Exercise Stress Testing

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Baptist Heart Specialists
The Stress Test has two roles in clinical care:

1. Diagnostic evaluation.

2. Assessment of long-term risk of patients at intermediate or high likelihood of having significant coronary disease.
# Exercise Stress Testing

<table>
<thead>
<tr>
<th>Method</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meta-Analysis</td>
<td>68%</td>
<td>77%</td>
</tr>
<tr>
<td>(24,000 pts.)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress-Echo</td>
<td>85%</td>
<td>85%</td>
</tr>
</tbody>
</table>

Ischemia Cascade

Clinical
- Electrocardiogram Abnormalities
- Angina / Chest Pain
- Myocardial Necrosis

Function
- Left Ventricular Regional Wall Motion Abnormalities
- Contractility Abnormalities (dP/dt)
- Relaxation Disturbances (Tau↑)

Spectroscopy
- Metabolic Abnormalities (ATP/PCr)

Start Perfusion Deficit

Reversible

Irreversible

20 – 30 Mins
<table>
<thead>
<tr>
<th>Stage</th>
<th>Duration</th>
<th>Degrees</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
<td>(3 min.)</td>
<td>10</td>
<td>1.7 mph</td>
</tr>
<tr>
<td>Stage II</td>
<td>(3 min.)</td>
<td>12</td>
<td>2.5 mph</td>
</tr>
<tr>
<td>Stage III</td>
<td>(3 min.)</td>
<td>14</td>
<td>3.4 mph</td>
</tr>
<tr>
<td>Stage IV</td>
<td>(3 min.)</td>
<td>16</td>
<td>4.2 mph</td>
</tr>
<tr>
<td>Stage V</td>
<td>(3 min.)</td>
<td>18</td>
<td>5.0 mph</td>
</tr>
</tbody>
</table>
Contraindications to Exercise Testing

**Absolute:**
- Acute myocardial infarction (2 days).
- High-risk unstable angina.
- Arrhythmias causing symptoms.
- Symptomatic severe aortic stenosis.
- Symptomatic heart failure.
- Acute pulmonary embolus.
- Acute myocarditis/pericarditis.
- Acute aortic dissection.
Relative Contraindications:

- Left Main Stenosis
- Moderate Valvular Stenosis
- Electrolyte Abnormalities
- Severe Hypertension (>200/110)
- Tachy/bradyarrhythmias
- HCM/LVOT Obstruction
- Mental/physical Impairment
- High-degree A-V Block
Indications for Terminating Exercise Testing

**Absolute:**

- Drop in systolic BP >10 mmhg from baseline, with evidence of ischemia.
- Moderate to severe angina.
- Increasing CNS symptoms (ataxia, etc.).
- Signs of poor perfusion (cyanosis, etc.).
- Technical difficulties in monitoring ECG, or BP.
- Patients’ desire to stop.
- Sustained ventricular tachycardia.
- ST elevation (>1mm) in leads without Q waves.
Relative:

- Drop in systolic BP (>10mmHg from baseline), without ischemia.
- Excessive ST depression (>2mm).
- Arrhythmias other than sustained V-tach.
- Fatigue, Dyspnea, Wheezing, Leg Pain.
- Development of BBB or IVCD that cannot be distinguished from V-Tach.
- Increasing chest pain.
- Hypertensive response (>250/115 mmHg)
Interpretation of Test

- 1mm (or greater) horizontal/downsloping ST-segment depression or elevation, 60 to 80 ms after the QRS complex.

- With ST elevation *can* localize site of ischemia.

- With ST depression *cannot* localize ischemia.
ECG changes during stress test
Confounders of Stress ECG Interpretation

- **LVH**: decrease specificity, sensitivity same.

- **Resting ST depression**: 2 mm of further ST depression, or 1 mm in recovery.

- **LBBB**: no association with ischemia. *(cannot interpret test)*

- **RBBB**: no association with ischemia. *(can interpret test)*
Blood Pressure Response

Increase in systolic BP, diastolic stays same.

