QUANTIFICATION OF CORONARY STENOSES BY CT: WHAT DATA DO WE HAVE?

RICARDO C. CURY, MD
DIRECTOR OF EDUCATION AND TELERADIOLOGY
MGH CARDIOVASCULAR CT CORELAB
DIRECTOR OF CLINICAL CARDIAC MRI
MASSACHUSETTS GENERAL HOSPITAL
HARVARD MEDICAL SCHOOL
Disclosure Information

- Research grant – Pfizer, Inc.
Outline

- Principles for stenosis quantification
- Literature review
- Limitations
- Potential applications
- Future aspects
MDCT vs QCA

HOW DO THE CT MEASUREMENTS COMPARE TO THE CATH MEASUREMENTS?

Vessel diameters in normal segments
(8 predefined locations per patient)

\[ y = 0.90 \times + 0.2 \]
\[ R^2 = 0.87 \]

Ferencik et al. AJC 2003; 92 (11) 1257-62
MDCT vs IVUS for lumen quantification

- 26 patients (17 men, 9 women)
- Mean age 62 years
- 16-slice MDCT
- IVUS (40 MHz catheter) performed in one artery per patient

Moselewski F et al. Am J Cardiol. 2004;94:1294-1297

**MDCT**
- 18 mm²

**IVUS**
- 21 mm²
MDCT vs IVUS

Results – Lumen quantification

Lumen area

R = 0.92

Bias + 0.7 mm², p = 0.02

Moselewski F et al. Am J Cardiol. 2004;94:1294-1297
Principles for stenosis quantification

HOW TO CALCULATE THE DEGREE OF STENOSIS?

$$DS = \left( \frac{(Rp + Rd)/2}{(Rp + Rd)/2} \right) - MLD$$

$$DS = \left( \frac{(41 + 44)/2}{41 + 44}/2 \right) - 26$$

$$DS = \frac{42.5 - 26}{42.5} = 39\%$$

Principles for stenosis quantification

Eccentric stenosis

Principles for stenosis quantification

Relation between DIAMETER vs AREA stenosis

Principles for stenosis quantification

2D QCA

3D QCA

36% stenosis

42% diameter

56% area

Cury: Quantification of stenosis by CT
Principles for stenosis quantification

CT vs IVUS – LAD stenosis
Principles for stenosis quantification

Which CT reconstruction method should I use?

AXIAL

MPR

MIP

CURVED MPR

VRT

CATH

Ferencik et al. ... Radiology June 2007
**Principles for stenosis quantification**

<table>
<thead>
<tr>
<th></th>
<th>Interactive evaluation</th>
<th>Pre-rendered reconstructions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Axial</td>
<td>MPR</td>
</tr>
<tr>
<td>Evaluable</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Sensitivity*</td>
<td>91%</td>
<td>91%</td>
</tr>
<tr>
<td>Specificity*</td>
<td>88%</td>
<td>92%</td>
</tr>
<tr>
<td>NPV*</td>
<td>97%</td>
<td>97%</td>
</tr>
<tr>
<td>PPV*</td>
<td>67%</td>
<td>76%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>88%</td>
<td>91%</td>
</tr>
</tbody>
</table>

**DON’T RELY IN THE VRT RECONSTRUCTIONS FOR DETECTION OF STENOSIS !!!**

*Ferencik et al. ... Radiology June 2007*
Principles for stenosis quantification

**IMAGE DISPLAY: Window and level settings**

- **Non-calcified or mixed lesions**
  - Window = 500 – 800 HU
  - Level = 150 – 300 HU

- **Calcified lesions:**
  - Window = 1500 – 2000 HU
  - Level = 300 – 700 HU

- **FWHM – normal segments**

---

*Dix et al. AJNR 1997;18:409-415*
<table>
<thead>
<tr>
<th>Reference</th>
<th>Journal/Year</th>
<th>n</th>
<th>r</th>
<th>Bias</th>
<th>2SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoffmann M.</td>
<td>JAMA 2005</td>
<td>103</td>
<td>0.87</td>
<td>+10</td>
<td>± 30%</td>
</tr>
<tr>
<td></td>
<td>segments &gt; 1.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kefer et al.</td>
<td>JACC 2005</td>
<td>52</td>
<td>0.75</td>
<td>+5</td>
<td>± 34%</td>
</tr>
<tr>
<td></td>
<td>segments &gt; 1.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cury et al.</td>
<td>AJC 2005</td>
<td>29</td>
<td>0.92</td>
<td>+4</td>
<td>± 16%</td>
</tr>
<tr>
<td></td>
<td>segments &gt; 1.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leber et al.</td>
<td>JACC 2005</td>
<td>55</td>
<td>0.54</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>All stenotic segments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raff et al.</td>
<td>JACC 2005</td>
<td>70</td>
<td>0.76</td>
<td>+1.3</td>
<td>± 28%</td>
</tr>
<tr>
<td></td>
<td>All stenotic segments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cury et al.</td>
<td>EJR 2006</td>
<td>38</td>
<td>0.84</td>
<td>+0.6</td>
<td>± 24%</td>
</tr>
<tr>
<td></td>
<td>segments &gt; 1.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caussin et al.</td>
<td>AJC 2006</td>
<td>40</td>
<td>0.88</td>
<td>--</td>
<td>± 43%</td>
</tr>
<tr>
<td></td>
<td>Intermediate lesions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dewey et al.</td>
<td>Invest Radiol. 2007</td>
<td>62</td>
<td>0.51</td>
<td>--</td>
<td>± 27%</td>
</tr>
<tr>
<td></td>
<td>segments &gt; 1.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Quantitative Coronary CTA

