What is a Stress Test?

- Tool for diagnosis and prognosis of cardiovascular disease
- Typically done on a treadmill or stationary bike with EKG and BP monitoring
  - With or without imaging
- Chemical stress testing simulates stress through pharmacological agents
  - Always combined with imaging
- NOT a screening test
Response to Exercise

- Stress test designed to produce ischemia
- General response to exercise
  - increased in HR, stroke volume, CO, venous return, increased systolic BP w/ little change in diastolic BP
- Obstructive plaque (i.e. > 70% of lumen) causes decreased augmentation of cardiac output and decreased coronary circulation
  - ischemia = EKG changes

General Indications

- Assess probability and extent of CAD in patients with symptoms suggestive of ischemia
- Assess effects of treatment
- Estimate prognosis
- Determine functional capacity

Basic Procedure

- Resting EKG and BP
- Continuous EKG monitoring
- Max HR = 200 – age (+/- 10 beats)
  - 80% reached = good, 90% reached = excellent
- Ex capacity reported in METS (unit of basal O2 consumption equal to 3.5ml/kg/min)
- Various protocols used → all compared by METS
  - Allows for adjustment to patient’s physical condition
- Recovery min 5 or greater with ongoing BP and EKG monitoring
Clinically significant MET Levels

- 1 MET: resting
- 2 METs: level walking at 2 mph
- 4 METs: level walking at 3 mph (3min/stage 1 Bruce Protocol)
- <5 METs: peak cost of basic ADL, usual limit s/p MI
- 10 METs: poor prognosis if age <65
- 13 METs: medical therapy as good as CABG (9min/stage 3 Bruce Protocol)
- 18 METs: excellent prognosis regardless of other exercise response (>12min/stage 4 Bruce Protocol)
- 20 METs: elite endurance athlete

Exercise Testing

**BICYCLE**
- low incidence of artifact
- easy to take accurate BPs
- not every knows how to ride a bike
- limited quadriceps strength
  - more easily fatigued
  - premature termination of test

**TREADMILL**
- walking natural and easy
- generally achieve higher workload
- difficult to take BP
- high artifact

Contraindications to Stress Testing

**ABSOLUTE**
- Symptomatic severe AS
- MI within preceding 48 hrs
- Acute PE/ pulm. infarction
- Symptomatic CHF
- Uncontrolled arrhythmia
- Acute stroke
- Aortic dissection
- Acute myocarditis/ pericarditis

**RELATIVE**
- Severe HTN (>200’ >110)
- Left ventricular outflow tract obstruction
- Electrolyte abnormalities
- High-grade AV block
- Moderate aortic stenosis
- Acute comorbid conditions (e.g. bronchitis, pneumonia, psychosis)
### Reasons to Stop Exercise

**Absolute Indications**
- Drop in SBP below baseline
- Mod to severe angina
- Neurological symptoms
- Signs of poor perfusion
- ST elevation > 1mm
- ST depression > 1mm (horizontal/downsloping)
- Serious arrhythmia
- Technical difficulties in monitoring EKG

**Relative Indications**
- Severe physical symptoms (fatigue, dyspnea)
- Increasing chest discomfort
- 10mmHg drop in SBP
- ST depression >2mm
- Less serious arrhythmia
- Ex-induced LBBB not distinguishable from VTach
- Hypertensive response (>220/110)
- Worrisome appearance

### Interpretation

- Positive if > 1mm horizontal or downsloping ST depression beyond baseline
  - Presence of symptoms increase likelihood for CAD
  - ST elevation rare - occurs in 0.1% of stress tests
- Attempt to achieve min 80% max predicted target heart rate for adequate level of stress
- Duration of exercise important, esp for prognosis
So What Does It Mean?

- Generally, must have significant lesion (i.e. 70% or greater) for it to
  - give you symptoms
  - show up on a stress test
  - need intervention

- Normal stress test does not mean arteries are clean or that you couldn’t have MI walking out of the hospital
  - Only means that you have no significant detectable lesions at this point in time to cause symptoms!

