Stress Testing Basics

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Some Basic Questions

- What is the difference between types of tests?
- When should exercise stress testing be done?
- How do we apply the results of stress testing to the workup of chest pain?
- How important is functional capacity?
- What is the prognostic value of stress testing and its role in guiding medical treatment?
Stress Testing in a Nutshell

- Some form of applied stress coupled with some form of ischemia detection
- Forms of stress include exercise and pharmacologic agents
  - Adenosine
  - Dobutamine
- Common forms of ischemia detection include EKG, echo, and radionuclide imaging

“Ischemic Cascade”

Advantages of Treadmill Exercise Test

- Gives measurable assessment of functional capacity in METs (metabolic equivalents)
  - 1 MET = standard amount of O₂ consumed at rest (the same for everyone) = 3.5 mL/kg/min
- More ‘physiologic’ than pharmacologic test
- Cheap and easy to administer
- Unlike pharmacologic testing, provides meaningful **prognostic** data
**How Accurate is TMST?**

Table 7: Meta-analysis of Exercise Testing (116)

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Number of Studies</th>
<th>Total Number of Patients</th>
<th>Sens (%)</th>
<th>Spec (%)</th>
<th>Predictive Accuracy (%)</th>
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<tbody>
<tr>
<td>Meta-analysis of standard exercise test</td>
<td>147</td>
<td>26,647</td>
<td>68</td>
<td>77</td>
<td>73</td>
</tr>
<tr>
<td>Meta-analysis without ST depression</td>
<td>58</td>
<td>11,048</td>
<td>67</td>
<td>72</td>
<td>69</td>
</tr>
<tr>
<td>Meta-analysis without ST depression or LVH</td>
<td>3</td>
<td>&gt;1000</td>
<td>70</td>
<td>70</td>
<td>69</td>
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<tr>
<td>Meta-analysis with ST depression</td>
<td>22</td>
<td>9,153</td>
<td>69</td>
<td>70</td>
<td>69</td>
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<tr>
<td>Meta-analysis with LVH</td>
<td>5</td>
<td>805</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Meta-analysis without LVH</td>
<td>10</td>
<td>2,970</td>
<td>72</td>
<td>72</td>
<td>74</td>
</tr>
</tbody>
</table>

**Note:**
- Sensitivity for multivessel CAD is ~80%
- Specificity improves with no baseline ST depression

**Confounding Factors in Stress EKG Interpretation:**
- Drugs: digitalis, diuretics, tri-cyclics
- LVH, especially with repol abnormality
- LBBB or presence of an IVCD, WPW
  - Adenosine testing preferred in LBBB
- Pre-test ST-T abnormality
- Female gender
- Hyperventilation

**Pharmacologic Stress:**
- Indicated when pt is unable to exercise
- More expensive and time-consuming
  - Dobutamine testing takes much longer than Adenosine testing
- Contraindications need to be considered
  - Adenosine contraindicated in pts with active wheezing or significant AV block
  - Dobutamine contraindicated when prone to tachyarrhythmia, large aortic aneurysm
Pharmacologic Stress Agents

- **Adenosine (vasodilator)**
  - Acts by increasing coronary flow 3 to 5 fold
  - Side effects include chest pain, flushing, dyspnea, bronchospasm, headache, heart block
  - Caffeine blocks adenosine binding, therefore patient may not have coffee for 24 hours prior to test
  - Requires 4 - 6 minutes infusion

- **Dobutamine (Inotrope)**
  - Stimulates β1-adrenergic receptors, causing increased contractility and HR, with little effect on β2- or α-receptors
  - Side effects: arrhythmias, hypotension, palpitations, nausea, anxiety, headache, tremor, and urinary urgency
  - Stepwise infusion to target heart rate 85% maximum predicted for age (220 – age)
  - Often requires addition of atropine to reach target HR

Types of Ischemia Detection

- **EKG**
  - Inexpensive, rapidly available, less labor-intensive
  - Sensitivity ~60%, Specificity ~80%
  - May be insufficiently sensitive for diabetic and female (esp. younger) patients
  - Limited specificity with abnormal baseline EKG

- **Adjunct imaging (echo, radionuclide)**
  - Can be performed in pts who can’t exercise or who have abnormal baseline EKG
  - Localizes ischemia, unlike EKG testing
  - Sensitivity and specificity is 80-85% in literature
  - Nuclear imaging probably more sensitive, echo more specific
Algorithm for Stress Testing

Indication

Diagnostic and Prognostic Purposes?

