Cardiac Stress Testing
Some Useful Considerations

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FINANCIAL OR OTHER RELATIONSHIP DISCLOSURE:

None
What Will Be Covered

• Chest pain evaluation and risk stratification
• Stress testing modalities, pros and cons
• Special topics: costs, women, radiation
• Cases with ARS
• Q&A

Why Stress Test?

• Stress testing to detect inducible ischemia has been “gold standard” noninvasive test used to diagnose CAD
• Designed to “provoke” cardiac ischemia by using exercise or pharmacological stress agents

- Increase myocardial work and oxygen demand
- Induce vasodilation-elicited heterogeneity in coronary flow
KEY POINT:

Stress testing is a great means of diagnosing fixed obstruction

Confusing Terminology!

1. Substernal CP
2. Brought on by exertion and/or emotional stress
3. Relieved with rest and/or NTG

- Typical angina: 3 features
- Atypical angina: 2 features
- Non-anginal/noncardiac CP: ≤1 feature
### History → Pretest Probability

<table>
<thead>
<tr>
<th>Age</th>
<th>Nonanginal Chest Pain</th>
<th>Atypical Angina</th>
<th>Typical Angina</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>30–39</td>
<td>4</td>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>40–49</td>
<td>13</td>
<td>3</td>
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<tr>
<td>50–59</td>
<td>20</td>
<td>7</td>
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<tr>
<td>60–69</td>
<td>27</td>
<td>14</td>
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</table>


### Posttest Probability -- Most Useful for Intermediate Risk Patients
Stress Testing Modalities

• Treadmill exercise ECG testing

• Echocardiography
  – Exercise
  – Pharmacologic (dobutamine, adenosine)

• Radionuclide myocardial perfusion imaging (MPS)
  – Exercise
  – Pharmacologic stressors (adenosine/regadenoson, dipyridamole, dobutamine)
  – Tracers (thallium, technetium, rubidium)

Sensitivity and Specificity

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
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</thead>
<tbody>
<tr>
<td>Exercise treadmill</td>
<td>68%</td>
<td>77%</td>
</tr>
<tr>
<td>Stress echocardiography</td>
<td>76%</td>
<td>88%</td>
</tr>
<tr>
<td>Myocardial perfusion imaging</td>
<td>88%</td>
<td>77%</td>
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</table>
Which is a baseline ECG finding that could lead to uninterpretable stress ECG?

A. >1 mm ST depression
B. Left bundle branch block
C. LVH
D. Wolff-Parkinson-White pattern
E. All of the above

Able to Exercise

<table>
<thead>
<tr>
<th>Test</th>
<th>Exercise Status</th>
<th>ECG Interpretable</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Able</td>
<td>Unable</td>
</tr>
<tr>
<td>Patients able to exercise*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise ECG</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Exercise with nuclear MPI or Echo</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test</th>
<th>Exercise Status</th>
<th>ECG Interpretable</th>
<th>COR</th>
<th>LOE</th>
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</thead>
<tbody>
<tr>
<td>Pharmacological stress with</td>
<td>X</td>
<td>Any</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>nuclear MPI or Echo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharmacological stress CMR</td>
<td>X</td>
<td>Any</td>
<td>Ila</td>
<td>B</td>
</tr>
<tr>
<td>CCTA</td>
<td>X</td>
<td>Any</td>
<td>Ila</td>
<td>C</td>
</tr>
</tbody>
</table>


**Which is the following is FALSE?**

A. ST depressions on exercise ECG can identify specific location of cardiac ischemia

B. 1-2 mm ST upsloping depressions in the inferolateral leads may be a normal variant

C. RBBB on baseline ECG can be interpretable on stress ECG

D. Imaging studies are often performed in conjunction with exercise ECG
Exercise Treadmill Testing

- If baseline ECG shows secondary ST-T wave changes, or ischemia, ETT cannot be performed
  - ≥ 1 mm ST depression
  - LBBB
  - Paced rhythm
  - Preexcitation (WPW pattern)
  - LVH
  - Digoxin use

- Poor diagnostic test, good prognostic test
- Location of ST depressions are not indicative of ischemic territory

Treadmill Exercise ECG Testing

**Advantages**
- Low cost
- Standard treadmill assessment of ischemia, functional capacity, and prognosis
- Widely available
- Accuracy tested in different populations

**Disadvantages**
- Lower sensitivity
- Specificity poor with marked ST-T abnormalities on resting ECG, digoxin use, LBBB or pacemakers, and women
- Does not localize site or extent of myocardial ischemia
Exercise Treadmill Testing

Duke treadmill score:

Minutes on Standard Bruce Protocol
- 5 x (mm ST depression)
- 4 x (angina)

angina: 0=none, 1=typical, 2=limiting

- Score of +5 or more: 97% 5-year survival
- Score of -11 or less: 72% 5-year survival

