFR/EDV</td>
<td>0.57 EDV/s</td>
</tr>
<tr>
<td>TPRF</td>
<td>300.00 ms</td>
</tr>
<tr>
<td>TPRF phase number</td>
<td>11</td>
</tr>
</tbody>
</table>
Data courtesy of Fujita Health University, Aichi, Japan

Wall thickness

ED wall thickness  ES wall thickness

Regional Wall Motion Analysis

Example: septal infarct, CHF

Example: septal infarct, CHF

Horizontal long axis view
Data courtesy of Fujita Health University, Aichi, Japan

**Example: aortic outflow tract**

**Example: Anterior wall motion abnormality**

| Multi-Detector Row CT of Left Ventricular Function with Dedicated Analysis Software versus MR Imaging: Initial Experience |
| • 4 slice scanner
| • Temporal resolution 125-250 msec
| • Comparable volumes, function compared to 32 msec temporal resolution MRI

---

**Time-effectiveness, Observer-dependence, and Accuracy of Measurements of Left Ventricular Ejection Fraction Using 4-channel MDCT**

T. Boehm1
H. Alkadhi2
R. Roffi3
J. K. Willmann4
L. M. Devriese5
B. Marinck1
S. Wilderthun1

• slight underestimation of EF with MDCT, related to low temporal resolution (125 ms)
• 63 min processing time for MDCT

---

**Table 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Multi-Detector Row CT</th>
<th>MR Imaging*</th>
<th>Pearson r Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-diastolic volume (mL)</td>
<td>104.8 ± 18.7</td>
<td>106.2 ± 19.6</td>
<td>0.98</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>End-systolic volume (mL)</td>
<td>57.2 ± 14.7</td>
<td>57.1 ± 14.5</td>
<td>0.99</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Stroke volume (mL)</td>
<td>47.6 ± 7.4</td>
<td>49.1 ± 7.9</td>
<td>0.92</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>46.1 ± 6.5</td>
<td>46.8 ± 5.9</td>
<td>0.97</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean time to peak EF (sec)</td>
<td>0.81 ± 0.2</td>
<td>0.82 ± 0.1</td>
<td>0.93</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean time to peak EF (sec)</td>
<td>0.81 ± 0.2</td>
<td>0.82 ± 0.1</td>
<td>0.93</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Peak EF (mL/sec)</td>
<td>247.7 ± 44.5</td>
<td>247.4 ± 44.5</td>
<td>0.16</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Peak EF (mL/sec)</td>
<td>247.7 ± 44.5</td>
<td>247.4 ± 44.5</td>
<td>0.16</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Time to peak EF (mL/sec)</td>
<td>143.8 ± 39.1</td>
<td>122.8 ± 48.3</td>
<td>0.66</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Time from end systole to peak EF (mL/sec)</td>
<td>282.9 ± 204.2</td>
<td>1554.8 ± 834.4</td>
<td>0.27</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

* Values are the mean ± standard deviation.
† Values were determined with the t-test.

Pig infarct model, heart rate 72-106
Mean CT temporal resolution 150 msec

---

**Mahnken, AH et al**
Radiology 2005; 236:112

Modified from Fig 3

• Similar global volumes (EDV, ESV)
• Different time dependent parameters (PER, time to PER, PFR, time to PFR)

---

**Pig infarct model, heart rate 72-106**
Mean CT temporal resolution 150 msec
Valve evaluation

Why Evaluate Valve Function on MDCT?

Echo: AVA is not determined directly but calculated using the continuity equation.
- TEE and TTE both operator dependent.
- Underestimation of severity due to failure to obtain a parallel intercept angle between the Doppler beam and aortic jet.
- MDCT: Noninvasive, nonoperator-dependent technique for direct measurement of AVA.
MDCT: Assessment of Mitral Valve Area

Figure 2
Willman, J, et al.
Radiology 2002; 225

MDCT: Assessment of Mitral Valve

Compared to Echo:
• Excellent correlation with valve leaflet thickness
• Excellent agreement with Mitral Annulus Calcification

Figure 3
Willman, J, et al.
Eur Radiology 2002; 12

MDCT: Assessment of Mitral Valve

<table>
<thead>
<tr>
<th>Abnormal Finding</th>
<th>MDCT</th>
<th>Echocardiography</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Thickening of mitral valve leaflets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5 mm</td>
<td>4 (25)</td>
<td>4 (25)</td>
</tr>
<tr>
<td>≥5 mm</td>
<td>12 (75)</td>
<td>12 (75)</td>
</tr>
<tr>
<td>Mitral valve annulus calcification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5 mm</td>
<td>7 (78)</td>
<td>6 (67)</td>
</tr>
<tr>
<td>≥5 mm</td>
<td>2 (22)</td>
<td>3 (33)</td>
</tr>
</tbody>
</table>

Numbers in parentheses are percentages

Table 3
Willman, J, et al.
Eur Radiology 2002; 12

MRI: valve regurgitation

Elliot Fishman, MD

Artificial Aortic Valve Function

Courtesy: Toshiba America Medical Systems

MRI: valve regurgitation

Elliot Fishman, MD
MDCT Perfusion/ Viability Imaging Rationale:

- Potential to perform CTA, function and viability in a single 15-20 minute exam
- AICD, pacemakers, MRI contraindication
- High spatial resolution (0.4 mm) compared to 6-8 mm slice resolution for MRI.