Able to Exercise?

Yes

Normal Rest ECG? No Digoxin?

Yes

Standard TMST

No

Pharmacologic Stress Imaging

Localization of Ischemia?

Able to Exercise?

Yes

Exercise Imaging Study Stress Echo or Nuclear Perfusion

No

Bottom Line

- If they can walk, treadmill them!
- Use adjunct imaging if sensitivity or specificity of treadmill EKG is expected to be reduced
- Tailor pharmacologic stress to avoid undesirable side-effects

When to Consider Exercise Testing

- Evaluation of exertional symptoms
- Determination of exercise capacity
- Guidance of exercise prescription
- Assessment of response to medical management in patients with known CAD
- Risk stratification in patients with known ischemic heart disease to determine need for angiography
  - Post-MI
  - Stable angina
- Evaluation of significance of valvular lesions
- Evaluation of chest pain

Adapted from Oh, et al.
Evaluation of Chest Pain

- Primary role of stress testing:
  - To help determine the likelihood that obstructive CAD is causing a patient's chest pain or dyspnea

- Secondary role of stress testing:
  - Risk-stratification…how likely is my patient to die of a cardiac event?

Bayesian Theory

PRE-TEST LIKELIHOOD

POST-TEST LIKELIHOOD

Say... what's a mountain goat doing way up here in a cloud bank?
Pre-test likelihood determined by history

- Quality, Location, and Relationship to Exertion

<table>
<thead>
<tr>
<th>Age</th>
<th>Non-Anginal Pain</th>
<th>Atypical Angina</th>
<th>Typical Angina</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 - 45</td>
<td>0.105</td>
<td>0.428</td>
<td>0.809</td>
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<tr>
<td>45 - 55</td>
<td>0.206</td>
<td>0.601</td>
<td>0.907</td>
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<tr>
<td>55 - 65</td>
<td>0.282</td>
<td>0.690</td>
<td>0.939</td>
</tr>
<tr>
<td>65 - 75</td>
<td>0.282</td>
<td>0.700</td>
<td>0.943</td>
</tr>
</tbody>
</table>

Maximizing Stress Test Utility

- Post-test probability of obstructive CAD causing patient's symptoms is determined by pre-test probability, sens/spec of test, and result of test
- Stress testing is most helpful in evaluating chest pain history that suggests intermediate likelihood
- Classic angina may not require stress testing for diagnostic purposes
- Prognostic data may be more important than test result ("positive" or "negative") in patients with clear angina or truly atypical chest pain

How are treadmill tests used to "risk stratify" patients?
**Duke Treadmill Score**

Ex Time (min on Bruce) - (5 x mm of ST dev) - (4 x treadmill angina index)

Survival

- 2 = 5
- -10 to +4
- -11

0 Years 10

**Is Functional Capacity Important?**

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Poor</th>
<th>Fair</th>
<th>Average</th>
<th>Good</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 20</td>
<td>&lt; 7</td>
<td>7-10</td>
<td>10-13</td>
<td>13-16</td>
<td>&gt; 16</td>
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<td>30-39</td>
<td>&lt; 7</td>
<td>7-9</td>
<td>9-11</td>
<td>11-15</td>
<td>&gt; 15</td>
</tr>
<tr>
<td>40-49</td>
<td>&lt; 6</td>
<td>6-8</td>
<td>8-10</td>
<td>10-14</td>
<td>&gt; 14</td>
</tr>
<tr>
<td>50-59</td>
<td>&lt; 5</td>
<td>5-7</td>
<td>7-9</td>
<td>9-13</td>
<td>&gt; 13</td>
</tr>
<tr>
<td>≥ 60</td>
<td>&lt; 4.5</td>
<td>4.5-6</td>
<td>6-8</td>
<td>8-11.5</td>
<td>&gt; 11.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 20</td>
<td>&lt; 8</td>
<td>8-11</td>
<td>11-14</td>
<td>14-17</td>
<td>&gt; 17</td>
</tr>
<tr>
<td>30-39</td>
<td>&lt; 7</td>
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<td>&gt; 13</td>
</tr>
</tbody>
</table>

