Nuclear Stress Testing and Multi-Modality Imaging

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No Financial Disclosures
Learning Objectives

• Order the Right Test for the Right Patient
• How to risk stratify patients
• Review the Appropriateness Criteria
• What information Does the Study Provide
• How does the Information Affect Clinical Management
A 46 year old male presents of an initial evaluation. He recently started exercising and notices he is very short of breath after 10 minutes of activity. He has not seen a physician in over 10 years. His vital signs are: blood pressure is 144/92 mmHg, pulse rate is 80 bpm, and BMI is 36.4. Examination is notable for moderate central obesity and a grade 2 systolic murmur along the left sternal border. Review of his lipid panels: Total cholesterol 220, HDL 36, LDL 140.

What is the appropriate management in this patient?

A. Trial of Diet and Exercise with 3 month follow-up  
B. Start on antihypertensive therapy  
C. Start on a statin  
D. Perform a Stress test
Who Should get a Stress Test?

• Appropriateness Criteria:
  – Establish the initial diagnosis
    • Men with atypical or typical chest pain
    • Women >40 yo with atypical or typical chest pain
  – Evaluate a change in symptoms in a patient with established disease
  – Evaluate response to medical therapy or procedure with or without change in clinical status
  – Guide therapy or management, regardless of symptom status
Basic Principles

Stress Echo

Functional significance of CAD
Post-MI Risk
Viability
Pre-operative
Valvular Heart Disease
Diagnosis of CAD
Exercise: Appropriate Indications

- Detection of obstructive coronary artery disease
  - Patients with an intermediate pretest probability
  - Patients with high-risk factors for CAD
    - DM, PVD, CVA
- Risk stratification of post-myocardial infarction
  - Sub-maximal test at 4-6 days
  - Symptom-limited at 14-21 days
  - Symptom-limited at 3-6 weeks after discharge.
- Risk stratification of patients with chronic stable CAD
  - Managed medically (low risk) or coronary revascularization (high risk)
- Risk stratification of ACS
  - Low-risk acute coronary syndrome patients without active ischemia and/or heart failure 6-12 hours after presentation
  - Intermediate-risk acute coronary syndrome patients 1-3 days after presentation without active ischemia and/or heart failure symptoms
- Risk stratification before non-cardiac surgery in patients with known CAD or those with high-risk factors for CAD
- Evaluate response to therapeutic interventions
  - Anti-ischemic drug therapy or coronary revascularization
Who Should NOT have a Stress Test

• Asymptomatic Patient
  – Low and intermediate risk
  – High risk patient is considered appropriate

• Symptomatic Patient
  – Acute Coronary Syndrome/STEMI
  – TIMI Score>3

• Atypical chest pain
  – Females <40 years of age
Risk Stratification

- Risk Stratification
  - Asymptomatic
    - Framingham, Reynolds
  - Symptomatic
    - TIMI, Grace
- Low Risk → False Positives
- High Risk → False Negatives
Risk Stratification: CAD Equivalents

- Diabetes
- Atherosclerotic disease
  - peripheral arterial disease
  - abdominal aortic aneurysm
  - Symptomatic moderate (50-69%) carotid stenosis
- Framingham 10-year risk of CAD of > 20%
Which Type of Stress Test?  
Exercise vs Chemical

**Exercise**
- Anyone that can achieve >5 METs!!
  - Walk up 2 flights of stairs

**Pharmacologic**
- Uninterruptable ECG
  - LBBB
  - Permanent pacemakers
  - Ventricular pre-excitation (Wolff- Parkinson-White syndrome)
- Cannot Exercise
- Atrial Fibrillation
Pharmacologic Stress Agents

• Vasodilator (Regadenoson, Adenosine, Dipyridamole)
  – Dilate coronary arteries
    • Coronary Steal
  – Caution: Bronchospastic lung disease and heart block

• Dobutamine
  – Increase myocardial oxygen demand
    • May induce ischemia
Absolute Contraindications to Stress Testing