Systolic BP inc. 10 mmhg/Stage.

Hypertensive Response.
Angina during Stress Test

Mortality

(+) Stress Test with angina  5%/yr.

(+) Stress Test, no angina  2.5%/yr.

Circ 1984;70:547-551.
Typical or definite angina defined as:

1) Substernal chest pain/discomfort that is

2) Provoked by exertion/emotional stress &

3) Relieved by rest and/or nitroglycerin.
Canadian Cardiovascular Society

Functional Classification

I. Angina with heavy exertion.

II. Slight limitation of ordinary activity. Walk > 2 blocks, climb > 1 flight of stairs.

III. Marked limitation of ordinary activity. Walk 1-2 blocks, 1 flight of stairs.

IV. Inability to carry on any physical activity without discomfort, may be present at rest.

Circ 1975;54:522.
Ventricular Tachycardia during Stress Test

- Rarely signifies ischemia.
- Represents arrhythmia induced by catecholamines.
7 PVCs/min or > 10% in recovery
Addition of Imaging Modality

Patients with:

1) ST depression > 1mm.
2) LBBB
3) IVCD, QRS >120 ms.
4) Paced rhythm.
5) Pre-excitation.
6) Digoxin (2 weeks)
Use of Exercise Testing to Diagnose Obstructive CAD

Class I

- Adult patients with an intermediate pretest probability of CAD.

(including those with RBBB, or less than 1 mm of resting ST depression)
<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Typical/Definite Angina Pectoris</th>
<th>Atypical/Probable Angina Pectoris</th>
<th>Nonanginal Chest Pain</th>
<th>Asymptomatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 – 39</td>
<td>Men</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>Intermediate</td>
<td>Very low</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>40 – 49</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>Intermediate</td>
<td>Low</td>
<td>Intermediate</td>
<td>Very low</td>
</tr>
<tr>
<td>50 – 59</td>
<td>Men</td>
<td>High</td>
<td>Low</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>Intermediate</td>
<td>Low</td>
<td>Intermediate</td>
<td>Very low</td>
</tr>
<tr>
<td>60 – 69</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
</tbody>
</table>

![Graph showing Estimated pre-test probability of CAD, % with certainty and uncertainty axes.](image-url)
Exercise Testing in Asymptomatic Persons without known CAD

Class I

None.
Risk Assessment and Prognosis in pts. with symptoms or a history of CAD

1. Pts. being evaluated with suspected or known CAD.
2. Pts. with CAD, with a change in clinical status.
3. Low-risk UA pts. 8 to 12 hrs after presentation.
4. Intermediate-risk UA pts., 2 to 3 days after presentation.
<table>
<thead>
<tr>
<th>Feature</th>
<th>High Risk</th>
<th>Intermediate Risk</th>
<th>Low Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At least one of the following features must be present</td>
<td>No high-risk feature but must have one of the following features</td>
<td>No high- or intermediate-risk feature but may have any of the following features:</td>
</tr>
<tr>
<td>History</td>
<td>Prolonged, ongoing (&gt;20 min) pain at rest</td>
<td>Prior MI, peripheral or cerebrovascular disease, or CABG, prior aspirin use</td>
<td>New-onset or progressive-CCSC III or IV angina in the past 2 weeks with moderate or high likelihood of CAD.</td>
</tr>
<tr>
<td>Character of Pain</td>
<td></td>
<td>Prolonged (&gt;20 min) resting angina, now resolved, with moderate or high likelihood of CAD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rest angina (&lt;20 min) or relieved with rest or sublingual NTG</td>
<td></td>
</tr>
<tr>
<td>Clinical Findings</td>
<td>Pulmonary edema, most likely related to ischemia</td>
<td>Age older than 70 years</td>
<td></td>
</tr>
<tr>
<td></td>
<td>New or worsening MR murmur</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$S_3$ or new/worsening rales</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hypotension, bradycardia, tachycardia</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Age older than 75 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECG Findings</td>
<td>Angina at rest with transient ST changes $\geq 0.05$ mV</td>
<td>T-wave inversions greater than 0.2 mV</td>
<td>Normal or unchanged ECG during an episode of chest discomfort</td>
</tr>
<tr>
<td></td>
<td>BBB, new or presumed new/sustained ventricular tachycardia</td>
<td>Pathologic Q waves</td>
<td></td>
</tr>
<tr>
<td>Biochemical</td>
<td>Elevated (e.g., troponin T or I greater than 0.1 mg per ml)</td>
<td>Slightly elevated (e.g., troponin T &gt;0.01 but &lt;0.1 mg per ml)</td>
<td>Normal</td>
</tr>
<tr>
<td>Cardiac Markers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Before discharge (submaximal at 4 to 6 days).