Exercise ECGs: Beyond the STs

- Exercise duration
- Onset/resolution/magnitude of symptoms/ST changes
- Impaired HR response ("chronotropic incompetence")
- ↓SBP with high workloads
- High-grade arrhythmias; e.g., prolonged VT; paroxysmal atrial fibrillation/flutter; high grade AV block
- Low exercise capacity, poor HR recovery, and failure to reach target HR are more important predictors of outcome than ST changes
A current of injury in lead aVR highly predictive of LMCA stenosis, especially when the ST elevations in aVR exceed those in V1 (Yamaji et al. J Am Coll Cardiol 2001;38:1348-54).
Stress Echocardiography

**Normal**

- Diastole:
  - Anterior
  - Septum
  - Lateral
  - Inferior

- Systole:

**Anterior/anteroseptal ischemia**

- Diastole:
  - Anterior
  - Septum
  - Lateral
  - Inferior

- Systole:

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Normal Stress Echo

![Normal Stress Echo](image)
### Stress Echocardiography - Exercise

**Advantages**
- Sensitivity and specificity comparable to exercise MPI
- No radiation
- Lower cost than MPI
- Assesses chamber size, wall thickness, valvular function

**Disadvantages**
- Subjective interpretation
- More difficult when resting wall motion abnormalities exist
- Poor image quality in a significant number of patients
- Prognostic value uncertain due to limited number of studies

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### Dobutamine Echocardiography

**Advantages**
- Useful in patients unable to exercise
- No radiation
- Myocardial viability
- Assesses ventricular function, chamber size, wall thickness, and valvular function
- Patients with asthma or COPD

**Disadvantages**
- Cannot assess functional capacity
- ECG abnormalities less likely to occur
- Requires extensive experience by reader
- Labor intensive
- Ventricular arrhythmias
- Subjective interpretation
### Exercise Myocardial Perfusion

**Advantages**
- Well-validated to detect severe coronary disease and to assess prognosis
- Results are reproducible
- Can assess left ventricular size
- More accurate determination of extent of coronary disease and prognosis
- Myocardial viability

**Disadvantages**
- Radiation exposure
- Cost
- Requires longer time commitment
- Specificity depends upon quality control of laboratory and specialty trained readers
- Artifacts
- Additional equipment and personnel needed

### Pharmacologic MPS

**Advantages**
- Accurately assesses coronary artery disease in patients unable to exercise
- Preoperative risk assessment of patients with claudication, musculoskeletal issues
- Relatively safe in selected patients, side effects are rapidly reversed

**Disadvantages**
- Cannot assess functional capacity
- ECG abnormalities less likely
- Contraindicated in hypotension, sick sinus syndrome, heart block, bronchospastic airway disease, or oral dipyridamole therapy
Cath: 60% proximal LAD, 90% proximal OM2, occluded RCA with collaterals

CABG: LIMA to LAD, SVG to RCA and OM1
## Estimated Effective Radiation Doses

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Estimated Effective Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest X-ray</td>
<td>0.1</td>
</tr>
<tr>
<td>SPECT</td>
<td></td>
</tr>
<tr>
<td>Technetium-99m tetrofosmin, rest—stress</td>
<td>8.6</td>
</tr>
<tr>
<td>Technetium-99m sestamibi, rest—stress</td>
<td>10.7</td>
</tr>
<tr>
<td>Thallium-201, stress—redistribution</td>
<td>16.9</td>
</tr>
<tr>
<td>Dual isotope thallium-201 technetium-99m sestamibi</td>
<td>23.7</td>
</tr>
<tr>
<td>CT coronary angiography</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>15</td>
</tr>
<tr>
<td>Newest</td>
<td>3</td>
</tr>
<tr>
<td>Diagnostic catheterization</td>
<td>7</td>
</tr>
</tbody>
</table>

## Cost of Stress Testing: UWMC

### Exercise Treadmill Test:
- Professional Fee: $111.30
- UWMC Facility Charge: $642.00
- Total Charges: $753.30

### Treadmill Echocardiogram:
- Professional Fee: $259.70
- UWMC Facility Charge: $1320.00
- Total Charges: $1579.70

### Regadenoson Myocardial Perfusion Study:
- Professional Fee: $289.40
- UWMC Facility Charge: $5614.17
- Total Charges: $5903.57
### Survival with Revascularization: Basics

- PCI has proven benefit in survival with ACS, post-cardiac arrest with ischemia-induced VT/VF
- Other than left main disease in a pt without prior CABG, there is no specific lesion for which PCI has any significant benefit in mortality (often Class IIb or Class III indication)
- CABG offers a survival benefit in most cases of severe CAD (1-3 vessel disease with/without proximal LAD involvement, often Class I, Class IIa)
- Single vessel disease without proximal LAD disease→no survival benefit with CABG or PCI
- SYMPTOMS despite medical therapy, esp in prior CABG pt, is a good indication for PCI

### Chest Pain in Women

- Unique presentation compared to men
  - Later presentation (10 years older)
  - More likely to present with chest pain than myocardial infarction
  - Less typical angina
  - Intense pain
  - Different descriptors (burning or sharp)
  - Symptoms unrelated to pain
  - Frequent pain in neck and throat
### Women