1. High-risk unstable angina
2. Decompensated CHF
3. BP > 200/110 mm Hg
4. Hemodynamically unstable cardiac arrhythmias
5. Severe symptomatic aortic stenosis
6. Acute PE
7. Acute myocarditis or pericarditis
8. Acute aortic dissection
9. Severe pulmonary hypertension
10. Acute MI < 4 days
11. Acutely ill
Exercise Tolerance Test

• Pros:
  – Easy to perform and cheap
  – No Chemicals or Radiation
  – Additional Prognostic Value
    • Duke Treadmil Score

• Cons:
  – Low sensitivity and specificity
  – Women have high false positives
Exercise Tolerance Test

• Treadmill
  – Bruce Protocol
• Bicycle
• Arm Crank Ergometry

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Speed (MPH)</th>
<th>Grade (%)</th>
<th>METS</th>
<th>Equivalent Activity Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3:00</td>
<td>1.7</td>
<td>10</td>
<td>4.6</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td>2</td>
<td>6:00</td>
<td>2.5</td>
<td>12</td>
<td>7.0</td>
<td>Escalating one to two flights of stairs</td>
</tr>
<tr>
<td>3</td>
<td>9:00</td>
<td>3.4</td>
<td>14</td>
<td>10.0</td>
<td>Swimming and doubles' tennis</td>
</tr>
<tr>
<td>4</td>
<td>12:00</td>
<td>4.2</td>
<td>16</td>
<td>12.9</td>
<td>Singles' tennis and skiing</td>
</tr>
<tr>
<td>5</td>
<td>15:00</td>
<td>5.0</td>
<td>18</td>
<td>15.0</td>
<td>Competitive athletes</td>
</tr>
<tr>
<td>6</td>
<td>18:00</td>
<td>5.5</td>
<td>20</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from American Heart Association Exercise Standards and the Duke Activity Status Index.
What is in the Report: ETT

• ECG response to stress
• Chest Pain
• Duke Treadmill Score
  • 4 year predicted event rate
    – Low risk <1%
    – High Risk >5%
• Functional Capacity
  • Less than 5 METS high MACE rate
  • Greater 10 METs good prognosis
  • Greater 13 METS good prognosis even with an abnormal exercise ECG response
Calcium Score

**Advantages**

- Rapid
- No contrast
- 100% specific for coronary atheromatous plaque
- High calcium score
  - *90% likelihood of >50% stenosis*

- Zero calcium score
  - *90-100% likelihood of < 50% stenosis*

- Progression of Dz
- Sub-clinical CAD

**Limitations**

- No LV data
- Does not detect “soft” plaque
  - *most infarcts occur in soft plaque < 50% obstructed*
- Significant “false +’s”
- Does not correlate with obstructive disease
- Limited outcome data
- Radiation: 0.8 mSv
  - estimated lifetime-attributable risk for lung cancer 1:26,000
Calcium Score

- **Indications:**
  - Asymptomatic Patient
  - No known CAD
  - Low risk with strong family history
  - Intermediate risk
  - Not indicated for high risk patient

- **Agatston score**
  - Measure of size/density of the calcified plaques

- **Total Score**
  - Minimal: < 10
  - Moderate: 11-99
  - Increased: 100-400
  - Extensive: >400
What is the Report: Calcium Score

<table>
<thead>
<tr>
<th>Calcium Score</th>
<th>Plaque Burden</th>
<th>Probability of Significant Coronary Artery Disease</th>
<th>Implications for CV risk</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No identifiable plaque</td>
<td>Very low, generally, 5%</td>
<td>Very Low</td>
<td>Reassure patient, discuss general public health guidelines for primary prevention of CV disease.</td>
</tr>
<tr>
<td>1 - 10</td>
<td>Minimal identifiable plaque burden</td>
<td>Very unlikely, under 10%</td>
<td>Low</td>
<td>Discuss general public health guidelines for primary prevention of CV diseases</td>
</tr>
<tr>
<td>11 - 100</td>
<td>Definite, at least mild atherosclerotic plaque burden</td>
<td>Mild or minimal coronary stenoses likely</td>
<td>Moderate</td>
<td>Counsel about risk factor modification, strict adherence with primary prevention goals. Daily ASA.</td>
</tr>
<tr>
<td>101 - 400</td>
<td>Definite, at least moderate atherosclerotic plaque burden</td>
<td>Non-obstructive CAD highly likely, although obstructive disease possible</td>
<td>Moderately High</td>
<td>Institute risk factor modification and secondary prevention goals. Consider exercise testing for further risk stratification. Daily ASA.</td>
</tr>
<tr>
<td>400+</td>
<td>Extensive atherosclerotic plaque burden</td>
<td>High likelihood (90+%) of at least one significant coronary stenosis</td>
<td>High</td>
<td>Institute very aggressive risk factor modification. Consider exercise for pharmacologic nuclear stress testing to evaluate for inducible ischemia. Daily ASA.</td>
</tr>
</tbody>
</table>
Stress Echo

