Chapter 21: Clinical Exercise Testing Procedures

Clinical Exercise Testing

- Clinical exercise testing is an extension of the history and physical examination
  - It provides information that helps the physician evaluate the patient in circumstances that will provoke the signs or symptoms of exertional myocardial ischemia or other manifestations of CVD or pulmonary disease

- Primary roles of a clinical exercise test:
  1. Diagnostic purposes
  2. Functional evaluation
  3. Determine prognosis or risk (e.g., surgical risk)
### BOX 21-1

**CLINICALLY ACCEPTED REASONS FOR PERFORMING AN EXERCISE TEST, INCLUDING THE LEVEL OF EVIDENCE SUPPORTING THE INDICATION**

<table>
<thead>
<tr>
<th>Class I</th>
<th>Conditions for which there is evidence and/or general agreement that a given procedure or treatment is useful and effective.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class II</td>
<td>Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment.</td>
</tr>
<tr>
<td>IIa:</td>
<td>Weight of evidence/opinion is in favor of usefulness/efficacy.</td>
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<tr>
<td>IIb:</td>
<td>Usefulness/efficacy is less well established by evidence/opinion.</td>
</tr>
<tr>
<td>Class III</td>
<td>Conditions for which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful.</td>
</tr>
</tbody>
</table>

Extension of the history and physical (allowing the physician to examine the patient during symptoms) (I)

Evaluate exertional discomfort (I)
- Chest discomfort
- Dyspnea
- Leg discomfort
- Palpitations
- Cerebral symptoms

Evaluate the presence of occult coronary artery disease (Ia, IIb)
- Risk stratification in patients with known cardiovascular disease (I)
- Follow-up of therapy (IIa)
- Exercise prescription (IIb)

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Contraindications

- Contraindications are conditions in which the risk associated with exercise testing is likely to exceed the information to be gained from the exercise test
  - Absolute
  - Relative
## Absolute and Relative Contraindications to Graded Exercise Testing

<table>
<thead>
<tr>
<th><strong>Absolute</strong></th>
<th><strong>Relative</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute MI (within 2 days)</td>
<td>Left main coronary stenosis</td>
</tr>
<tr>
<td>High-risk unstable angina</td>
<td>Stenotic valvular heart disease</td>
</tr>
<tr>
<td>Uncontrolled cardiac arrhythmias</td>
<td>Electrolyte abnormalities</td>
</tr>
<tr>
<td>Active endocarditis</td>
<td>Tachyarrhythmias</td>
</tr>
<tr>
<td>Symptomatic severe aortic stenosis</td>
<td>Bradyarrhythmias</td>
</tr>
<tr>
<td>Symptomatic heart failure</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>Pulmonary infarction</td>
<td>Hypertrophic cardiomyopathy</td>
</tr>
<tr>
<td>Acute myocarditis or pericarditis</td>
<td>High-degree AV block</td>
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<tr>
<td>Inability to obtain consent</td>
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</tbody>
</table>

* Relative contraindications can be superseded if benefits outweigh risks of exercise

Resting ECG

- What is the purpose of the test?
- Will it limit the assessment of ischemia, if present?
- Should adjunctive procedures be considered?
  - Radionuclide imaging (perfusion studies)
  - Echocardiography
The AHA guidelines for exercise testing laboratories state that nonphysician healthcare professionals, including exercise physiologists, can safely supervise clinical exercise tests when appropriately trained and possessing specific performance skills (e.g., ACSM certification).

- Direct physician supervision is suggested when testing of patients with high-risk medical conditions, such as heart failure or high-grade dysrhythmias.
- Otherwise, having supervising physician in the immediate area and readily available to respond to emergencies and questionable interpretation.

Data suggest that there are no differences in morbidity and mortality rates related to supervision of the clinical exercise test by a physician versus a properly trained, nonphysician healthcare professional.

