Predictive Implications of Stress Testing  
(Chapt. 14)

- Sensitivity
- Specificity
- Predictive Value
- Patient Risk

1979, Weiner and coworkers

*Stress testing has very little diagnostic value. A positive stress test increased the post-risk of CAD by only 6-20%, and a negative stress test decreased risk by only 2-28%.*

1995, Ellstad, pg 353

*“The predictive power of the normal as well as the abnormal maximal stress test can provide us with a very useful tool in the clinical management of CAD patients.”*

Factors to improve the accuracy of stress testing

- Bayes Theorem application
- Patient selection
  - exclude WPW, BBB, etc.
- Aggressive termination criteria
- Additional measurements (HR, BP, exercise time)

Predictive value and Relative Risk

- **Predictive Value of a Stress Test**
  - A measure of how accurately an exercise test identifies an individual with CAD or w/o CAD
  - depends on the sensitivity and specificity of the test

- **Relative Risk**
  - A measure of the ability of the stress test to predict future cardiac events
  - depends on the predictive value of the test and the population risk

Sensitivity = ability to detect disease when it is present.

Specificity = ability to correctly exclude disease when it is absent.

Most common criteria used are:

- CAD is determined from angiography (>70% occlusion of at least one vessel)
- Positive test is determined from ST segment changes of >1 mm and other abnormal test results.
Methods to “Validate” Stress Test Results

• How do you determine whether the test was positive?
  – ST depression, 0.5, 1.0, 1.5, <2.0 mm
  – ST depression with angina
  – exercise endurance, HR response

• How do you determine whether there is CAD?
  – Angiogram, 50-75% artery occlusion
  – Ventricular function tests, imaging

Possible Test Results

• True positive (TP) = a positive result in someone with CAD
• True negative (TN) = a negative result in someone without CAD
• False positive (FP) = a positive result in someone without CAD
• False negative (FN) = a negative result in someone with CAD

Possible Test Results

• True positive (TP) = a positive result in someone with CAD
• True negative (TN) = a negative result in someone without CAD
• False positive (FP) = a positive result in someone without CAD
• False negative (FN) = a negative result in someone with CAD

Contingency Table

<table>
<thead>
<tr>
<th>Test Result</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
</tr>
<tr>
<td>Positive</td>
<td>True-pos</td>
</tr>
<tr>
<td>Negative</td>
<td>False-neg</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
</tr>
<tr>
<td></td>
<td>True-neg</td>
</tr>
</tbody>
</table>

The likelihood of an asymptomatic 30-39 yr-old woman of having CAD despite a “positive” treadmill stress test is only 0 to 10% (> 2.5 mm ST depression) (Robergs 97, table 15)

What type of potential error is this?

False Positive

Sensitivity Example

• 100 elderly men with CAD perform a stress test
  – 10 have a positive result (true positive)
  – 90 have a negative result (false negative) but have CAD
• What is the sensitivity of this test?
  – Sens. = TP/all patients with CAD
    = TP/(TP + FN) x 100
    = 10/(10 + 90) x 100
    = 10%

How do you measure sensitivity?

• Sensitivity = (TP / All patients with abnormal angiograms) x 100
  A measure of the proportion of patients with a positive test to the total number of patients with CAD
  Sensitivity = TP / (TP + FN) x 100

• Sensitivity for clinical exercise testing is approximately 68% for correctly identifying someone with CAD (uses ST depression > 1mm)
**Sensitivity Example 2**
• 100 women take a stress test (4 have CAD, 96 do not)
  – 10 positive stress tests
    • 2 TP, 8 FP
  – 90 negative stress tests
    • 2 FN, 88 TN
• Sensitivity = TP/(TP + FN) x 100
  = 2/(2 + 2) x 100
  = 50%

**Exercise testing sensitivity**
• “This poor sensitivity (aver 68%) has led some investigators to suggest routine exercise testing is nearly useless for the management of patients with CAD” (Thompson 01, pg 21)
• Sensitivity ranges from 23-90%, depending on the population studied (Bayes theorem)

