WHAT IS NEW IN CARDIAC CT IMAGING?

STRESS CT PERFUSION

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Disclosure Information

- Research grant – Pfizer, Inc.
- Research grant – Astellas Pharma
- Research grant – GE Healthcare
- Consultant – Astellas Pharma

Use of adenosine in cardiac CT is an off label use.
A great debate in cardiac imaging:

ANATOMY vs PHYSIOLOGY
ANATOMY vs PHYSIOLOGY

- Does this patient have CAD?
- Obstructive vs Non-obstructive?

- What is the physiological significance of the lesion?
- What is the short and long-term prognosis for this patient?
- Does this patient need revascularization vs OMT?

Coronary CTA

Myocardial Perfusion Imaging
Practical Tips and Tricks

Practical tips and tricks in cardiovascular computed tomography: Diagnosis of myocardial infarction

Ron Blankstein, MD\textsuperscript{a}, Ian S. Rogers, MD, MBA\textsuperscript{a}, Ricardo C. Cury, MD\textsuperscript{a,b,*}

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1. Rest Perfusion Defect
2. Wall motion abnormality
3. Wall thinning
4. Fatty metaplasia or calcifications
Perfusion and Viability

Normal Myocardium

Infarcted Myocardium

Ischemic Myocardium

Contrast injection

< 1 min

First-Pass

> 5-10 min

Delayed Enhancement

Time
Blankstein R, Cury RC. *JCCT 2009*
Can CT assess perfusion during adenosine infusion?

- 8 dogs prepared with LAD stenosis and MDCT performed 5 minutes into adenosine infusion (.14-.21 mg/kg/min)
- Myocardial SD was significant different in the stenosed territory vs remote
- Correlated to changes in microsphere derived estimates of MBF

George et al. JACC 2006; 48: 153-160
Rationale for Stress CT

- The physiologic significance of many lesions identified by coronary CT angiography is unknown.

- A single test that combines both the anatomical information of CTA along with the physiological significance provided by myocardial perfusion would be beneficial.
Comprehensive Cardiac CT with Stress Myocardial Perfusion

- Coronary anatomy
- Plaque type and distribution
- Functional significance of moderate-severe lesions by detecting “reversible” myocardial perfusion defects in the corresponding coronary territory
- LV systolic function and wall motion
- Myocardial Viability
HOW TO DO IT

- 12 Lead EKG
- Adenosine Infusion pump
- BP Monitor
- Double-Head Injector

- 12 Lead EKG pre and post study
- Continuous BP and EKG monitoring
- 2 I.V. Lines (contrast and adenosine infusion)
- 30 Minutes protocol
### Adenosine Stress 64- and 256-Row Detector Computed Tomography Angiography and Perfusion Imaging: A Pilot Study Evaluating the Transmural Extent of Perfusion Abnormalities to Predict Atherosclerosis Causing Myocardial Ischemia


<table>
<thead>
<tr>
<th>Stenosis &gt; 50%</th>
<th>CTA + CTP / QCA + SPECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per-patient</td>
</tr>
<tr>
<td>n=27</td>
<td>N=87</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>88% (14/16)</td>
</tr>
<tr>
<td>Specificity</td>
<td>91% (10/11)</td>
</tr>
<tr>
<td>PPV†</td>
<td>93% (14/15)</td>
</tr>
<tr>
<td>NPV‡</td>
<td>83% (10/12)</td>
</tr>
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</table>

Myocardial Ischemia Extent of Perfusion Abnormalities to Predict Angiography and Perfusion Imaging: A Pilot Study
Evaluating the Transmural Adenosine Stress 64- and 256-Row Detector Computed Tomography

George et al. 64- and 256-Row MDCT Myocardial Perfusion Imaging. Circ Imaging Sep 2009
Adenosine-Induced Stress Myocardial Perfusion Imaging Using Dual-Source Cardiac Computed Tomography

Ron Blankstein, MD,*† Leon D. Shturman, MD,* Ian S. Rogers, MD, MBA,* Jose A. Rocha-Filho, MD,* David R. Okada, MD,* Ammar Sarwar, MD,* Anand V. Soni, MD,* Hiram Bezerra, MD,*‡ Brian B. Ghoshhajra, MD, MBA,* Milena Petranovic, MD,* Ricardo Lourcigo, MD,* Gudrun Feuchtner, MD,*§ Henry Gcwirtz, MD,* Udo Hoffmann, MD, MPH,* Wilfred S. Mamuya, MD, PhD,*‖ Thomas J. Brady, MD,* Ricardo C. Cury, MD*¶

*Boston and Brookline, Massachusetts; Cleveland, Ohio; Innsbruck, Austria; and Miami, Florida

Stress CT Cardiac cath SPECT

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Dual Source CT Protocol

- Stress Perfusion (~5 Minutes)
  - HR ~ 79
  - Adenosine
  - Contrast

- Rest Scan (~7 Minutes)
  - HR ~ 69
  - Contrast

- Delayed Enhancement

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Blankstein R et al. JACC 2009 Sept.