- In addition, when a clinical exercise test is performed on a high-risk population, such as patients with chronic heart failure, nonphysician supervision has been observed to be safe when a physician is immediately available.
Testing Mode

- Treadmill vs. bike
  - *Peak work capacity and VO2 will be 10% lower on a bike vs. a treadmill*

- Arm ergometer

- Seated stepper
Test Protocols

- **Bruce protocol**
  - *Most common in the U.S.; lots of normative data*
  - *Physician familiarity*
  - *Time efficient*
  - *Good for patients with moderate or higher functional capacity*

- Protocols with a lower initial work rate and smaller increments are better for older and less functional patients
  - *Less handrail support and better estimation of functional capacity*
<table>
<thead>
<tr>
<th>FUNCTIONAL CLASS</th>
<th>CLINICAL STATUS</th>
<th>O₂ COST ( \text{mL/kg/min} )</th>
<th>METS</th>
<th>BICYCLE ERGOMETER</th>
<th>TREADMILL PROTOCOLS</th>
<th>METS</th>
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<tr>
<td></td>
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<td></td>
<td>BRUCE MODIFIED 3 min Stages MPH %GR</td>
<td>BRUCE 3 min Stages MPH %GR</td>
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<td>NORMAL AND I</td>
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<td>6.0 22</td>
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<td>4.2 16</td>
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<td>SYMPTOMATIC</td>
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<td>3.4 14</td>
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Relation of METs to stages in the various testing protocols. Functional class refers to New York Heart Association class; Abbreviations: kpm = kilopond-meters; MPH = miles per hour; %GR = percent grade. Source: AHA 2001, Circulation 104: 1694-1740


**Monitoring**

The following should be monitored throughout the test

- Continuous monitoring
  - ECG
    - *Heart rate, Rhythm, Repolarization changes*
  - Assessed each stage
    - Blood pressure
    - Symptoms
      - *Chest pain, shortness of breath, dizziness, claudication*
    - Perceived exertion

- Signs and symptoms should be continuously monitored and the need to terminate the test considered
BOX 5.2  Indications for Terminating Exercise Testing

ABSOLUTE INDICATIONS

- Drop in systolic blood pressure of >10 mm Hg from baseline blood pressure despite an increase in workload when accompanied by other evidence of ischemia
- Moderately severe angina (defined as 3 on standard scale)
- Increasing nervous system symptoms (e.g., ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties monitoring the ECG or systolic blood pressure
- Subject’s desire to stop
- Sustained ventricular tachycardia
- ST elevation (+1.0 mm) in leads without diagnostic Q-waves (other than V1 or aVR)

ECG, electrocardiogram; PVC, premature ventricular contraction.

Baseline refers to a measurement obtained immediately before the test and in the same posture as the test is being performed.

**RELATIVE INDICATIONS**

- Drop in systolic blood pressure of >10 mm Hg from baseline\(^a\) blood pressure despite an increase in workload in the absence of other evidence of ischemia
- ST or QRS changes such as excessive ST depression (>2 mm horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response (systolic blood pressure of >250 mm Hg and/or a diastolic blood pressure of >115 mm Hg).

ECG, electrocardiogram; PVC, premature ventricular contraction.

\(^a\)Baseline refers to a measurement obtained immediately before the test and in the same posture as the test is being performed.

**Predicted Maximal Heart Rate**

- Termination of a test based on a predetermined workload or percentage of predicted maximal heart rate (PMHR) is difficult to justify
  - *Ending a test based on a predetermined arbitrary endpoint tends to heavily stress the most debilitated patients and suboptimally challenge healthy well-conditioned patients*

- Failure to perform a symptom-limited maximal test will result in an inaccurate assessment of functional capacity

- 85% PMHR
  - *Early studies showed that 50% of ischemic abnormalities were observed by the time 85% PMHR was achieved.*
  - *Sensitivity is increased in tests when more than 85% PMHR is achieved*
Early studies suggested that the sensitivity of ST segment changes can be maximized by placing the patient in a sitting or supine position immediately following exercise.

- More recent data have demonstrated that the prognostic value of the pattern of HR and BP recovery during the postexercise period may be more important.

Since profound hypotension during recovery, resulting from a large drop in venous return, can cause ischemia by decreasing perfusion pressure into the myocardium, performing gentle exercise may support venous return and thus hemodynamic stability.

- The moments after the exercise test are uniquely “teachable moments” when the clinician can discuss outcomes of the test and lifestyle behaviors (e.g., smoking, exercise).
Exercise Testing Is Generally Safe

- Early studies reported that the risk of serious complications is on the order of **6 per 10,000 tests**.

