Stress Echocardiography

The Optimal Choice in Cardiac Risk Stratification
Excellent diagnostic accuracy
Outstanding prognostic capabilities
Low risk compared to alternatives
Portability
Best cost efficiency
Additional clinical information
Diagnostic accuracy

- Detection of >50% stenosis by angiography
- Average sensitivity  88%
- Average specificity  83%
Compared to Nuclear Perfusion Imaging

Schinkel et al.
Prognostication
Risk of MI or cardiac death

Very low risk, <1%/yr
- Normal exercise echocardiogram with good exercise capacity
- 7 METS men
- 5 METS women

Low risk, <2%/yr
- Normal pharmacologic stress echocardiogram
  - Adequate study, >85% max predicted HR
  - Low to intermediate pretest probability of CAD
Prognostication
Risk of MI or cardiac death

High Risk, >3%/yr

- Extensive rest RWMA >4 segments.
- Resting LVEF <40%
- Extensive ischemia, >4 segments.
- Multivessel ischemia
- Low ischemic threshold
- Decrease in exercise EF
- Resting WMA and remote ischemia
Limited Risk + Quick + Easy

- No radiation exposure
  - Particularly important in young women
- No contrast exposure in CKD patients
- Test completed <30 mins
  - Including interpretation
- No issues with claustrophobia
## Cost Efficiency

<table>
<thead>
<tr>
<th>Procedure</th>
<th>National Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT angiography</td>
<td>$483</td>
</tr>
<tr>
<td>Exercise Treadmill ECG</td>
<td>$753</td>
</tr>
<tr>
<td>Stress Echocardiography</td>
<td>$1597</td>
</tr>
<tr>
<td>Cardiac MRI</td>
<td>$2399</td>
</tr>
<tr>
<td>SPECT imaging</td>
<td>$2997</td>
</tr>
<tr>
<td>Diagnostic Catheterization</td>
<td>$2650</td>
</tr>
</tbody>
</table>
Additional Clinical Information

- Left ventricular hypertrophy
- Valvular heart disease
- Pericardial disease
- Right sided heart disease
- Diastology
- Aortic root pathology
Parasternal Long Axis
Parasternal Short Axis
Apical Four Chamber
Apical 2 Chamber
Technical Challenges

- WMA due to HTN or non-ischemic cardiomyopathies
- Tethering
  - Significant calcification of mitral annulus – false +
- Abnormal septal motion
  - LBBB
  - RV apical pacing
  - Post CABG
- Obesity and COPD
Case 1 Summary

- Intermediate risk – pretest probability
  - Middle aged diabetic, hypertensive male

- CAD equivalent patient
  - Prognosis more important than diagnosis.

- Exercise stress protocol
  - No physical limitation and normal repolarization.
### Pretest Probability of CAD

<table>
<thead>
<tr>
<th>Age (y)</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>Intermediate</td>
<td>Very low</td>
</tr>
<tr>
<td>40–49</td>
<td>Men</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
<td>Very 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>Intermediate</td>
<td>Low</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>Intermediate</td>
<td>Low</td>
</tr>
</tbody>
</table>

Gibbons et al. 2002. ACC/AHA Practice Guidelines
Bayes’ Theorem

- The probability of a patient having a disease after a test is performed is a product of:
  - Pretest probability of disease in population tested.
  - Sensitivity and specificity of the test

JACC. 1989;13(7):1653-1665
Exercise ECG vs Exercise SPECT

![Graph showing effects of population prevalence on non-invasive prediction of CAD.](image)

<table>
<thead>
<tr>
<th>Tests</th>
<th>Code</th>
<th>Non-Dx Test</th>
<th>Sensitivity (Dx-Tests)</th>
<th>Specificity (Dx-Tests)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_x$ECG</td>
<td>▲-▲</td>
<td>35</td>
<td>84%</td>
<td>62%</td>
</tr>
<tr>
<td>$201_{TI}$</td>
<td>●-●</td>
<td>9</td>
<td>88%</td>
<td>74%</td>
</tr>
</tbody>
</table>

JACC. 1989;13(7):1653-1665
Why not regular exercise treadmill?