- 16-slice MDCT vs coronary angiography
- 42 coronary lesions
- Exclusion: segments with motion artifacts and dense calcifications

57% vs 54%

Cury et al. AJC 2005, 96:784-787
QUANTITATIVE CORONARY CTA

CALIBRATION OF MDCT IMAGES

10 mm grid

Cury et al. AJC 2005,96:784-787
QUANTITATIVE CORONARY CTA

DEGREE OF CORONARY STENOSIS

CORRELATION

\[ r^2 = 0.93 \]

BLAND-ALTMAN ANALYSIS

Bias +4% ± 16% 2SD

Cury et al. AJC 2005,96:784-787
QUANTITATIVE CORONARY CTA

MIXED PLAQUE LAD

81% vs 69%

81% vs 69%
Tools available in the WS
Comparison of cross-sectional and thin-slab MIP images
60 stenotic lesions
Exclusion: segments with motion and dense calcifications

82% vs 90%

Cury et al. EJR 2006, March:345-350
RCA STENOSIS

MDCT CS = 76%
MLD = 0.9mm

Angiogram = 90%
MLD 0.4mm

Cury et al. EJR 2006, March:345-350
QUANTITATIVE CORONARY CTA

CS - MPR

- R² = 0.83
- Bias -2.8% ± 24% 2SD
- < 50% Bias + 9% 
- > 50% Bias - 8%

MIP

- R² = 0.84
- Bias 0.6% ± 24% 2SD
- < 50% Bias + 13%
- > 50% Bias - 4%

Cury et al. EJR 2006, March:345-350
QUANTITATIVE CORONARY CTA

MDCT VS QCA \( r=0.75 \)
MRI VS QCA \( r=0.6 \)

Receiver-operating characteristic curves comparing diagnostic accuracies of visual and quantitative measurement of diameter stenosis (DS) by magnetic resonance (MR) and multidetector row computed tomography (MDCT) for detection of >50% DS by quantitative coronary angiography on a per-vessel basis (Slide 2 of 2)

MDCT visual AUC 0.84
MDCT quant. AUC 0.94

Kefer et al. JACC 2005
**QUANTITATIVE CORONARY CTA**

**CT vs CATH**  
**Correlation** $r = 0.87$  
**Bias** $+10\% \pm 30\%$ 2SD

---

**Figure 5.** Bland-Altman Analysis of Stenosis Grading Using Multislice Computed Tomography (MSCT) vs Conventional Invasive Coronary Angiography

---

Dashed lines indicate 95% confidence limits; bold line, bias.

---

**Intramodality variability of invasive angiogram**  
**Limits of agreement:** $-15\%$ to $21\%$

---

Hoffmann M et al. JAMA. 2005;293:2471-2478
LIMITATIONS

CALCIUM

Calcium: false-positive, false-negative!
Major cause of false positive findings (94%)

Hoffmann, Moselewski, Cury et al Circulation 2004
LIMITATIONS

MOTION ARTIFACTS - HIGH HR

FC = 51bpm
FC = 73bpm
FC = 94bpm

BMI > 30

Ferencik M et al. EJR 2006
ENHANCE CLINICAL DECISION MAKING

Is this a significant stenosis or not?

What do you consider a significant stenosis?
> 50% or > 70%

> 50% for left main
> 70% for LAD, LCX and RCA
Potential applications

Degree of coronary stenosis

- 0%
- 40%
- 70%
- 100%

Mild
- Risk factor modification and medical treatment

Moderate
- Stress Myocardial Perfusion (MRI or NM)
  - FFR

Severe
- Cardiac Cath
Potential applications

- Intermediate lesions – between 40 and 70 %
- Follow-up CT studies: Progression or even regression of disease
- End-point in drug trials for monitoring treatment
- Spatial resolution of CT scanners need to improve!

Isotropic 0.2 x 0.2 x 0.2 mm
Future aspects

Volume CT System

Detector
40 x 30 cm$^2$
Resolution: 250 $\mu$m$^3$

Tube
Future aspects

Instent Restenosis

IVUS

VCT
Future aspects

Improve Clinical Utility of Coronary CT Angiography

Increase Specificity  Spatial Resolution !!!
Conclusions

- Quantification of coronary stenosis is feasible
- Excellent image quality is mandatory
- Principles for stenosis quantification
- Tendency to overestimate stenosis severity by MDCT
- May enhance visual estimation of stenosis if performed properly, especially for intermediate lesions
- Improvement in spatial resolution is necessary, not only adding more detectors!
Acknowledgements

Massachusetts General Hospital
Thomas J. Brady, MD
Suhny Abbara, MD
Maros Ferencik, MD, PhD
Udo Hoffmann, MD
Ahmed Tawakol, MD
Shawn Teague, MD
Johannes Rieber, MD
Jonathan Dodd, MD
Michael Shapiro, MD
Tej Sheth, MD
Javed Butler, MD
Khalid Shash, MD
Vithaya Chaithirapan, MD
Jamaluddin Moloo, MD

University of Erlangen
Stephan Achenbach, MD

Rotherdam Thoraxcenter
Erasmus Medical Center
Koen Nieman, MD