- More recent data shown risk of serious complications is **< 2 per 10,000 tests**
  
  - Proper attention to contraindications for exercise testing, careful monitoring during the test, and recognizing criteria for terminating the exercise test all contribute to improved safety.
Test Interpretation

- Clinical responses (symptoms)
- ECG responses
- Exercise capacity
- Hemodynamic responses
- Integrated response (exercise test scores)
<table>
<thead>
<tr>
<th>AGE</th>
<th>SEX</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>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>50-59</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
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<td>Intermediate</td>
<td>Low</td>
<td>Low</td>
<td>Very low</td>
</tr>
<tr>
<td>60-69</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

\(^a\)No data exist for patients who are <30 or >69 years, but it can be assumed that prevalence of CVD increases with age. In a few cases, patients with ages at the extremes of the decades listed may have probabilities slightly outside the high or low range. High indicates >90%; intermediate, 10%-90%; low, <10%; and very low, <5%.


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ECG Responses

• Minimal diagnostic threshold for ischemia is at least 1 mm of horizontal/downsloping ST segment depression that is 80 msec beyond the j point
  
  - *ST segment changes that occur early during an exercise test, are evident in multiple leads, or persist into recovery predict either severe single-vessel CAD or multivessel disease*

• Dysrhythmias that increase in frequency or complexity with progressive exercise, are associated with ischemia, or are associated with hemodynamic instability are thought to be more malignant than isolated dysrhythmias
Exercise Capacity

- A high maximal oxygen uptake (VO₂) can be inferred to predict a relatively high cardiac output and therefore the absence of serious limitations of left ventricular function
  - The error in estimating exercise capacity from various published prediction equations is about ± 1 MET (3.5 mL/kg/min)
  - This is comparatively unimportant (<10% error) in young, healthy individuals with 13- to 15-MET exercise capacities but is much more significant (15%-25% error) in individuals with reduced exercise capacities typical of those observed in patients with CVD (4-8 METs)
Hemodynamic Responses

- A decrease in systolic BP, especially to below the pre-exercise level, particularly when linked with ECG abnormalities or symptoms, is suggestive of a decreasing cardiac output and is an unequivocal criteria to terminate an exercise test
  - *Patients who cannot achieve an adequate HR response to exercise have a poorer prognosis beyond that accounted for by symptoms or ECG changes*
  - *Chronotropic incompetence:* Failure to achieve 80% of the predicted HR reserve

- Failure of the HR to recover promptly after exercise provides independent information related to prognosis
  - *Poor response:* Decrease in HR of <12 beats during the first minute of recovery
**Integrated Response**

- **Duke Score/Index**
  - Exercise capacity, ST segment changes, angina
  - See *Clinical Exercise Testing Related to Cardiovascular Disease* lecture
    - Duke Nomogram

- Heart rate (HR) performance curve
  - Response of HR above ventilatory threshold
  - More accelerated HR response might be suggestive of reduced stroke volume
Sample nomogram shows testing results of 55 yro male sheet-metal worker with atypical chest pain

- Patient reached **7 METs** before the test was stopped because of exercise-limiting angina.
- **2mm** horizontal ST-segment depression at max exercise.
- Predicted annual cardiovascular mortality for this patient **4.0%**, which is high.
**Radionuclide Imaging**

- Augments information provided by the ECG by evaluating myocardial perfusion
  - *Delivery of the isotope is proportional to coronary flow*

- In the case of myocardial infarction, the necrotic tissue does not result in uptake of the isotope
  - *Nonreversible, or fixed, perfusion deficit*

- In the case of ischemia, the tissue uptake in the ischemic region is reduced during exercise by virtue of the relative reduction of blood flow (and thus isotope)
  - *Reversible perfusion deficit/defect; i.e., the deficit in myocardial perfusion is reversed with rest*
Echocardiography

- Augments information provided by the ECG by evaluating cardiac wall motion
  - Reduced coronary flow results in reduced myocardial perfusion and eventual cardiac wall motion abnormalities
- Typically performed in the supine position before and immediately after the exercise test