- Diagnostic accuracy is less: greater release of catecholamines during exercise → coronary vasoconstriction → higher incidence of abnormalities

- False positive results more common during menses or pre-ovulation, and post-menopausal on estrogen

- Initial evaluation of women with suspected CAD, normal ECG, and ability to exercise should be ETT

- In symptomatic women with intermediate likelihood of CAD, imaging procedures should be considered as initial test when resting ECG is abnormal, or exercise capacity is questionable

### Diabetic Patients

- May not have classic symptoms

- May have silent ischemia or infarction
  - DIAD Trial
    - 22% with silent ischemia in asymptomatic patients
    - 5% with large defects
  - Retrospective studies suggest higher rates of silent ischemia (up to 60%) with high risk findings in 20%
Case #1

• 67 year old man s/p inferior STEMI and 4 vessel CABG in 2008 presents with exertional chest pressure x 2 weeks that occurs while walking his dog
• ECG demonstrates sinus rhythm with inferior Q waves
• Prior resting echo confirms prior MI, thinning and akinesis of the inferoposterior wall

What test would you order?

A. None--reassurance and look for other causes of chest pain
B. Exercise treadmill test (ETT)
C. Treadmill echocardiography (TME)
D. Dobutamine stress echocardiography (DSE)
E. Exercise myocardial perfusion study (MPS)
F. Nuclear myocardial perfusion study (MPS)
Assessment of Case #1

• Typical angina
• High pretest probability
• Recommend stress testing for risk stratification and to localize area of ischemia
• Exercise preferred to pharmacologic testing
• Myocardial perfusion imaging may be more interpretable than echocardiography (baseline wall motion abnormalities)

Case #2

• 52 year old woman with history of hypertension, tobacco use disorder, and severe COPD who presents with sharp chest pain with exertion associated with palpitations, relieved by rest
• On exam, patient has diffuse expiratory wheezing
Baseline ECG

What test would you order?

A. None—reassurance and look for other causes of chest pain
B. Exercise treadmill test (ETT)
C. Treadmill echocardiography (TME)
D. Dobutamine stress echocardiography (DSE)
E. Exercise myocardial perfusion study (MPS)
F. Nuclear myocardial perfusion study (MPS)
Assessment of Case #2

- Atypical chest pain
- Intermediate pre-test probability (at least 31%, not including risk factors)
- Recommend stress testing for further risk stratification
- Stress testing with imaging due to baseline ECG abnormalities (WPW pattern, pre-excitation)
- Dobutamine echocardiography (active wheezing on exam); adenosine is contraindicated

Case #3

- 30 year old woman with no risk factors who presents with recurrent sharp chest pain, not associated with exertion, lasting a few seconds
- Normal exam, ECG
What test would you order?

A. None--reassurance and look for other causes of chest pain
B. Exercise treadmill test (ETT)
C. Treadmill echocardiography (TME)
D. Dobutamine stress echocardiography (DSE)
E. Exercise myocardial perfusion study (MPS)
F. Nuclear myocardial perfusion study (MPS)

Analysis of Case #3

• Non-cardiac chest pain
• Very low retest probability (2%)
• Reassurance
• Identify non-cardiac cause
Case #4

• 64 year old man with history of chronic atrial fibrillation, hypertension, and dyslipidemia who presents with recent substernal chest pressure lasting 5 minutes, occurs at rest, sometimes associated with exertion

Baseline ECG
What test would you order?

A. None - reassurance and look for other causes of chest pain
B. Exercise treadmill test (ETT)
C. Treadmill echocardiography (TME)
D. Dobutamine stress echocardiography (DSE)
E. Exercise myocardial perfusion study (MPS)
F. Nuclear myocardial perfusion study (MPS)

Assessment of Case #4

• Atypical chest pain
• Intermediate pre-test probability (at least 72%, not including risk factors)
• Recommend stress testing for further risk stratification
• Stress testing with imaging due to >1 mm ST segment depressions at baseline
• Stress echocardiography (no radiation)
Case #5

- 45 year old man with history of hypertension presents with sharp chest pain
- Symptoms do not occur specifically with exertion
- ECG and exam normal

What test would you order?

A. None—reassurance and look for other causes of chest pain
B. Exercise treadmill test (ETT)
C. Treadmill echocardiography (TME)
D. Dobutamine stress echocardiography (DSE)
E. Exercise myocardial perfusion study (MPS)
F. Nuclear myocardial perfusion study (MPS)
Analysis of Case #5

- Non-cardiac chest pain
- Intermediate pretest probability (at least 13%, not including hypertension)
- Recommend further risk stratification with stress testing
- Normal ECG: exercise treadmill test

Take Home Points

- Pre-test probability should be used to decide whether stress testing is indicated or not
- Exercise treadmill test is the appropriate initial screening test for most patients
- Stress testing modality should be chosen based on co-morbidities, ability to ambulate, purpose of evaluation
- Full review of primary data, discussion with specialists, will yield optimal management