Cardiac Stress testing:
Choosing the Right Test and When

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Disclosures and conflict of interest

None
Objectives

1. To be able to choose the optimal type of stress tests for a patient with suspected ischemic heart disease

2. To understand diagnostic accuracy of different stress tests

3. To be able to explain basics of each stress test to a patient

4. To know contraindications to stress testing
CASE 1.

A 70 yo M with DM, HTN, severe COPD on home oxygen at 4 L/min (quit tobacco 2014), who was recently evaluated by Family Medicine for worsening shortness of breath for the past 2 weeks.

Which stress test is most appropriate?

A. Treadmill Exercise  
B. Treadmill + Stress ECHO  
C. Treadmill + Nuclear myocardial perfusion scan  
D. Pharmacological Nuclear myocardial perfusion scan  
E. Dobutamine Stress Echo  
F. Coronary angiography
CASE 2.

A 62 yo M with HTN, hypercholesterolemia and atypical chest pain that sometimes happens during exercise, but also at rest. He has known chronic and poorly controlled atrial fibrillation in the setting of LBBB, recently underwent pacemaker implantation.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
CASE 3.

A 58 yo policeman with medically treated 65% mid LAD stenosis (cath 2011), recently noticed some chest pain while exercising at the gym.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
CASE 4.

A 49 yo F with strong family history of premature CAD, BMI 30, HTN, 3 weeks ago joined weight loss exercise program and started having chest pressure with exertion. Baseline ECGs show T wave inversions in leads II, III, aVF and V5-V6.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
CASE 5.

A 68 yo M with DM2, CKD, HTN, LDL 123, reports having L sided chest pressure with minimal exertion for the past 2 months, getting worse with multiple daily episodes within the past week. Last night woke up at 3AM due to 7/10 chest pain. ECG shows LBBB.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
**Principles of stress testing**

- Functional or stress testing is the “gold standard” noninvasive test to induce ischemia and diagnose ischemic heart disease.

- The production of ischemia depends on the severity of stress imposed (i.e., submaximal exercise can fail to produce ischemia) and the severity of the flow disturbance.

- Coronary stenoses < 70% are often undetected by functional testing.

- Noninvasive diagnostic tests range from evidence on technical quality through test accuracy (sensitivity and specificity associated with test interpretation), to changes in diagnostic thinking, effect on patient management, and patient outcomes, to societal costs and benefits.
Bayes’ Theorem

Thomas Bayes, an English theologian and mathematician who was the first to use probability assessments inductively.

The probability of a new event, or ‘true’ positive stress test, depends on the pre-test risk of the patient which have been derived from empiric data.
Probability of Coronary Artery Disease

The diagram illustrates the probability of coronary artery disease (CAD) based on pre-test clinical probability and post-test findings. The x-axis represents the pre-test (clinical) probability of CAD (%), ranging from 0 to 100. The y-axis shows the post-test probability of CAD (%), ranging from 0 to 100.

Key findings include:
- Individuals with no risk factors have a lower post-test probability of CAD regardless of pre-test probability.
- Individuals with atypical chest pain have a higher post-test probability of CAD compared to those with typical angina.
- The presence of ST segment changes (ST+) and ST segment changes (ST-) affect the post-test probability of CAD.

The graph visually represents how different clinical findings can alter the probability of CAD, providing a clear understanding of risk assessment in this context.
# Chest Pain:

<table>
<thead>
<tr>
<th>Type</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Angina</td>
<td>3/3</td>
</tr>
<tr>
<td>Atypical Chest Pain</td>
<td>2/3</td>
</tr>
<tr>
<td>Non Anginal Chest Pain</td>
<td>1/3</td>
</tr>
</tbody>
</table>

Typical Angina
- Substernal chest pain
- Brought on by exertion
- Relieved with rest or nitroglycerin
Diagnostic testing is most valuable in INTERMEDIATE pre-test probability of Ischemic heart disease

Table 9. Pretest Likelihood of CAD in Symptomatic Patients According to Age and Sex* (Combined Diamond/Forrester and CASS Data)

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Nonanginal Chest Pain</th>
<th>Atypical Angina</th>
<th>Typical Angina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>30-39</td>
<td>4</td>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>40-49</td>
<td>13</td>
<td>3</td>
<td>51</td>
</tr>
<tr>
<td>50-59</td>
<td>20</td>
<td>7</td>
<td>65</td>
</tr>
<tr>
<td>60-69</td>
<td>27</td>
<td>14</td>
<td>72</td>
</tr>
</tbody>
</table>

CAD indicates coronary artery disease; and CASS, Coronary Artery Surgery Study.