- Sensitivity for single vessel disease
  - 25-60%
- Sensitivity for 3 vessel disease
  - 80-90%
- Prognosis
  - Duke Treadmill score
    - Exercise time -5(ST deviation) -4(anginal index score)
    - >4 = low risk – annual mortality 0.25%
    - >-9 = high risk – annual mortality 5%
<table>
<thead>
<tr>
<th>Criterion for (+) ST</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2.0 mm</td>
<td>10%</td>
<td>97%</td>
</tr>
<tr>
<td>≥ 1.0 mm</td>
<td>75%</td>
<td>65%</td>
</tr>
<tr>
<td>≥ 0.5 mm</td>
<td>90%</td>
<td>45%</td>
</tr>
</tbody>
</table>

MODIFIED RECEIVER-OPERATOR CHARACTERISTIC CURVE
Exercise Echocardiography or Exercise SPECT Imaging?:
A Meta-analysis of Diagnostic Test Performance

Echo vs MPI

- Lower false positives
- Higher specificity
- Significantly higher discriminatory capability

Men: prognosis following Dob Stress echo
Incremental Prognostic Information

Diabetic Risk stratification
Exercise Echocardiography

![Graph showing event rates over years for different vessel distributions.](image-url)
Case 2 Summary

- Intermediate risk – pretest probability
  - Young diabetic hypertensive female
- CAD equivalent: prognosis > diagnosis
- Obese female
  - Higher likelihood of low functional capacity.
- Poor precordial R wave progression
  - Usually not old anterior wall myocardial infarction.
  - ? Bra size – increased chances of anterolateral perfusion abnormality on MPI
- Consider radiation exposure to breast tissue.
  - CTA
  - MPI
  - Coronary angiography
Exercise ECG in Women

- Meta-analysis of 19 trials with at least 50 subjects
  - Mean sensitivity of 61%
  - Mean Specificity of 70%

- High false positive rate
  - Circulation 1977 – false positive rate 38%.

- Higher likelihood of submaximal exercise
Diagnosis of CAD in Women

**Table 3. Comparison of Echocardiography in Patients Undergoing Bicycle or Treadmill Exercise**

<table>
<thead>
<tr>
<th></th>
<th>Treadmill Echocardiography (n = 38)</th>
<th>Bicycle Echocardiography (n = 19)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Abnormal</td>
<td>Normal</td>
</tr>
<tr>
<td>No CAD</td>
<td>17</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>CAD</td>
<td>4</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>80%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Specificity</td>
<td>94%</td>
<td></td>
<td>73%</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>94%</td>
<td></td>
<td>73%</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>91%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>87%</td>
<td></td>
<td>84%</td>
</tr>
</tbody>
</table>

Diagnosis of CAD in Women

Ex echo vs Ex ECG

![Graph showing comparison of sensitivity, specificity, and accuracy between exercise echocardiography (Ex echo) and exercise electrocardiogram (Ex ECG).]

<table>
<thead>
<tr>
<th></th>
<th>High Probability (n = 32)</th>
<th>Intermediate Probability (n = 72)</th>
<th>Low Probability (n = 57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>67 ± 6</td>
<td>61 ± 8</td>
<td>55 ± 10</td>
</tr>
<tr>
<td>Typical angina</td>
<td>32</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Atypical angina</td>
<td>0</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>22</td>
<td>29</td>
<td>8</td>
</tr>
</tbody>
</table>

## Diagnosis of CAD in Women

<table>
<thead>
<tr>
<th>Study</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marwick et al</td>
<td>81%</td>
<td>80%</td>
</tr>
<tr>
<td>Sawada et al</td>
<td>86%</td>
<td>86%</td>
</tr>
<tr>
<td>Williams et al</td>
<td>88%</td>
<td>84%</td>
</tr>
<tr>
<td>Roger et al</td>
<td>85%</td>
<td>46%</td>
</tr>
<tr>
<td>Masini et al</td>
<td>79%</td>
<td>93%</td>
</tr>
</tbody>
</table>
Transpulmonary echoconstrast
Image optimization with Contrast

- Stress Stage:
  - Rest: 72±24 (No Contrast), 95±8 (Contrast)
  - Peak: 67±27 (No Contrast), 96±7 (Contrast)

- Confidence Score:
  - Low: 28 (No Contrast), 4 (Contrast)
  - Medium: 36 (No Contrast), 22 (Contrast)
  - High: 36 (No Contrast), 74 (Contrast)

*P < 0.001, P < 0.001 vs. No Contrast
Gender Differences in Prognosis

Following normal Dobutamine Echocardiography

Risk Stratification in Women

Risk Stratification and Prognosis of High Risk Females Undergoing Stress Echocardiography

Pretest probability of CAD >85%

77% DSE
Dyspnea: a high risk symptom

J Am Coll Cardiol. 2004;43(12):2242-2246
Case 3 Summary

- Known severe CAD s/p surgical revascularization.
  - Atypical symptoms
  - Focus on prognosis prevails
- On medical therapy – not optimized (SBP 140).
- Inferior Q waves
  - Scar versus viable myocardium
- Obese male
  - Diaphragmatic attenuation with MPI
Obstructive disease defined as >50% stenosis.

Predates availability of echo contrast.