**Test factors that influence sensitivity (ACSM)**

<table>
<thead>
<tr>
<th>Enhance</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>• maximal test</td>
<td>• submaximal test</td>
</tr>
<tr>
<td>• multi-lead EKG</td>
<td>• insufficient EKG</td>
</tr>
<tr>
<td>• additional data</td>
<td>• cardiac drugs (beta blockers, nitrates, calcium channel blockers)</td>
</tr>
<tr>
<td></td>
<td>• pre-existing EKG changes (LVH, LBBB, WPW)</td>
</tr>
</tbody>
</table>

**If a treadmill protocol has a 68% sensitivity, what does this tell you?**
That 68% of individuals with CAD are detected with this test.

**What is specificity?**
• Specificity = (TN / all patients without CAD) x 100
  – Specificity = ability to correctly exclude disease when it is absent
  – Spec = TN/(TN + FP) x 100
• Specificity in clinical exercise testing is approximately 77%

“A test should not be classified as negative unless the patient has attained an adequate level of cardiovascular stress, generally > 85% predicted maximal HR.”

ACSM pg 126
What type of error do you risk by not performing a maximal exercise test?

- False Negative

Specificity is increased by:
- Not testing patients with pre-existing abnormal resting EKG (false positives)
  - Hypertrophy of the left ventricle
  - Certain medications (digitalis)
  - Mitral valve prolapse
  - Anemia
  - Female gender
- Specificity = TN/(TN + FP) x 100

Specificity Example
- 100 45 yr-old baseball players are screened for CAD (20 CAD, 80 no CAD)
  - 40 have a positive stress test (18 TP, 22 FP)
  - 60 have a negative stress test (2 FN, 58 TN)
- What is the specificity of this test?
  - Spec. = TN/(TN + FP) x 100
    = 58/(58 + 22) x 100
    = 72.5%

Sensitivity and Specificity of Various Stress Tests

<table>
<thead>
<tr>
<th>Stress Test</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise EKG</td>
<td>40-80</td>
<td>60-90</td>
</tr>
<tr>
<td>Exercise Echo</td>
<td>85</td>
<td>85-90</td>
</tr>
<tr>
<td>Dobutamine echo</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Exercise SPECT</td>
<td>85-90</td>
<td>85</td>
</tr>
</tbody>
</table>

SPECT = single photon emission computed tomography (thallium or Tc)

Predictive Value of a Test

The ability of a stress test to correctly identify CAD or no-CAD
- PV for a positive test = TP / (TP + FP) x 100
  - The proportion of true positives of all positive results
- PV for a negative test = TN / (TN + FN) x 100
  - The proportion true negatives of all negative results

Relative Risk
- The predictive value tells you the accuracy of the exercise test
- HOWEVER--
- To predict relative risk for an individual, the PV must be interpreted in light of the patient's age, gender, symptoms, and amount of ST segment depression
Patient relative risk

- If a patient has a positive stress test, his risk is dependent on:
  - the sensitivity of the test
  - the specificity of the test
  - the patient population

- RR = risk of having CAD with a positive stress test/risk of having CAD with a negative stress test

Relative Risk, example

- A patient has a relative risk of 5. What does this mean?
  - He is 5 times more likely to have CAD since he had a positive stress test than if he had a negative stress test

Stress Test results and Survival

Conclusions

- What is meant by the test sensitivity?
  - Ability to correctly identify patients with CAD

- What is meant by the test specificity?
  - Ability to correctly clear those without disease

- How does one calculate the predictive value of a test? (% identified correctly)
  - PV+ = TP/all positive results
  - PV- = TN/all negative results

Conclusions, cont.

- What can enhance the predictive value of exercise testing?
  - (max test, additional measurements, patient selection)

- What needs to be considered to determine the relative risk for an individual?
  - Predictive value of a test & patient population risk

- So, if all this is done, is it worthwhile performing a stress to screen for CAD disease?
  - Most agree yes