2. Early after discharge (symptom limited; 14 to 21 days).

3. Late after discharge (symptom limited; 3 to 6 weeks).
Exercise Testing After PCI

Select high risk patients:

1) Decreased LV function.
2) Multivessel CAD.
3) Proximal LAD.
4) Hx. of Aborted Sudden Death.
5) Diabetes Mellitus.
6) Hazardous Occupations.
7) Suboptimal PCI results.
Exercise Testing After CABG

Test is more useful when the likelihood of coronary disease progression is enhanced:

1) 5 years post-bypass.
2) Typical ischemic symptoms.
3) Diabetes Mellitus.
4) Hemodialysis.
Valvular Heart Disease

Class I

-In chronic AI, assessment of functional capacity, especially if symptoms are equivocal.
Most Important Prognostic Indicators

1) Chronotropic Incompetence
2) Heart Rate Recovery
3) Exercise Capacity
4) Duke Treadmill Score
Heart rate reserve is the difference between a person's maximum predicted HR (220 – age), and the resting HR.

\[
\%HRR = \frac{HR_{\text{peak}} - HR_{\text{rest}}}{(220 - \text{age} - HR_{\text{rest}})} \times 100
\]
Chronotropic Incompetence

A person, not on a beta blocker, who fails to reach 80% of their heart rate reserve has chronicotropic incompetence.

Strong independent predictor of mortality amongst patients not taking beta-blockers.*

Chronotropic Incompetence

Framingham Heart Study

Circ 1996;93:1520.
Heart Rate Recovery

During exercise, HR increases due to withdrawal of vagal tone, and increase of sympathetic tone.

During recovery, there is a rapid reactivation of vagal tone leading to a decrease in heart rate.
Abnormal: 1 minute

Treadmill EST < 12 bpm

Stress-Echo < 18 bpm
Highly predictive of death in negative and positive stress tests.

Exercise Capacity

1 MET (metabolic equivalent) = 3.5 ml \( \text{O}_2 / \text{kg/min} \)

Stage 1 = 5 METS

Stage 2 = 6 - 8 METS

Stage 3 = 8 - 10 METS

<table>
<thead>
<tr>
<th>Age</th>
<th>Poor</th>
<th>Fair</th>
<th>Average</th>
<th>Good</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 29</td>
<td>&lt; 7.5</td>
<td>8-10</td>
<td>10-13</td>
<td>13-16</td>
<td>&gt;16</td>
</tr>
<tr>
<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>60-69</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>70-79</td>
<td>&lt; 3.5</td>
<td>3.5-4.5</td>
<td>4.5-6.5</td>
<td>6.5-8</td>
<td>&gt;8</td>
</tr>
<tr>
<td>&gt;80</td>
<td>&lt; 2.5</td>
<td>2.5-4</td>
<td>4-5.5</td>
<td>5.5-7</td>
<td>&gt;7</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>10-12.5</td>
<td>12.5-16</td>
<td>&gt;16</td>
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<td>7-8.5</td>
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<td>11.5-15</td>
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<td>9.5-13</td>
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<td>5.5-8</td>
<td>8-9.5</td>
<td>&gt;9.5</td>
</tr>
<tr>
<td>&gt;80</td>
<td>&lt; 3.5</td>
<td>3.5-4.5</td>
<td>4.5-6.5</td>
<td>6.5-7.5</td>
<td>&gt;7.5</td>
</tr>
</tbody>
</table>
Figure 3. Functional capacity, angiographic coronary disease, and risk for death. Functional capacity is a much more powerful predictor of death than the presence or absence of obstructive coronary lesions. Reproduced from Myers et al^{108} with permission from the Massachusetts Medical Society. Copyright 2002 Massachusetts Medical Society. All rights reserved.
Exercise Capacity

“The strongest predictor of the risk of death among both normal subjects, and those with cardiovascular disease”.