Risk Stratification after Revascularization

Bountioukos M et al. Heart 2004;90:1031-1035
Risk Stratification after Revascularization

- **Non-ischaemic DSE**
- **Ischaemic DSE without prior angina**
- **Ischaemic DSE + prior angina**

<table>
<thead>
<tr>
<th>Years of follow up</th>
<th>Non-isch DSE</th>
<th>Isch DSE without angina</th>
<th>Isch DSE + prior angina</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>194</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>1</td>
<td>120</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>68</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

*p = NS*
End-diastolic wall thickness as a predictor of recovery of function in myocardial hibernation
EDWT
High Negative Predictive Value

169 abnormal segments revascularized

EDWT ≤ 0.6 cm
58

EDWT > 0.6 cm
111

Contractile Reserve (-)
47

Contractile Reserve (+)
11

Contractile Reserve (-)
35

Contractile Reserve (+)
76

Rec (-)
45

Rec (+)
9

Rec (-)
32

Rec (+)
26

Rec (-)
2

Rec (+)
3

Rec (-)
3

Rec (+)
50

Recovery (7%)

Recovery (66%)

J Am Coll Cardiol. 2000;35(5):1152-1161
Predicting Viability

![Bar Chart]

- EDWT >0.6 cm: 94%
- Ti-201 ≥60%: 91%
- DSE Biphasic: 88%
- DSE any improvement: 91%
- EDWT >0.6 cm & DSE (any improvement): 88%
- DSE (any improvement): 77%
Sensitivity and specificity of dobutamine stress echocardiography and nuclear imaging for the prediction of functional outcome in acute myocardial infarction

Schinkel A et al. Eur Heart J 2003;24:789-800
Case 4 Summary

- High clinical suspicion for non-ischemic etiology
  - Limited CAD risk factors
  - CHF presentation

- EF too low to base evaluation of coronary anatomy solely on clinical acumen.
  - Further verification required.
  - Clinical optimization may require treatment of any concomitant CAD.
Diagnosing CAD in Dilated Cardiomyopathy

Long-axis excursion normally increases with stress
The Ischemic Cascade

- Flow maldistribution
- Hypoperfusion
- Diastolic dysfunction
- Systolic dysfunction
- ECG changes
- Angina
- Echo

Schinkel A et al. Eur Heart J 2003;24:789-800
Myocardial Contrast Echocardiography
Myocardial Contrast Echocardiography

Salerno M, and Beller G A Circ Cardiovasc Imaging
2009;2:412-424
Myocardial Contrast echocardiography
Enhanced detection of subendocardial ischemia
Myocardial Contrast echocardiography
Enhanced detection of subendocardial ischemia

Dobutamine MCE with normal augmentation but delayed perfusion in inferoseptum

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMR</td>
<td>85%</td>
<td>76%</td>
</tr>
<tr>
<td>MCE</td>
<td>90%</td>
<td>81%</td>
</tr>
</tbody>
</table>

J Am Coll Cardiol Img. 2010;3(9):934-943
Myocardial Contrast Echo Perfusion

Pros
- No ionizing radiation
- Improved spatial resolution compared to MPI
- Better detection of subendocardial ischemia
- Absolute quantification of myocardial blood flow
- 80% concordance with SPECT imaging

Cons
- Attenuation artifacts
- No FDA approved agents – research protocols only.
Strain imaging
### Regional Report (AP2)

<table>
<thead>
<tr>
<th>Segment</th>
<th>Time to Peak</th>
<th>Peak Value</th>
<th>Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>382.58 ms</td>
<td>-28.96 %</td>
<td>-133.85 ms</td>
</tr>
<tr>
<td>BI</td>
<td>516.43 ms</td>
<td>-9.62 %</td>
<td></td>
</tr>
<tr>
<td>MA</td>
<td>469.58 ms</td>
<td>-4.88 %</td>
<td>194.64 ms</td>
</tr>
<tr>
<td>MI</td>
<td>274.94 ms</td>
<td>-15.38 %</td>
<td></td>
</tr>
<tr>
<td>ApA</td>
<td>692.66 ms</td>
<td>-11.84 %</td>
<td></td>
</tr>
<tr>
<td>ApI</td>
<td>288.33 ms</td>
<td>-21.26 %</td>
<td></td>
</tr>
</tbody>
</table>

Max. Delay = 417.71 ms

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**Quantifiable Data**
Left Ventricular 3D imaging
Quantitative Evaluation of Regional LV systolic dysfunction
Survival free of cardiac death and myocardial infarction are shown in men and women, with exercise capacity $\geq$6 metabolic equivalent (METs) and <6 METs. 

Prognostic value of exercise echocardiography