*Each value represents the percent with significant CAD on catheterization.

Adapted from Forrester and Diamond (52,73).

50-yo man with atypical angina, the probability of CAD is ~50%
Types of stress to provoke ischemia

Patient CAN exercise

1. Treadmill
2. Treadmill + ECHO
3. Treadmill + SPECT Nuclear stress test

Patient can NOT exercise

Pharmacological

Vasodilator
- Regadenosone
- Adenosine

Beta-agonist
- Dobutamine

4. SPECT Nuclear stress test
5. PET Nuclear stress test
6. Dob ECHO

↑ myocardial work and oxygen demand

Induce vasodilation-elicited heterogeneity in induced coronary flow
## Diagnostic accuracy and cost comparison

<table>
<thead>
<tr>
<th>Type of stress test:</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Tech+Prof fees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>UIHC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$</td>
</tr>
<tr>
<td>Treadmill</td>
<td>61-68% F</td>
<td>70-77% F</td>
<td>1,137</td>
</tr>
<tr>
<td></td>
<td>68% M</td>
<td>77% M</td>
<td></td>
</tr>
<tr>
<td>Treadmill + Stress ECHO</td>
<td>70-85%</td>
<td>77-89%</td>
<td>2,994</td>
</tr>
<tr>
<td>Treadmill + SPECT Nuc MPI</td>
<td>82-88%</td>
<td>70-88%</td>
<td>5,823</td>
</tr>
<tr>
<td>Pharm SPECT Nuclear MPI</td>
<td>88-91%</td>
<td>75-90%</td>
<td>5,823</td>
</tr>
<tr>
<td>Pharm PET Nuclear MPI</td>
<td>92-93%</td>
<td>83-85%</td>
<td>5,975</td>
</tr>
<tr>
<td>Dobutamine Stress test</td>
<td>85-90%</td>
<td>79-90%</td>
<td>2,994</td>
</tr>
</tbody>
</table>

MC* - Medicare coverage

*Courtesy: J. Bluemke MS-HSM

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Sampson UK et al, J Am Coll Cardiol. 2007 Mar 13;49(10):1052-8
Pellikka PA et al, ASE Recommendations for Performance, Interpretation, and Application of Stress Echocardiography. JASE 2007; 1021
2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the Diagnosis and Management of Patients With Stable Ischemic Heart Disease
To Stress or Not To Stress?

- Management of most stable CAD with medical therapy first rather than routine PCI.

- Significant cost and harm is associated with unnecessary testing, false positives, and additional procedures.

- Information from stress testing should be meaningful to direct management.
Indications for stress testing

1. To diagnose and risk stratify patients with suspected CAD, or known CAD with a change in clinical status

2. To assess location and degree of ischemia in those with known CAD prior to revascularization

3. To determine effectiveness of medical therapy and/or revascularization therapy in patients with CAD
Types of stress to provoke ischemia

Patient CAN exercise

1. Treadmill
2. Treadmill + ECHO
3. Treadmill + SPECT Nuclear stress test

IMAGING

↑ myocardial work and oxygen demand

Patient can NOT exercise

Pharmacological

- Vasodilator
  - Regadenosone
  - Adenosine
- Beta-agonist
  - Dobutamine

- SPECT Nuclear stress test
- PET Nuclear stress test
- Dob ECHO

Induce vasodilation-elicited heterogeneity in induced coronary flow
Treadmill Exercise Stress Test

1918 - *Bousfield* noted ST depressions during angina
1929 - *Masters* and *Oppenheimer* developed a standardized exercise test

↑ Cardiac Output, ↑ Stroke Volume
↑ Sympathetic discharge
↓ Parasympathetic discharge
↑ Epinephrine/NE
↑ Skeletal blood flow, ↓ PVR
↑ SBP, ↓/= DBP