MET = metabolic equivalents (1 MET = 3.5 ml/kg per min of oxygen consumption)

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**Mortality & Functional Capacity**

- 10% at 2 yrs
- 5% at 2 yrs

Snader, Marwick, Pashkow, Harvey, Thomas, Lauer. JACC 1997;30:641-8
Guiding Medical Management

- Usual primary prevention matters
- Intermediate or high-risk treadmill studies suggest need for more aggressive risk reduction
- Consider adjunct imaging studies to further risk stratify symptomatic patients
  - Meta-analysis of studies that evaluated event-free survival following exercise stress imaging in patients with known or suspected CHD showed NPV for MI and cardiac death was 99 and 98 percent over ~3 yrs in both men and women
- Repeat testing to gauge ‘angina threshold’

What about an Abnormal Stress Test in an Asymptomatic Patient?

- Prevalence of severe CAD is low, so pre-test probability is low… high false (+) rate
- Predicts increased risk for cardiac event, particularly patients with:
  - More than 1 CAD risk factor (higher probability)
  - Poor exercise capacity, decreased HRR
  - Early onset ST dep or downsloping in recovery
- In most cases suggests risk modification, not angiography, is indicated

From the Guidelines

*Exercise Testing in Asymptomatic Persons Without Known CAD*

**Class I** (Recommended)

None.

**Class III** (Not Recommended)

Routine screening of asymptomatic men or women.
Post-MI Risk Stratification

- Less useful in Primary PTCA era
- Submax (70% MPHR) or Symptom-limited
  - Ischemic ST depression: 27% 1-yr mortality
  - No ischemic ST ability: 2% 1-yr mortality
- Ex capacity < 4 METS carries poor prognosis
- Even patients treated with lytics are now routinely sent for f/u cath prior to discharge


When is treadmill testing a bad idea?

Other than when not indicated…

Table 1. Contraindications to Exercise Testing

<table>
<thead>
<tr>
<th>Absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute myocardial infarction (within 2 d)</td>
</tr>
<tr>
<td>High-risk unstable angina*</td>
</tr>
<tr>
<td>Uncontrolled cardiac arrhythmias causing symptoms or hemodynamic compromise</td>
</tr>
<tr>
<td>Symptomatic severe aortic stenosis</td>
</tr>
<tr>
<td>Uncontrolled symptomatic heart failure</td>
</tr>
<tr>
<td>Acute pulmonary embolus or pulmonary infection</td>
</tr>
<tr>
<td>Acute myocarditis or pericarditis</td>
</tr>
<tr>
<td>Acute aortic dissection</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left main coronary stenosis</td>
</tr>
<tr>
<td>Moderate or severe valvular heart disease</td>
</tr>
<tr>
<td>Electrolyte abnormalities</td>
</tr>
<tr>
<td>Severe arterial hypertension</td>
</tr>
<tr>
<td>Tachy or bradyarrhythmias</td>
</tr>
<tr>
<td>Hypertrophic cardiomyopathy and other forms of outflow tract obstruction</td>
</tr>
<tr>
<td>Mental or physical impairment leading to inability to exercise adequately</td>
</tr>
<tr>
<td>High-degree atrioventricular block</td>
</tr>
</tbody>
</table>
Complications of Stress Testing

- Death: < 1 in 20,000
- MI: < 1 in 2,500
- Serious non-fatal arrhythmia: <1 in 1000 (higher in those with history of VT/VF)

Myths about Stress Testing

- CP + Abnormal Stress Test = Cath
  - Remember: Angioplasty and stenting for stable angina offers no mortality or MI-preventive benefit over medical therapy
  - Angioplasty does offer better relief of angina
- All pts need to be off Bblocker prior to TMST
  - Pts with known CAD should be tested on BB
- Abnl stress + no severe CAD = false (+)
  - Angiography shows epicardial anatomy

Summary

- Exercise testing provides inexpensive, valuable prognostic info…if they can walk, make ’em walk
- Adjunct imaging improves sensitivity, is able to localize ischemia, and may be utilized to further risk-stratify the intermediate risk TMST
- Stress testing is most useful in evaluating CP of intermediate likelihood for CAD
- Low-risk abnormal stress tests can often be managed medically