Advantages

• No Radiation
• No Contrast
  – Echo contrast is lipid microbubble
• Assess LV Function and Valves
• Exercise or Dobutamine
• Study Duration 1 hour

Disadvantages

• Does not detect presence of CAD
• False negative results:
  – sub-maximal exercise
  – single vessel disease
  – moderate (50 - 70%) stenosis
• Sensitivity of 79 – 85%
• Specificity of 72 – 87%
Stress Echo
What is in the Report? Stress Echo

• Detection of wall motion abnormality
• Baseline Ventricular and Valve Function
• Diastolic function
• Pulmonary Hypertension
Exercise Stress Echo

Safety

• **Life threatening complications**
  - 3.5/10,000 MI
  - 4.8/10,000 serious arrhythmias
  - 0.5/10,000 deaths

• **High risk patients with h/o VT**
  - 2.3% required cardioversion, defibrillation, or intravenous drug administration
  - 0.05% in controls with heart disease but no previous sustained arrhythmia
  - Prior to MADIT II
Exercise Stress Echo

- Sensitivity of 79 – 85%
- Specificity of 72 – 87%
- False negative results are more likely with:
  - sub-maximal exercise
  - single vessel disease
  - moderate (50 - 70%) stenosis
- Sensitivity lower in women due to a lower prevalence of disease

Marwick J, JACC 1992 Jan 19(1).
Dobutamine Stress Echo

DSE vs. Exercise echo

N=334

Multi-vessel

Single vessel
Coronary CT Angiogram
Stenosis – Left Anterior Descending Artery

Muenster University Hospital, Germany
64-Slice CT Coronary Angiography
Left Main Coronary Stenosis
## Diagnostic Performance by 64-Slice Computed Tomography to Defect Significant Coronary Stenosis (>50%) Pooled Data

<table>
<thead>
<tr>
<th>Test Type</th>
<th>No. of Patients</th>
<th>Sensitivity (Range)</th>
<th>Specificity (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmental Analysis</td>
<td>518</td>
<td>90% (76-99%)</td>
<td>96% (95-97%)</td>
</tr>
<tr>
<td>Patient Analysis</td>
<td>374</td>
<td>96% (88-100%)</td>
<td>92% (85-100%)</td>
</tr>
</tbody>
</table>

Leschka, Eur Heart J 2005.  
Ropers, AJC 2006.  
Schuijf, Am J Cardiol 2006.  
Ong, Am Heart J 2006.
Nuclear Stress
Nuclear Report
Cardiac PET
Diagnostic Accuracy – To Coronary Artery

• 50% Lesion

• 70% Lesion
Cardiac MRI
Cardiac MR

Advantages

- Function (± stress)
- Perfusion
- Delayed enhancement
- VIABILITY
- Coronary wall
- No radiation
- No renal toxicity

Limitations

- Off-line interpretation
- Gating / motion artifact
- Pacemakers / ICD
- High tech / MD skills
- Availability
Adenosine Perfusion First-Pass

