Chapter 22:
Diagnostic Procedures for Cardiovascular Disease

Diagnosis of Cardiovascular Disease

Includes:

- *Medical history
- *Physical examination (PE)
- Variety of noninvasive and invasive tests
  - ECG, blood work, stress test, angiogram, etc.

*History and PE are the cornerstone of the evaluation and clinical workup of the patient with suspected heart disease and provide the basis for subsequent testing.
**ACC/AHA Task Forces on Practice Guidelines**

- **Strength of the evidence**
  - Level A: Data derived from multiple randomized clinical trials or meta-analyses
  - Level B: Data derived from a single randomized trial or nonrandomized studies
  - Level C: Information derived only from consensus opinion of experts, case studies, or standard-of-care

- **Recommendations for performing a certain diagnostic test or treatment**
  - Level I: Conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, useful, and effective, and in general suggest an action **SHOULD BE DONE**
  - Level II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment
    - IIa: The weight of evidence/opinion is in favor of usefulness/efficacy; interpreted as “probably should do it”
    - IIb: The usefulness/efficacy is less well established by evidence/opinion; interpreted as “can consider doing it”
  - Level III: Conditions for which there is evidence and/or general agreement that a procedure/treatment is not useful/effective and in some cases may be harmful; in general, this is interpreted that the action **SHOULD NOT BE DONE**
Role of Clinical Exercise Physiologists

- Should be familiar with both the general decision-making process of cardiovascular diagnosis and the specific diagnostic procedures used to make the diagnosis.

- Can provide insight and educate patients about diagnostic procedures and why a diagnostic assessment was or was not performed.

- Increasing role in the administration and preliminary interpretation of some cardiac diagnostic procedures.

- Specific questions concerning diagnosis, prognosis, and management should be referred to the patient’s physician.
1. Chest discomfort
2. Dyspnea (shortness of breath with exertion)
3. Orthopnea (shortness of breath with lying down)
4. Paroxysmal nocturnal dyspnea (waking at night short of breath)
5. Peripheral edema
6. Cardiac palpitations
7. Syncope (fainting)
8. Cough
Chest Discomfort

- Most common symptom in patients with heart disease
  - Patients usually consider it a “bothersome” discomfort, rather then pain.

- Key components:
  - Location and type of sensation
  - Does it occur with myocardial stress such as exertion or mental stress?
  - Is it relieved with rest/relaxation or by using nitroglycerin?

- If only one of these components is present, then it is considered “nonangina” pain.

- If two components are present, then it is “atypical” angina.

- If all components are present, then it is considered “typical” angina.

- Women have more atypical chest discomfort than men.

- Patients with diabetes more commonly have atypical features or no symptoms at all, despite the presence of significant disease.
Appropriate components of the medical history may include the following:

- **Medical diagnosis.** Cardiovascular disease, including myocardial infarction and other acute coronary syndromes; percutaneous coronary artery procedures, including angioplasty and coronary stent(s); coronary artery bypass surgery; valvular surgery(s) and valvular dysfunction (e.g., aortic stenosis/mitral valve disease); other cardiac surgeries, such as left ventricular aneurysmectomy and cardiac transplantation; pacemaker and/or implantable cardioverter defibrillator; presence of aortic aneurysm; ablation procedures for dysrhythmias; symptoms of angina pectoris; heart failure; peripheral vascular disease; hypertension; diabetes; metabolic syndrome; obesity; pulmonary disease, including asthma, emphysema, and bronchitis; cerebrovascular disease, including stroke and transient ischemic attacks; anemia and other blood dyscrasias (e.g., lupus erythematosus); phlebitis, deep vein thrombosis or emboli; cancer; pregnancy; osteoporosis; musculoskeletal disorders; emotional disorders; eating disorders.

- **Previous physical examination findings.** Murmurs, clicks, gallop rhythms, other abnormal heart sounds, and other unusual cardiac and vascular findings; abnormal pulmonary findings (e.g., wheezes, rales, crackles); plasma glucose, hemoglobin A1c, serum lipids and lipoproteins, or other significant laboratory abnormalities; high blood pressure; edema.