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Pt #16

CT Perfusion (stress)

SPECT MPI

Coronary CT Angiography

Stress

Rest

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77 y/o, male, prior NSTEMI 3 months ago, new onset of chest pain.

100 kV for stress and rest perfusion – Total radiation = 7 mSv

David Okada – Applied Radiology 2009

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77 y/o, male, prior NSTEMI 3 months ago, new onset of chest pain

Radiation exposure = 12 mSv for SPECT and 7 mSV for Cardiac cath

David Okada – Applied Radiology 2009
<table>
<thead>
<tr>
<th>Stenosis &gt; 50%</th>
<th>Per vessel analysis (n=102)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Stress CT</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>79% (33/42)</td>
</tr>
<tr>
<td>Specificity</td>
<td>80% (48/60)</td>
</tr>
<tr>
<td>PPV†</td>
<td>73% (33/45)</td>
</tr>
<tr>
<td>NPV‡</td>
<td>84% (48/57)</td>
</tr>
</tbody>
</table>

*Blankstein R et al. JACC 2009 Sept.*
(A) CT Perfusion

Stress

Rest

(B) CT Delayed

(C) Invasive Angiography

(D) SPECT MPI

Stress

Rest

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<table>
<thead>
<tr>
<th>Stenosis &gt; 50%</th>
<th>Per patient analysis (n=34)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Stress CT</td>
<td>Stress SPECT</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>92% (23/25)</td>
<td>92% (23/25)</td>
</tr>
<tr>
<td>Specificity</td>
<td>67% (6/9)</td>
<td>67% (6/9)</td>
</tr>
<tr>
<td>PPV†</td>
<td>89% (23/26)</td>
<td>89% (23/26)</td>
</tr>
<tr>
<td>NPV‡</td>
<td>75% (6/8)</td>
<td>75% (6/8)</td>
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Blankstein R et al. JACC 2009 Sept.

Incremental Value of Adenosine-induced Stress Myocardial Perfusion Imaging with Dual-Source CT at Cardiac CT Angiography

Jose A. Rocha-Filho, MD
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Udo Hoffmann, MD, PhD
Gudrun Geuchtner, MD
Wilfred S. Mamuya, MD, PhD
Thomas J. Brady, MD
Ricardo C. Cury, MD

Purpose: First, to assess the feasibility of a protocol involving stress-induced perfusion evaluated at computed tomography (CT) combined with cardiac CT angiography in a single examination and second, to assess the incremental value of perfusion imaging performed with cardiac CT angiography in a dual-source technique for the detection of obstructive coronary artery disease (CAD) in a high-risk population.

Materials and Methods: Institutional review board approval and informed patient consent were obtained before patient enrollment in the study. Thirty-five patients at high risk for CAD were prospectively enrolled for evaluation of the feasibility of
Case 1: 70-year-old man with diabetes, hypertension, old infarct

Step 1 CTA
Proximal stent restenosis

Step 2 CT perfusion
Normal perfusion

Step 3 final call
Non significant stenosis

Gold standard
Mild proximal stent stenosis

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Case 2: 63 y-o male, history of CAD, episode of syncope. Hypertension and hyperlipidemia

Reading

Step 1 CTA
- RCA Non interpretable
- LCX Possible stenosis

Step 2 ct perfusion
- RCA Normal perfusion
- LCX Abnormal perfusion

Step 3 final call
- RCA Non-significant stenosis
- LCX Significant stenosis

Gold standard
- RCA Non significant stenosis
- LCX Significant stenosis
### Combined results of CTA + CTP

<table>
<thead>
<tr>
<th>Stenosis &gt; 50%</th>
<th>Per Patient Analysis (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CTA</td>
<td>CTA + CTP</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>96 (24/25)</td>
<td>96 (24/25)</td>
</tr>
<tr>
<td>Specificity</td>
<td>70 (7/10)</td>
<td>100 (10/10)</td>
</tr>
<tr>
<td>PPV†</td>
<td>88.9 (24/27)</td>
<td>100 (24/24)</td>
</tr>
<tr>
<td>NPV‡</td>
<td>87.5 (7/8)</td>
<td>90.9 (10/11)</td>
</tr>
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</table>