Adapted from A. Lardo

Acute Myocardial Infarction: Contrast-enhanced MDCT in a Porcine Model
Udo Hoffman, Ryan Millea, Christian Enzweiler, Maros Ferencik, Scott Gulick, Jim Titus, Stephan Achenbach, Dylan Kwiat, David Sosnovik, Thomas J. Brady

- Porcine AMI model (N=7)
- 4 slice MDCT scanning
- 3 hours post-coronary ligation – LAD or LADD
- CT Infarct size 17 ± 6 % similar to TTC 14 ± 6 %

Characterization of Acute MI Using Contrast Enhanced MDCT
Albert C. Lardo, Marco Cordeiro, Veronica Fernandes, Andre Schmidt, Menekhem Zviman, Joao A. C. Lima
Circulation 2004;110 (Supplement):III-522

- Canine AMI model (N=7)
- 32 slice MDCT - 1 hour post-reperfusion.
- Imaging each 5 min up to 40 min post-contrast
- CT infarct size 24 ± 7 %, mean difference 4%
- r = 0.93 with TTC

Adapted from A. Lardo
**MDCT Infarct Imaging**

*Visipaque - 150 ml injection*

- Post infarct
- Post contrast 30 sec
- Post infarct
- Post contrast 5 min


**Infarct Enhancement**

![Graph showing infarct enhancement with HU values](image)

141.8±30.1
302.5±42.8
257.6±21.3


**MDCT Viability Imaging**

![Images of MDCT viability imaging](image)


**Comparison of MDCT and TTC Infarct Measurement**

![Graph showing comparison between MDCT and TTC infarct measurement](image)

R² = 0.922


**3D Visualization of Infarct Extent**

![3D visualization of infarct extent](image)

adapted from A. Lardo

**MDCT Infarct Imaging**

90 min occlusion/reperfusion model

- 2 hrs
- 8 weeks

Chronic Infarct Imaging

**MDCT**

- Infarct size = 128.8 mm²

**Pathology**

- Infarct size = 119.7 mm²


Contrast Enhanced CT Imaging

60 minute occlusion/reperfusion model

- 5 days
  - Infarct = 21.22 cm²
  - Rim thickness = 0.4mm

- 33 days
  - Infarct = 10.41 cm²
  - Rim thickness = 1.4mm

- 67 days
  - Infarct = 8.38 cm²
  - Rim thickness = 2.5mm

adapted from A. Lardo

Cardiac Ablation for Arrhythmia

- Catheter based treatment to kill electrically active viable cell islets
- Pre-procedural MDCT for anatomic correlation
- Visualization of RF ablation lesions

MDCT Lesion Appearance

5 minutes post contrast

adapted from A. Lardo

CT Lesion Appearance

adapted from A. Lardo
MDCT Lesion Morphology

- Hypoenhanced core: coagulative necrosis and microvascular obstruction (contrast does not enter local microcirculation)
- Hyperintense periphery: edema, cell necrosis

MDCT Perfusion Imaging

Requirements:
- Vasodilator (adenosine)
- During first-pass, contrast-enhanced MDCT.
- Rapid imaging from base to apex.

Possible Advantages:
- Simultaneous coronary imaging.
- Imaging of the entire LV

Helical MDCT Perfusion

Helical MDCT perfusion imaging in a canine model of LAD stenosis during adenosine infusion. (Gantry rotation time: 400 ms, Detector collimation: 0.5 X 32, tube current: 400 mA, tube voltage: 120 kV, Visipaque™ 2.5 ml/sec for 100 ml)

MDCT Dynamic Perfusion

Serial imaging of the mid-left ventricle over time in a canine model of LAD stenosis. (Detector collimation: 8 mm X 4, 120 kV, 150 mA, Visipaque™ 10 ml/sec for 3 seconds.)

MDCT Perfusion

Conclusions: Noncoronary MDCT

- Global and regional left ventricular function can be assessed by MDCT and coupled with coronary CTA.
- MDCT stress perfusion, viability and scar imaging has high spatial resolution, promising tool.
Acknowledgements

- Al Lardo, Ph.D.
- Rich George, M.D.
- Jun Dong, M.D.
- Elliot Fishman, M.D.
- João Lima, MD
- Rob van der Geest, PhD

Conclusion - MDCT

Potential for comprehensive morphologic and functional assessment.