**End-Point:** Heart Rate, Blood Pressure, Exercise Capacity, ECG, Symptoms

**Target HR:** 220 - patient’s age (SD: 10-12 beats/min) x 0.85

- Time: ~30 min; STAFF: cardiac therapist, cardiologist
- Achieve 85% max predicted HR (220-age), for an optimal test
- Bruce Protocol starts at 1.7 mph / 10% grade, speed and grade increase q 3 min
- Hold beta-blocker therapy for 24-48 h before testing, depending on objectives
- **Patient should eat breakfast, wear sport shoes/clothes**
Treadmill Exercise Stress Test

**Indications**
- Best in patients at intermediate risk for CAD
- Normal resting ECG (including RBBB)
- Moderate physical functioning or no disabling comorbidity

**Advantages**
- Widely available
- Least expensive
- Provides a good measure of functional capacity

**Limitations**
- Non-diagnostic with abnormal baseline ECG:
  - LBBB, paced rhythm, LVH, ST-segment depressions ≥ 0.5 mm
- Lower sensitivity and specificity than imaging
- Non-localizing (unless ST segment elevations)
Absolute contraindications to Exercise Stress Testing

- Recent myocardial infarction (within 2-4 days)
- Unstable angina
- Uncontrolled and hemodynamically compromising arrhythmia
- Active endocarditis
- Severe and symptomatic aortic stenosis
- Decompensated heart failure
- Acute pulmonary embolism/deep vein thrombosis
- Acute myocarditis and/or pericarditis
- Active Aortic dissection
- Physical disability that compromises patient’s safety

Relative contraindications to Exercise Stress Testing

- Obstructive left main stenosis
- Moderate to severe aortic stenosis
- Arrhythmia with uncontrolled heart rates
- Advanced or complete heart block
- Hypertrophic obstructive cardiomyopathy with severe resting gradient
- Recent cerebrovascular event
- Limited ability to cooperate
- Blood pressures >200/110 mmHg at rest
- Uncorrected medical conditions (anemia, electrolyte imbalance, hyperthyroidism, etc.)
Treadmill Exercise Stress Test - Prognostic findings

**Favorable**

- Workload > 10 METS (IV/Bruce protocol) < 1% mortality

**Unfavorable**

- Workload < 4 METS (Bruce < I)
- ST depression > 1mm 5% mortality
- Duration of symptom limited exercise < 6 METS
- Failure to increase systolic BP > 120 mmHg or sustained decrease in BP >10 mm Hg below rest
- ST depression > 2 mm at < 6 METS, > 5 leads, persisting > 5 min recovery
- Exercise induced ST elevation
- Angina pectoris at low exercise workloads
- Reproducible sustained or symptomatic VT

Weiner DA et al, Prognostic Importance of a Clinical Profile and Exercise Test in Medically Treated Patients With Coronary Artery Disease. JACC, 1984;3:772
Duke treadmill score:

Exercise minutes - (ST deviation in mm x 5) - (angina index x 4)

0 = none
1 = non-limiting CP
2 = exercise-limiting CP

<table>
<thead>
<tr>
<th>Score</th>
<th>Risk Level</th>
<th>5 year survival rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;-11</td>
<td>HIGH RISK</td>
<td>75%</td>
</tr>
<tr>
<td>-10 to 4+</td>
<td>MODERATE RISK</td>
<td>75-95%</td>
</tr>
<tr>
<td>≥+5</td>
<td>LOW RISK</td>
<td>97%</td>
</tr>
</tbody>
</table>

• **HX:** 60 yo M, BMI 25, no cardiac history referred by Family Practice for palpitations. Resting Echo was normal, EF 56%. Reports 2 weeks of frequent palpitations with 2/10 chest tightness and neck pain. Physically very active, kayaking almost daily.