- False positives and negatives can occur
  - History, pretest probability important
When to consider Stress Testing

- **Typical** angina (definite)
  - 1. Substernal CP or discomfort that is
  - 2. Provoked by exertion or emotional stress and
  - 3. Relieved by rest and/or nitroglycerin

- **Atypical** angina (probable)
  - CP or discomfort that lacks one of the typical characteristics above

- **Non-anginal** CP
  - CP or discomfort that meets one or none of the typical angina characteristics above

Pretest Probability of CAD by age, gender and symptoms

<table>
<thead>
<tr>
<th>AGE</th>
<th>M/F</th>
<th>Typical/Definite Angina</th>
<th>Atypical/Probable Angina</th>
<th>Non-Anginal Chest Pain</th>
<th>Asymptomatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-39</td>
<td>M</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Intermediate</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>40-49</td>
<td>M</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>50-59</td>
<td>M</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>60-69</td>
<td>M</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
</tbody>
</table>

High >90% ; Intermediate 10-90% ; Low 5-10% ; Very Low <5%

Adapted from ACC/AHA 2002 Guideline Update for Exercise Testing

When to consider Stress Testing

- ACC/AHA Guidelines recommendations:
  - Diagnosis of CAD
    - Class I: intermediate pre-test probability of CAD based on gender, age and symptoms
    - Class IIa: suspected vasospastic angina
    - Class IIb: high or low pre-test probability of CAD by age, gender or symptoms
Further Guideline Recommendations

• Risk assessment & prognosis of symptomatic pts or those with CAD
• Post MI prognostic assessment, activity prescription or cardiac rehab evaluation
• Evaluation of ex capacity and response to treatment in patients with heart failure for transplant consideration
• Pre-op assessment of pts with intermediate/high risk for non-cardiac surgery
• Revascularization assessment

Exercise Treadmill Testing

• Whenever possible, treadmill test best
  – Gain info re: ex capacity, onset of ischemia
• Limited usefulness with baseline EKG changes
  – cannot monitor for or interpret diagnostic ST changes
  – can still do for functional assessment and prognosis
• Decreased diagnostic accuracy
  – Beta-blockers, calcium channel blockers (diltiazem, verapamil), nitrates
  – obesity, musculoskeletal disabilities, deconditioning

Reasons to add Imaging

<table>
<thead>
<tr>
<th>ELECTROGRAPHIC</th>
<th>CLINICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBBB</td>
<td>Assessing functional significance of borderline angiographic stenosis</td>
</tr>
<tr>
<td>LVH with strain pattern</td>
<td>Prior MI/multivessel CABG/PTCA</td>
</tr>
<tr>
<td>Digitalis effect</td>
<td>Inability to exercise to adequate workload</td>
</tr>
<tr>
<td>Resting ST depression</td>
<td></td>
</tr>
<tr>
<td>WPW</td>
<td></td>
</tr>
<tr>
<td>Paced ventricular rhythms</td>
<td></td>
</tr>
</tbody>
</table>

*Imaging increases accuracy, sensitivity and specificity*
Nuclear Imaging

• Myocardial perfusion scan = blood flow study
  – Normal coronary blood flow at rest even w/narrowing up to 85%
  – Stress ↑ flow 2-2.5 fold w/ex or 3-4 fold w/vasodilation during pharmacologic stress
  – tracer gets trapped in myocardium in proportion to regional blood flow w/decreased uptake in diseased vessels

• Advantage
  – computer-calculated ejection fraction (gold standard)
  – high accuracy
  – localization/quantification of diseased artery
  – high prognostic value
Echocardiography

- Diagnosis of regional wall motion abnormalities, estimation of Ejection Fraction (EF), detection of valvular/pericardial disease
- Advantage
  - versatile, no radiation, portable
  - less costly than nuclear stress test
- Disadvantage
  - Operator dependent
  - difficult to obtain adequate images in obese/large-breasted patients

Echo uses 16-segment model of left ventricle
- corresponds to each major coronary artery perfusion territory to identify ischemia via wall motion abnormalities

Stress Echo

Normal Abnormal
When to Choose Pharmacologic Stress Testing

- Medications, co-morbid conditions (e.g. PVD, morbid obesity, neurologic or orthopedic disorders), EKG abnormalities (e.g. LBBB, ventricular pacing, WPW), poor motivation
  - Always combined with imaging
  - Lose information regarding functional capacity and functional importance of lesions
- regadenoson/adenosine/dipyridamole -> nuclear
- dobutamine -> echo

Regadenoson/Adenosine/Dipyridamole

- Simulate stress via vasodilation
  - In diseased arteries, attenuation of vasodilation
- Contraindication
  - Bronchospasms/Asthma (except for regadenoson), more than 1st AV Block, resting BP <90, use of methylxanthines (theophylline, caffeine)
- Side effects common
  - Cardiac: CP, SOB, ST segment changes, 1st/2nd AV Block
  - Not reliable predictors of CAD
  - Non-cardiac: flushing, N/V, HA, lightheaded

Regadenoson/Adenosine/Dipyridamole

- Regadenoson/Adenosine
  - Quick onset, side effects cease rapidly
    - Caffeine works well for reversal
    - Safe in asthmatics
- Dipyridamole
  - Slower infusion, longer half-life, generally requiring reversal with aminophylline
- Adenosine and Dipyridamole relatively contraindicated in asthma
  - Give albuterol prior to test
Regadenoson/Adenosine/Dipyridamole