SYNDROME X SUBJECT

(Pennell) et al. NEJM 2002; 346:1948-53

<table>
<thead>
<tr>
<th>Comparator</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>82 ± 9</td>
<td>82 ± 10</td>
</tr>
<tr>
<td>Angio</td>
<td>82 ± 9</td>
<td>82 ± 8</td>
</tr>
<tr>
<td>SPECT</td>
<td>84 ± 9</td>
<td>94 ± 5</td>
</tr>
<tr>
<td>PET</td>
<td>82 ± 3</td>
<td>87 ± 1</td>
</tr>
</tbody>
</table>

Wilke et al. JMRI 1999; 10:676
Coronary Angiogram
Anatomic Vs Functional
Multi-Modality
Atherosclerosis vs Coronary Thrombus

• Atherosclerosis (CAD)
  – Progressive
Atherosclerosis vs Coronary Thrombus

• Acute Myocardial Infarction
  – Plaque Rupture
  – Soft and mixed plaque
$$ Costs $$
Accuracy

- Compared to Coronary Angiography:
- Treadmill test: sensitivity 50-68%, specificity 70-90%
- Stress Echo: sensitivity of 85% and a specificity of 77%
- Nuclear test: sensitivity 81-87%, specificity 73-85% for significant (>50%) stenosis
- CCTA: Sens was 0.85, with a specificity of 0.90, for >50% stenosis
- PET Sens 84-88 Spec 84-94
- mean sensitivity with PET (92.6% [95% Confidence Interval, 88.3% to 95.5%]) compared with SPECT (88.3% [95% confidence interval, 86.4% to 90.0%]) (P=0.035). No significant difference in specificity was observed between PET (81.3% [95% confidence interval, 66.6% to 90.4%]) and SPECT (75.8% [95% confidence interval, 72.1% to 79.1%]) (P=0.39).
- Cardiac MRI from 83% to 86% both
Radiation Exposure
Stress Test at Predicting MI
Cardiac Testing in Women

- Cardiovascular disease is the leading cause of death for women in the United States, but a considerable body of research has demonstrated that women have different patterns of coronary artery disease and different responses to cardiac testing than their male counterparts. Women are more likely to have nonobstructive or single-vessel disease when compared with men, which decreases the diagnostic accuracy of stress testing. For example, treadmill testing in one meta-analysis was shown to have a sensitivity and specificity of 61% and 70%, respectively, for women compared with 72% and 77%, respectively, for men.[25]

- Calcium scoring is limited because women tend to have 3- to 5-fold greater mortality rates for a given calcium score than men, suggesting that separate guidelines for interpreting scores in women should be developed.

- SPECT imaging is technically limited in women because breast tissue and relatively small left ventricle size can generate false-positive results. Technetium is less prone to attenuation artifacts than thallium and thus has higher specificity. The American Heart Association has recommended that the exercise tolerance test is still the initial test of choice for a low-risk or intermediate-risk symptomatic woman with no contraindications.
Left Bundle Branch Block
The Obese Patient

• Difficult to Image
  – Soft Tissue Attenuation
• Decreased Accuracy

• Cardiac PET or 2 Day Nuclear study BMI >35
Bronchospastic Lung Disease

• Not good candidates for Exercise
“Screening” Test

- Indicated for High risk population only
- Only “screens” for High Grade Stenosis
- Take advantage of Calcium Score
- Optimize Medical Therapy!!!
Poor Candidates for Anti-platelet Therapy

• Assess Surgical Candidacy for CABG
• Can they take Aggressive Anti-platelet Therapy
  – BMS: 1 uninterrupted month of Plavix
  – DES: 12 uninterrupted months of Plavix
• May consider for risk stratification: elective surgery, medical therapy
Case

• A 46 year old male presents of an initial evaluation. He recently started exercising and notices he is very short of breath after 10 minutes of activity. He has not seen a physician in over 10 years. His vital signs are: blood pressure is 144/92 mmHg, pulse rate is 80 bpm, and BMI is 36.4. Examination is notable for moderate central obesity and a grade 2 systolic murmur along the left sternal border. Review of his lipid panels: Total cholesterol 220, HDL 36, LDL 140.

What is the appropriate management in this patient?

A. Trial of Diet and Exercise with 3 month follow-up
B. Start on antihypertensive therapy
C. Start on a statin
D. Perform a Stress test
Thank You!