• **PMH:** Palpitations 10 years ago, psoriasis

• **MEDS:** none

• **PE:** BP 120/57, P 50; no elevated JVP; clear lungs; regular rate without murmur; no lower extremity edema; good distal pulses

• **Labs:** Tch 166, HDL 43, TG 59, LDL 111 mg/dL, TSH nl, K 4.0, Mg 1.9
Baseline ECG

Resting HR : 63 bpm

Resting BP: 126/74 mmHg

NSR, Multiple PVCs with ventricular trigeminy
Peak Exercise ECG

Peak HR: 126  Peak BP: 179/66  METS: 12.8 (10 min)
79% MPHR  Chest pain: none

1.5 mm ST elevations, 2 mm inferolateral ST depressions, PVCs

Coronary Angiography

Multivessel obstructive CAD involving left main LM 35%, LAD 40% - 95%, D1 50%, LCx 80%, OM2 70%, RCA 40%
Indications for cardiac imaging

1. Left bundle branch block (LBBB)
2. Paced rhythms
3. Abnormal ST segment at baseline, 0.5 mm
4. Digoxin effect
5. LVH with repolarization abnormalities
6. Wolff-Parkinson-White syndrome (WPW)
7. Patients with prior revascularization
8. Consider use in women
Types of stress to provoke ischemia

Patient CAN exercise

Exercise

1. Treadmill
2. Treadmill + ECHO
3. Treadmill + SPECT Nuclear stress test

IMAGING

↑ myocardial work and oxygen demand

Patient can NOT exercise

Pharmacological

Vasodilator
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Induce vasodilation-elicted heterogeneity in induced coronary flow
**End-Point:**

HR, BP, Exercise Capacity, ECG, Symptoms, ECHO images, Wall motion abnormalities and POST peak LVEF

**Target HR:**

220 - patient’s age \( (SD: 10-12 \text{ beats/min}) \times 0.85 \)

- Time: \(~1\text{h}\); STAFF: sonographer, ECG tech/cardiac rehab, cardiologist
- Achieve 85% max predicted HR (220-age), for an optimal test
- Bruce Protocol starts at 1.7 mph / 10% grade, speed and grade increase q 3 min
- Beta-blocker may be held for 24-48 h, depending on clinical objectives
- **Patient should eat breakfast, wear sport shoes/clothes**
Treadmill + Stress ECHO

**Advantages**
- Readily available
- Provides direct visualization of wall motion, LV function, and anatomy
- Can localize region of abnormality
- May detect valvular abnormalities
- Higher specificity than perfusion imaging (77-89% vs 70-88%)
- Higher sensitivity than Treadmill alone (70-85% vs 61-68%)
- No radiation

**Limitations**
- Technically difficult with poor acoustic windows
- Requires an experienced sonographer
- Less sensitive than myocardial perfusion imaging (requires ischemia)
- Fewer clinical data than perfusion imaging
- Interpretation is subjective
- Interpretable image quality may be obtained during submaximal HR
### Treadmill Exercise + ECHO Stress Test - Prognostic findings

<table>
<thead>
<tr>
<th>Outcome After Normal Exercise Echocardiography and Predictors of Subsequent Cardiac Events: Follow-Up of 1,325 Patients /23 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROBERT B. MCCULLY, MB, ChB, FACC, VERONIQUE L. ROGER, MD, FACC,</td>
</tr>
<tr>
<td>DOUGLAS W. MAHONEY, MS, BARRY L. KARON, MD, FACC, JAE K. OH, MD, FACC,</td>
</tr>
<tr>
<td>FLETCHER A. MILLER, Jr., MD, FACC, JAMES B. SEWARD, MD, FACC,</td>
</tr>
<tr>
<td>PATRICIA A. PELLIKKA, MD, FACC</td>
</tr>
<tr>
<td>Rochester, Minnesota</td>
</tr>
</tbody>
</table>

- **MACE event rate of** 0.9% per year: cardiac death, nonfatal MI, coronary revascularization

- Multivariate predictors of cardiac events: angina, low work load, LVH, and advancing age

- **Excellent outcomes**: event free survival was 99.2%, 97.8%, and 97.4% at 1, 2, and 3 years

- False-negative stress Echo is more common in patients with single-vessel disease or disease of the left circumflex artery (smaller supply)

*Pellikka PA et al, ASE Recommendations for Performance, Interpretation, and Application of Stress Echocardiography. JASE 2007; 1021*
Normal ECHO Stress Test - Example

Hemodynamics:
- Protocol: Bruce
- Max Predicted HR: 166 bpm
- % Mex Predicted HR: 88%
- Peak BP: 182/84 mmHg
- Stress duration: 9.32 min
- METS: 10

Normal Resting Echo images:

Normal Stress Echo images:

**HX:** 31 yo M, musician, BMI 24, ex-smoker, no family history of cardiac disease, now with exertional chest tightness and SOB during bad concerts.

