Validation of CT Perfusion Imaging Against Invasive Angiography and FFR on a 320-MDCT Scanner

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Disclosures

- Study funding
  - ATLANTA II
    - [www.clinicaltrials.gov](http://www.clinicaltrials.gov) (NCT00817102)
    - Abbott Vascular, Volcano Therapeutics Inc.

- Principal Investigators
  - Szilard Voros, MD, FACC, FSCCT
  - Grant Funding: Abbott Vascular, Abbott Pharmaceuticals, Volcano Therapeutics Inc, Toshiba, Vital Images, Merck, Cardiogenesis

- Zhen Qian, PhD: No disclosures
Background

Previous Work on CT perfusion

- Stress CT perfusion imaging\(^1\)\(^2\) has been reported on 64- and 256-MDCT single and dual source scanners
- Validation was done against stress nuclear test and invasive angiography
  - Limitation: Not a hemodynamic measurement
- Visual comparison of myocardial intensity in stress and rest\(^1\) and transmural perfusion ratio\(^2\) were used to quantify myocardial perfusion
  - Limitation: Not a standalone absolute measurement. Difficult to handle homogeneous myocardial perfusion defect.


Background

CT perfusion on 320-MDCT

- CT perfusion on 320-MDCT has not been published
- 320-MDCT’s potentials and limitations:
  - Whole heart scan in a single heart beat: better contrast homogeneity.
  - Lower temporal resolution than dual source CT, but improved temporal uniformity
  - Lower overall contrast media
  - Lower overall radiation dose
Purpose

- Investigate 320-multi-detector row vasodilator stress and rest volumetric CT’s ability of myocardial perfusion quantification
- Investigate the feasibility of a blood pool-normalized measurement to quantify myocardial perfusion
- Investigate the feasibility of a refined reference standard that uses both morphological and hemodynamic measurements

Methods

Rest and Stress CT Perfusion Protocol

- Flowchart

CT imaging protocols for both rest and stress CTP: 320-MDCT with prospectively triggered, single-beat, volumetric acquisition; detector width 0.5 mm, voltage 120 kV, current 200-550 mA. Reconstruction at 65-75% R-R.
Methods

Angiography and FFR Protocol

- XRA: ≥70% stenosis was abnormal
  - Visual assessment
- After standard XRA, FFR was measured after intracoronary injection of adenosine in all 3 vessels with angiographically severe or moderate lesions
  - 3 independent FFR measurements were averaged for each lesion
- FFR ≤0.75 was considered abnormal
- CAD was defined as:
  - XRA: ≥70% or
  - FFR ≤0.75

Methods

Study Design - Arterial territories

- AHA 17-segment model *
- Territories supplied by LAD, LCx, and RCA
  - LAD: 1, 2, 7, 8, 13, 14, 17
  - LCx: 5, 6, 11, 12, 16
  - RCA: 3, 4, 9, 10, 15

Methods

Study Design – Myocardial Intensity Quantification

- Reconstruction: 0.5 mm slices
- Average 3 measurements in each segment (in HU)
- Normalization to blood pool intensity: Segment / Blood Pool

Statistical Analysis

- In each arterial territory, we calculated the mean intensity value (absolute value), and the normalized value (divided by the average blood pool intensity)
- t-test was done between territories with obstructive arterial disease, and without obstructive disease. p≤0.05 considered significant.
- ROC analysis was performed to predict perfusion defect. Sensitivity, specificity, AUC were calculated.
Results

Patient information

- 8 patients
  - Gender: M: 3; F: 5
  - Age: 61.3 ± 9.6
- 136 myocardial segments, and 24 arterial territories.
- 11 of the 32 arteries had CAD (based on XRA and FFR)
- 11 of the 24 arterial territories were supplied by artery with obstructive CAD

Results

Visual Comparison

![Stress, Rest, X-ray Angiography images]

SCCT 2010, Las Vegas, NV, July 17, 2010
Results

Comparison of myocardial territories with and without CAD

<table>
<thead>
<tr>
<th>t-test</th>
<th>CAD</th>
<th>No CAD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress (ABS)</td>
<td>119.4±32.9</td>
<td>123.4±30.2</td>
<td>0.76</td>
</tr>
<tr>
<td>Rest (ABS)</td>
<td>91.0±22.0</td>
<td>97.6±17.1</td>
<td>0.42</td>
</tr>
<tr>
<td>S/R Ratio (ABS)</td>
<td>1.36±0.27</td>
<td>1.28±0.16</td>
<td>0.44</td>
</tr>
<tr>
<td>Stress (Norm)</td>
<td>0.27±0.03</td>
<td>0.32±0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Rest (Norm)</td>
<td>0.16±0.04</td>
<td>0.19±0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>S/R Ratio (Norm)</td>
<td>1.88±0.47</td>
<td>1.87±0.43</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Results

ROC Analysis

<table>
<thead>
<tr>
<th>ROC Analysis</th>
<th>AUC</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress (ABS)</td>
<td>0.58</td>
<td>0.67</td>
<td>0.58</td>
</tr>
<tr>
<td>Rest (ABS)</td>
<td>0.60</td>
<td>0.65</td>
<td>0.50</td>
</tr>
<tr>
<td>Stress (Norm)</td>
<td>0.79</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td>Rest (Norm)</td>
<td>0.73</td>
<td>0.67</td>
<td>0.75</td>
</tr>
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</table>
Discussion
Comparison with previous work

- Predictive performance of normalized stress CT perfusion is comparable to previous studies

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>AUC</th>
</tr>
</thead>
</table>
| Blankstein et al  
in Jacc 2009          | 0.75        | 0.87        | 0.80 |
| George et al *  
in Circ Cardiovascular Imaging 2009 | 0.91        | 0.91        | 0.90 |
| Our Method                        | 0.67        | 1          | 0.79 |

* The predictive performance was based on the combination of CTA and CTP.

Discussion
Predictive measurements for CT perfusion

- Normalized myocardial intensity is a good absolute measurement for perfusion study
- Stress perfusion (AUC=0.79) outperformed rest perfusion (AUC=0.73)
  - When specificity fixed at 90%, sensitivity increased from 40% to 67% by using stress perfusion
- Rest perfusion is predictive (t-test p=0.05, ROC AUC = 0.73). It may contain additive value to conventional CTA analysis.
  - Data not shown, but decreased rest perfusion correlated with FFR before the injection of adenosine
- In this sample, stress/rest ratio did not predict CAD. More investigation is needed.
Unique aspects

- One of the first myocardial perfusion studies with 320-MDCT
- Utilizes regadenosone
- Quantification was performed by normalizing to the blood pool
- One of the first studies to use FFR as part of the “reference standard”

Limitations

- Limited patient number
  - We have a CT perfusion study currently being carried out in our lab that will enroll 60 patients
- Arterial territory is a coarse atlas
  - We are developing a patient-specific polar map based on the vessel geometry from CTA
- Didn’t consider beam hardening
Conclusions

- 320-MDCT can detect perfusion defect when compared with invasive angiography and fractional flow reserve
- Myocardial intensity normalized by the LV blood pool intensity both at stress and rest are absolute measurements that are predictive of perfusion defect