- **Regadenoson:**
  - Rapid IV push followed by immediate nuclear tracer injection, reversal at 4 with caffeine if symptomatic
- **Adenosine:**
  - Infusion via syringe pump then tracer injection over 6 min, reversal with caffeine if symptomatic
- **Dipyridamole:**
  - 5 min infusion, tracer injection at 7 min, reversal with Aminophylline at 10 min

General Procedure

- Must hold all caffeine, theophylline or aminophylline x 12 hours prior
- All require 45-60 min wait between tracer injection and nuclear scan
- Continuous EKG monitoring
- Patient must be able to
  - Lie flat
  - Able to raise arms above head
  - If claustrophobic, may need pretreatment w/ Ativan

Dobutamine

- Combined with echo rather than nuclear scan
- Synthetic catecholamine
  - Predominantly inotropic w/ chronotropic effect
  - Dose-related increase in HR, BP, myocardial contractility
  - Hemodynamic effects similar to exercise
- Caution with asthma
  - Beta-blockers frequently needed for reversal
- Side effects
  - Palpitations, HA, paresthesia, nausea, tremor, ventricular arrhythmia, marked ST depression, HTN
  - Usually resolve after discontinuation of infusion, but beta-blockers may be needed for reversal
General Procedure w/Dobutamine

- Rest echo images
- Dobutamine infusion
  - 10 to 40 mcg/kg/min in three minute increments
  - Atropine prn for HR augmentation
  - Echo images at peak HR
- Beta blocker if needed for HR/BP reversal after discontinuation of dobutamine infusion
- Continuous EKG monitoring

Is Stress Testing Safe?

- 1 in 2,500 risk of major coronary event
  - Death probably more 1 in 10,000
- Risk of pharmacologic stress testing same
- Other risks
  - Injury with treadmill
  - Side effects/allergies with pharmacologic testing
  - Exercise or pharmacologically induced arrhythmia or heart block
  - Hypotension/hypertension

Meds – To Hold or Not to Hold

- Drugs in question
  - Beta-blockers
  - Diltiazem and Verapamil
  - Theophylline
  - Nitrates
- Typically held 24 – 48 hrs
- Held mostly for diagnostic test, but physician may wish to continue med depending on reason for test
To Hold or Not to Hold

• **Type of Study**
  - Vasodilator studies (Dipyridamole/Regadenoson/Adenosine)
    - hold theophylline, aminophylline and caffeine products (even decaf)
    - Aminophylline and caffeine used as reversal agent!
  - Exercise testing, Dobutamine studies
    - Hold beta-blockers, diltiazem, verapamil
    - Beta blocker used as reversal agent for dobutamine

• **Reason for Study**
  - Diagnostic
    - Rate slowing meds and nitrates interfere with results
  - Prognostic or exercise prescription
    - Are meds effective in controlling pt’s symptoms?
  - Can pt safely go without?
    - Need for prevention of arrhythmia or HTN
      - If BP concern but exercise is wanted, provider may consider using ACEI or non-rate slowing CCB
  - **Timing of study**
    - Is there enough time to hold meds (tends to be a hospital issue rather than for office testing)

Stressing Asymptomatic Patients

• Understandable desire to want to prevent death from CAD given its significant morbidity and mortality
• Advanced obstructive CAD can exist without symptoms
  - First manifestation often MI/death
  - Early detection might reliably identify pts at risk
Stressing Asymptomatic Patients

- ½ to 1/3 of people with normal coronary arteries have an abnormal EKG
- ~30% of patients with angiographic CAD have a normal EKG
- A lot of coronary events occur without resting EKG abnormalities
- Angiogram best, but invasive
  - Doesn’t assess functional significance of lesion, esp in asymptomatic patients

Stressing Asymptomatic Patients

- Goal of screening for possible CAD
  - Prolong life, improve quality of life
- Identification of ischemia
  - possible motivation for exercise, diet, medications
- False positive stress test
  - inappropriate anxiety, “labeling”, adverse work-related and insurance consequences
  - Can lead to further testing and possible complications
- Positive stress test
  - more predictive of later development of angina than occurrence of major coronary event

Guideline Recommendations

- Class I – NONE
- Class IIb
  - Multiple CAD risk factors (HTN, HLPD, DM, smoking, FamHx of Premature CAD)
  - Men > age 45 or women > age 55 who want to start a vigorous exercise program
  - Occupations which impact public safety
    - firefighters, police, pilots
  - High risk for CAD secondary to other diseases
    - DM, renal failure, PVD
  - Calcium score CT Scan >75 percentile

  Risk reduction for all patients!