*Rocha-Filho et al. – Radiology 2010 Feb.*

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Stress Dual Energy CT

SPECT  DECT  MRI

STRESS

REST

Delayed Enhancement

Balazs Ruzsics, PhD and Joseph Schoepf, MD - MUSC

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Dipyridamole Stress and Rest Myocardial Perfusion by 64-Detector Row Computed Tomography in Patients With Suspected Coronary Artery Disease

Roberto C. Cury, MD\textsuperscript{a}, Tiago A. Magalhães, MD\textsuperscript{a}, Anna C. Borges, MD\textsuperscript{b}, Afonso A. Shiozaki, MD\textsuperscript{a}, Pedro A. Lemos, MD\textsuperscript{c}, José Soares Júnior, MD\textsuperscript{b}, José Cláudio Meneghetti, MD\textsuperscript{b}, Ricardo C. Cury, MD\textsuperscript{d,e}, and Carlos E. Rochitte, MD\textsuperscript{a,*}
Patient n -2

Myocardial perfusion by CT

Roberto C. Cury – AJC 2010 In press
64 – SLICE STRESS MYOCARDIAL CT PERFUSION

Roberto C. Cury – AJC 2010 In press
Coronary CT Angiography

Degree of coronary stenosis

- 0%: Absence of CAD
- 40-50%: Mild, Non-diagnostic
- 70%: Moderate, Non-diagnostic
- 100%: Severe, Occluded

- Risk factor modification and medical treatment
- Reassurance
- Stress MPI (CTP)
- Optimal Medical Therapy
- Cardiac Cath
- DE-MRI (CT)

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Limitations

1. All single center studies

2. Standardized protocols are needed for Stress/Rest CTA studies

3. CT related artifacts (e.g. beam hardening, motion) are often challenging to differentiate from true perfusion defects
Newer Methods for Noninvasive Assessment of Myocardial Perfusion
Cardiac Magnetic Resonance or Cardiac Computed Tomography?
Eike Nagel, MD, PriD, João A. C. Lima, MD, Richard T. George, MD
London, United Kingdom; and Baltimore, Maryland
Section Editor: Christopher M. Kramer, MD

Nuclear scintigraphy is the most commonly used technique for assessing myocardial perfusion in cardiovascular medicine in 2009. However, the pendulum

EDITORIAL COMMENT

Stress Computed Tomography Myocardial Perfusion
Steps, Questions, and Layers*
Stephan Achenbach, MD
Erlangen, Germany

Cardiac computed tomographic angiography (CTA) is establishing itself as a method that allows robust visualization of the coronary arteries in a noninvasive fashion. It is certainly not a widespread replacement for diagnostic invasive coronary angiography, nor a screening technique, but if image quality is adequate (which requires that state-of-the-art equipment is used and adequate imaging protocols are validated), patients are appropriately selected, a specific lesion causes ischemia (16–19)—usually considered a prerequisite to justify revascularization.

Contrast-enhanced computed tomography (CT) imaging of the heart shows not only the coronary arteries, but also the myocardium. It has been shown that chronic hypoperfusion can easily be seen by CT, for example, in patients after myocardial infarction (20,21). Early data suggest that CT may also be able to detect stress-induced perfusion defects (22,23), and in this issue of the Journal, Blankstein et al. (24) present the first series of patients studied by adenosine-induced stress myocardial perfusion imaging using contrast-enhanced dual-source CT. In fact, their examination protocol was comprehensive and approached what some may be referring to as a “1-stop shop.” Thirty-three patients who had a nuclear stress test and underwent invasive coronary angiography were studied by CT. The scan protocol consisted of an initial contrast-enhanced scan acquired during adenosine infusion, a second contrast-enhanced scan acquired at rest, and a third scan performed without additional contrast. The initial adenosine stress contrast-enhanced scan served to visualize the coronary arteries and identify coronary artery stenoses, as well as to the exclusion of flow-limiting disease.
Coronary CT Angiography

Clinical likelihood for coronary artery disease

0% 100%

Age, Gender  Risk factors  Stress Test

Asymptomatic
Low  Intermediate  High

Symptomatic
Low  Intermediate  High

Calcium scoring  Coronary CTA  Cath or Stress Perfusion Imaging
Conclusions

1. Coronary CTA with Stress/Rest Myocardial CT perfusion is feasible.

2. The diagnostic accuracy of stress perfusion CT for detecting significant stenosis is similar to SPECT MPI and with comparable radiation dose.

3. Stress CT perfusion can improve diagnostic accuracy of coronary CTA, in high risk patients.

4. Future multi-center trials are needed to confirm the results of these promising preliminary trials.
PERFUSION CT TEAM @ MGH

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Quantification and Display of Myocardial CT Perfusion