Appropriate components of the medical history may include the following:

- History of symptoms. Discomfort (e.g., pressure, tingling, pain, heaviness, burning, tightness, squeezing, numbness) in the chest, jaw, neck, back, or arms; light-headedness, dizziness, or fainting; temporary loss of visual acuity or speech, transient unilateral numbness or weakness; shortness of breath; rapid heart beats or palpitations, especially if associated with physical activity, eating a large meal, emotional upset, or exposure to cold (or any combination of these activities).
- Recent illness, hospitalization, new medical diagnoses, or surgical procedures.
- Orthopedic problems, including arthritis, joint swelling, and any condition that would make ambulation or use of certain test modalities difficult.
- Medication use, drug allergies.
- Other habits, including caffeine, alcohol, tobacco, or recreational (illicit) drug use.
- Exercise history. Information on readiness for change and habitual level of activity: type of exercise, frequency, duration, and intensity.
- Work history with emphasis on current or expected physical demands, noting upper- and lower-extremity requirements.
- Family history of cardiac, pulmonary, or metabolic disease, stroke, or sudden death.

BOX 22-3  DIFFERENTIAL DIAGNOSIS OF CHEST DISCOMFORT

CARDIAC
- Angina
- Acute coronary syndrome
- Mitral valve prolapse
- Pericarditis
- Aortic stenosis
- Aortic dissection

GASTROINTESTINAL
- Peptic ulcer disease
- Esophageal spasm or reflux disease
- Cholecystitis or cholelithiasis

PULMONARY
- Pneumonia
- Pleurisy
- Pulmonary embolism

MUSCULOSKELETAL
- Costochondritis

TRAUMA
- Cervical and thoracic spine disorders
Determining the Probability of CAD

Based on the history and physical exam, if...

- Low probability of CAD, then treat risk factors and assess for a noncardiac cause of the patient’s symptoms (e.g., referrals for gastrointestinal testing, pulmonary function testing, musculoskeletal assessment).

- Intermediate-risk patients who are appropriate candidates for an exercise test should undergo an ECG or an ECG plus imaging (radionuclide or echocardiography) stress test. Pharmacologic stress assessment is considered when a patient cannot perform exercise.
  - If high-risk following stress testing, then cardiac catheterization may be appropriate.

- High-risk patients may be referred for a stress test or cardiac catheterization. As a general rule of thumb, if pretest probability for significant coronary disease is >80%, it is more clinically and cost effective to refer directly to coronary angiography.
Prognosis and the Exercise Test

- Strong relationship between cardiovascular and all-cause mortality and work capacity (estimated METs)
- Duke Treadmill Score
- Recovery heart rate
- Measured VO$_2$ is the best single predictor of survival among all cardiac diagnostic tests.
Accuracy of Diagnostic Tests

- Positive test: Clinical judgment is that the patient has the abnormality.
- Negative test: Clinical judgment is that the patient does not have the abnormality (i.e., the finding was normal).
- Any clinical test, even if considered the “gold standard,” will not always correctly identify whether a person has or does not have an abnormality.
- False-positive result: Test result is positive, but the patient is later found to not have the abnormality.
- False-negative result: Test result is negative, but the patient is later found to have the abnormality.
- Tests that accurately assess a patient as positive or negative for an abnormality are considered true-positive and true-negative results, respectively.
Sensitivity and Specificity

- Sensitivity: How often the test uncovers an abnormality or disease in a population with the abnormality or disease

- Specificity: How often the test is negative or normal in a population without the abnormality or disease

- Success of any diagnostic test is dependent on the technical performance of the test, the appropriateness of the test for the person being evaluated, and the interpretation or clinical judgment of the clinician who evaluates the results.
Predictive Value

- Predictive value: Ability of a test to accurately determine the presence or absence of an abnormality or disease in a single person.

- The predictive value relies on the test sensitivity and specificity and the prevalence of disease in the population being tested.

- Positive predictive value is the probability of disease being present in a person with a positive test.

- Negative predictive value is the probability of disease being absent in a person with a negative test.