“Each 1-MET increase in exercise capacity conferred a 12% improvement in survival”.

NEJM 2002;346:793-801.
Exercise Capacity

In pts. with CAD > 13 METS (Stage IV) prognosis excellent regardless of whether medical or surgical therapy is selected.*

Documented CAD, ≥ 2 mm ST-segment depression. Stage IV had a 100% 5-year survival rate.**

*Circ 1984;70:226.

**Circ 1982;65:482.
Exercise Capacity

Review of literature of previous 20 years:

Patients with an exercise capacity of at least 10 METS are at very low risk for death, and gained no benefit from coronary bypass grafting, even when severe coronary disease is present.

Exercise Capacity

In the Coronary Artery Surgery Study (CASS), patients with 3-vessel disease, and high exercise capacity (≥ 10 METS), showed no benefit from surgery.

JACC 1986;8:741-748.
Predicting long-term survival in patients undergoing bypass surgery

<table>
<thead>
<tr>
<th>Predictor</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ejection Fraction</td>
<td>0.00001</td>
</tr>
<tr>
<td>Final Exercise Stage</td>
<td>0.00001</td>
</tr>
<tr>
<td>No. of diseased vessels</td>
<td>0.0076</td>
</tr>
</tbody>
</table>

Circ 1984;70 suppl I, I-226.
Duke Treadmill Score

Treadmill Score = Exercise time - 5X (amount of ST-seg. deviation in mm) - 4X exercise angina index

(0-no angina, 1 angina, 2 if angina stops test).

High Risk = -11, mortality > 5% annually.

Low Risk = +5, mortality 0.5% annually.

Normogram to determine prognosis.

NEJM 1991;325:849.
Use of Exercise Test Results

ACC/AHA Guidelines:

“Patients with a low-risk exercise test result (mortality $\leq 1\%/yr$) can be treated medically without need for referral to cardiac catheterization.”
Patients with a high-risk exercise test result (mortality $\geq 4\%$/yr), should be referred for cardiac catheterization.”
ACC/AHA Guidelines:

“Pts. with an intermediate-risk result (mortality of 2% to 3%/yr), should be referred for additional testing, either cardiac catheterization, or an exercise imaging study.”
<table>
<thead>
<tr>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative/positive/equivocal standard ST-segment response to exercise. The ST/HR index of $\leq 1.6 \mu V/bpm$ is consistent with the absence of obstructive coronary disease and makes anatomically, functionally, and prognostically important coronary disease unlikely; the ST/HR index $&gt; 1.6 \mu V/bpm$ is consistent with the presence of obstructive coronary disease and predicts increased cardiovascular risk.</td>
</tr>
<tr>
<td>The estimated functional capacity of XX METs predicts high/low risk of all-cause mortality.</td>
</tr>
<tr>
<td>The Duke treadmill score of X predicts a cardiac mortality of X% per year over the next 5 years. This implies a (low/intermediate/high) risk.</td>
</tr>
<tr>
<td>The chronotropic response index of 0.XX predicts an increased/decreased risk of death compared with the Duke treadmill score. For patients not on $\beta$-blockers, a value of $\leq 0.80$ raises concerns; for patients on $\beta$-blockers, a value $\leq 0.62$ is abnormal.</td>
</tr>
<tr>
<td>The heart rate recovery of XX bpm further predicts an increased/decreased risk of death.</td>
</tr>
<tr>
<td>The presence/absence of frequent ventricular ectopy during recovery further increases/decreases predicted risk of death.</td>
</tr>
</tbody>
</table>