- It is important that the proper population, techniques, and interpretation be applied to any clinical test to enhance the predictive value. It is this criterion on which studies in the literature are evaluated and recommendations are made for diagnostic testing.
# TABLE 22-1. COMPARISON OF TESTS FOR SENSITIVITY, SPECIFICITY, AND PREDICTIVE ACCURACY

<table>
<thead>
<tr>
<th>GROUPING</th>
<th>STUDIES, n</th>
<th>TOTAL PATIENTS, n</th>
<th>SENSITIVITY, %</th>
<th>SPECIFICITY, %</th>
<th>PREDICTIVE ACCURACY, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard exercise test</td>
<td>147</td>
<td>24,047</td>
<td>68</td>
<td>77</td>
<td>73</td>
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<tr>
<td>Thallium scintigraphy</td>
<td>59</td>
<td>6,038</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>SPECT</td>
<td>30</td>
<td>5,272</td>
<td>88</td>
<td>72</td>
<td>80</td>
</tr>
<tr>
<td>Adenosine SPECT</td>
<td>14</td>
<td>2,137</td>
<td>89</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>Exercise echocardiography</td>
<td>58</td>
<td>5,000</td>
<td>84</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>Dobutamine echocardiography</td>
<td>5</td>
<td>&lt;1,000</td>
<td>88</td>
<td>84</td>
<td>86</td>
</tr>
<tr>
<td>Dobutamine scintigraphy</td>
<td>20</td>
<td>1,014</td>
<td>88</td>
<td>74</td>
<td>81</td>
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<tr>
<td>Coronary calcium score</td>
<td>16</td>
<td>3,683</td>
<td>60</td>
<td>70</td>
<td>65</td>
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</tbody>
</table>

SPECT, single-photon emission computed tomography.

Graded Exercise Test

The decision to perform a graded exercise test should be made based on several criteria:

- Pretest likelihood that the patient has CAD
- Can patient adequately exercise to symptom-limited maximum?
- Will the ECG be interpretable at peak exercise for possible ischemia?
<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>
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</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>Very low</td>
<td>Very low</td>
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<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>Very low</td>
<td>Very low</td>
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<tr>
<td>50–59</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>Intermediate</td>
<td>Low</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>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

*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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BOX 22-4  
CANDIDATES FOR EXERCISE ELECTROCARDIOGRAPHIC ASSESSMENT (REGULAR STRESS TESTING WITHOUT IMAGING)

APPROPRIATE CANDIDATES/APPLICATIONS
Able to exercise to achieve adequate myocardial stress (i.e., >85% of predicted peak heart rate or double product > ~ 24,000)
If repolarization abnormality is either right bundle branch block or (<1 mm ST-segment depression not caused by digoxin use
Screening for significant coronary artery disease (CAD) when the 10-year Framingham risk is >20%
Diagnosis of chest discomfort in intermediate-risk patients based on age, sex, and symptoms
Prognosis of patients with established CAD, heart failure, and for entry into cardiac rehabilitation
Guiding medical and revascularization therapy in patients with established CAD

INAPPROPRIATE CANDIDATES
Women with baseline ST/T wave abnormalities
Low or high risk of ischemic heart disease, including asymptomatic patients with possible ischemia during ambulatory electrocardiographic monitoring or those with acute coronary syndromes
Pre-existing repolarization abnormalities (left bundle branch block, left ventricular hypertrophy with strain, digoxin, ventricular pacing, nonspecific ST-segment depression >1 mm)
Pre-excitation syndrome (Wolff-Parkinson-White)
Patients unable to exercise to an adequate myocardial stress level (i.e., <85% of predicted peak heart rate or double product < ~ 24,000) because of arthritis, pulmonary disease, or peripheral vascular disease
Clinical Workup “Gap”

- There is a clinical workup “gap” between what is recommended by the ACC/AHA Guidelines for Exercise Testing and what is commonly practiced by the medical community.

- Although the guidelines recommend that patients with chest discomfort, a normal resting ECG, and who are able to ambulate be scheduled for an exercise test with ECG monitoring alone, in clinical practice, many physicians faced with this scenario begin with an imaging test.

- Although this strategy provides a slight improvement in predictive accuracy over the stress ECG combined with the Duke Treadmill Score, it does so at a significantly increased cost.
Imaging Studies

- Echocardiography or myocardial perfusion imaging

- Imaging studies provide slightly higher sensitivity and specificity than exercise testing with ECG alone.

- Candidates for imaging studies are those with an uninterpretable ECG and those who are unable to exercise to a level high enough to produce an adequate myocardial stress.

- They allow for the patient to be further risk stratified to either a low- or high-risk group. If equivocal, then either a different imaging test or coronary angiography may be suggested as a next step in the diagnostic process.
Echocardiography

- Echocardiography (cardiac ultrasound) uses high-frequency sound waves that bounce off cardiac structures and return to the transducer providing information regarding internal structures.
  - Allows measurement of chamber size and wall motion, as well as identifying valvular structures and pericardial effusions.
- Cardiac Doppler uses the principle of Doppler shift to evaluate intracardiac blood flow.
  - Blood velocity and volumetric flow can be measured to determine intracardiac gradients, valve areas, valvular regurgitation, and intracardiac pressures.
- Exercise echocardiography allows assessment of wall motion abnormalities, ejection fraction, and systolic and diastolic function before versus after exercise.
  - Normal response: Augmentation of wall motion
  - Abnormal response: Hypokinesis, akinesis, dyskinesis
- Pharmacologic techniques: Dobutamine stress testing
  - Increase myocardial oxygen demand (positive chronotropic and inotropic)
BOX 22-5
CANDIDATES FOR REST AND EXERCISE ECHOCARDIOGRAPHY ASSESSMENT WITH ECHOCARDIOGRAPHY (STRESS-ECHO)

APPROPRIATE CANDIDATES

Rest
Suspected valvular disease
Suspected ventricular dysfunction
Patients with systolic murmur suggestive of aortic stenosis

Exercise
Women with baseline ST/T-wave abnormalities
Intermediate pretest probability of coronary artery disease and uninterpretable rest electrocardiogram (high- and low-risk patients may also be considered but may be more appropriate for myocardial perfusion imaging studies)
Previous revascularization (percutaneous coronary intervention or coronary artery bypass surgery) and questions concerning segmental myocardial viability

INAPPROPRIATE CANDIDATES

Rest
Patients with multiple myocardial infarctions
Those with complex wall motion abnormalities
Those with a poor imaging window (e.g., obese patients and patients with chronic obstructive pulmonary disease)

Exercise
Those who cannot adequately ambulate (may be more suitable to perform a pharmacologic test)
Myocardial Perfusion Imaging

- A radioactive isotope injected at rest and peak exercise is proportionally distributed within the myocardium in relation to regional myocardial blood flow and muscle viability.

- In a normal myocardium, rest and stress images show accumulation of the isotope throughout the LV, reflecting integrity of regional blood supply.

- In areas of decreased perfusion, there is delayed uptake and slower washout. The presence of this “perfusion defect” on stress images not present at rest images indicates ischemia.

- Areas of scar from previous infarction characteristically show no uptake, either at rest or with stress.

- Ventricular size, wall motion, ejection fraction, and wall thickness can also be assessed.

- Pharmacologic techniques: Dipyridamole or adenosine
  - Vasodilators result in a mismatch of blood flow increase between the normal and diseased coronary arteries.
BOX 22-6  CANDIDATES FOR NUCLEAR MYOCARDIAL PERFUSION IMAGING (STRESS-NUCLEAR)

APPROPRIATE CANDIDATES

Women with baseline ST/T-wave abnormalities

Those who have an uninterpretable resting electrocardiogram (i.e., left bundle branch block, left ventricular hypertrophy, digoxin, >1 mm ST-segment depression)

Use in conjunction with pharmacologic modes if patient cannot exercise

Those unable to achieve a high heart rate or systolic blood pressure

Intermediate- and high-risk symptomatic patients

INAPPROPRIATE CANDIDATES

Those who have contraindications to testing

In those patients with a history of bronchospasm, use of adenosine or dipyridamole is contraindicated

In those patients with a history or high risk of serious arrhythmias, use of dobutamine is contraindicated
Positron Emission Tomography (PET)

- PET scanning is one of the most accurate methods for noninvasively identifying and assessing the severity of CAD.
- Noninvasive detection of coronary artery stenosis
  - Typically reserved for patients with equivocal radionuclide scans
- Assessment of myocardial viability in patients with CAD and LV impairment, which is useful in determining if revascularization would be beneficial
Cardiac Magnetic Resonance Imaging (MRI)

- Cardiac MRI is used primarily to evaluate the patient for structural heart disease.
  - Assess the extent of damage to the LV as a complication of ischemic heart disease
  - Assess the type of cardiomyopathy and quantify physiologic parameters such as wall stress and LV volume
  - Visualize the pericardium and assess its thickness in pericardial disease
  - Evaluate intracardiac and pericardial neoplastic disease
  - Provide information regarding morphology, size of shunts, and valvular function in congenital heart disease
  - Evaluate the thoracic aorta for dissection, false lumens, periaortic disease, and abnormalities of the thoracic aortic arch
- Cardiac MRI can be used as the imaging method for pharmacologic stress with adenosine, dipyridamole, or dobutamine.
- Like echocardiography, wall motion can be evaluated.
Coronary Computed Tomography Angiography (CTA)

- CTA generates a calcium score, which is an evaluation of the degree of coronary calcium.
  - All human atheromas eventually become calcified.

- CTA generates images of the coronary arteries (with and without calcium) that are comparable to conventional angiography.

- Studies have shown CTA to be superior to conventional evaluations done in the emergency department in patients with acute chest discomfort.
BOX 22-7  CANDIDATES FOR CORONARY COMPUTED TOMOGRAPHIC ANGIOGRAPHY

APPROPRIATE CANDIDATES

Suspected coronary artery disease (CAD) based on history and physical (chest discomfort)
Intermediate pretest probability of CAD
Uninterpretable baseline electrocardiogram, inability to exercise
Uninterpretable/equivocal completed stress test with or without imaging

INAPPROPRIATE CANDIDATES

Asymptomatic patients
Significant chronic kidney disease or allergic reaction to iodinated contrast
Hyperparathyroidism or known disorders of calcium/phosphate metabolism
Medically unstable patients (noncardiac medical problems)
Coronary Angiography

- Coronary angiography using the cardiac catheterization technique is considered the gold standard for assessing the presence of CAD.

- Narrowing of a coronary artery can be identified, located with respect to the coronary artery anatomy, and quantified for the amount of stenosis within a given artery.

- Angiography cannot determine if a coronary artery lesion is flow limiting and causing ischemia during stress, and therefore, most patients undergoing this test are previously symptomatic.

- Coronary artery stenosis >70% is required to cause ischemia.

- Lesions of 50%-70% are considered borderline significant and are only considered clinically important if they correspond to abnormalities seen on the stress imaging test or the patient is experiencing typical angina.

- Lesions ≤50% are not generally thought to cause ischemia.
BOX 22-8  
CARDIAC CATHETERIZATION AND CORONARY ANGIOGRAPHY

APPROPRIATE CANDIDATES
Positive stress testing with or without imaging
Very high pretest probability of coronary artery disease (CAD) based on clinical evaluation
Known CAD in the setting of acute coronary syndrome

INAPPROPRIATE CANDIDATES
Asymptomatic patients
Patients who are deemed not candidates for revascularization
Significant chronic kidney disease or allergic reaction to iodinated contrast (relative contraindications)
Intravascular Ultrasound (IVUS)

- Coronary angiography visualizes the coronary lumen and thus may underestimate the size of a plaque in a remodeled artery.

- IVUS is an intracoronary diagnostic procedure performed during cardiac angiography.

- IVUS provides visualization of the lumen and wall of the vessel and assessment of plaque size.

- IVUS can be used after coronary angioplasty to evaluate vessel patency and to look for complications, such as coronary artery dissection.

- IVUS can provide information about the deployment of a coronary stent.