**PMH:** ex-smoker

**MEDS:** none

**PE:** BP 110/70, P 58; no elevated JVP; clear lungs; regular rate without murmur; no lower extremity edema; good distal pulses

**Labs:** Tch 124, HDL 33, TG 45, LDL 82
Baseline ECG

Resting HR: 92 bpm  
Resting BP: 106/69 mmHg

NSR, no STT changes
Peak Exercise ECG

Peak HR: 167
Chest pain: 2/10
Peak BP: 157/59
88% MPHR
METS: 10 (9 min)

2 mm antero-lateral ST depressions, 1 mm ST elevations in aVR
Hemodynamics

Protocol: Bruce
Max Predicted HR: 189 bpm
% Mex Predicted HR: 88%
Peak BP: 157/69 mmHg
Stress duration: 9.2 min
METS: 10


Normal Resting Echo images

Abnormal Stress Echo images
Coronary Angiography

Lack of left main coronary due to giant cell vasculitis

Left Coronary Arteries

Right Coronary Artery
When should we order Treadmill Stress ECHO vs Treadmill Stress Test + Transthoracic ECHO?
Back to the CASE: 31 yo M

Treadmill exercise ECG: ABNORMAL

Resting Echo images: NORMAL

True Positive vs False Positive?
Types of stress to provoke ischemia

- **Exercise**
  - 1. Treadmill
  - 2. Treadmill + ECHO
  - 3. Treadmill + SPECT Nuclear stress test

- **Pharmacological**
  - Vasodilator
    - Regadenosone
    - Adenosine
  - Beta-agonist
    - Dobutamine
  - 4. SPECT Nuclear stress test
  - 5. PET Nuclear stress test
  - 6. Dob ECHO

**Induce vasodilatation-elicited heterogeneity in induced coronary flow**

**↑ myocardial work and oxygen demand**
Treadmill Exercise + SPECT Nuclear Myocardial Perfusion Scan

**Resting images** → **Exercise** → **Post-stress images**

**End-Point:** HR, BP, Exercise Capacity, ECG, Symptoms and coronary flow:
- Rest: >90% stenosis detection
- Stress: >50% coronary stenosis detection

**Target HR:** 220 - patient’s age (SD: 10-12 beats/min) x 0.85

- Time 1h; STAFF: Cardiac rehab/ARNP, nuclear tech, Cardiologist/Radiologist
- Bruce Protocol starts at 1.7 mph / 10% grade, speed and grade increase q 3 min
- Gated SPECT Tc99m agents have high photon flux which permits ECG gating
- Quinones et al.: 292 patients, exercise ECHO vs SPECT vs Cath
  Exercise ECHO and SPECT have comparable diagnostic accuracy:
  - 85% vs 85% sensitivity; 88% vs 81% specificity
- Prefer NPO → possible vasodilator conversion if submaximal HR

SPECT Nuclear Myocardial Perfusion Scan

Application:
- LBBB or paced rhythm
- Tachydysrhythmias
- Beta blocker medication

Advantages
- Can be used in patients with moderate to high pre-test probability
- Perfusion and function
- Can localize disease
- Can risk stratify
- Pharmacologic stress may be performed
- Higher sensitivity than stress echo (flow heterogeneity)

Limitations
- Relatively expensive
- Decreased specificity (attenuation artifact)
- Radiation exposure

<table>
<thead>
<tr>
<th>Compares perfusion</th>
<th>Rest vs Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>N</td>
</tr>
<tr>
<td>Ischemia</td>
<td>N</td>
</tr>
<tr>
<td>Scar</td>
<td>Abn</td>
</tr>
</tbody>
</table>

Long Vertical Axis
Long Horizontal Axis
Short Axis
Nuclear Myocardial Perfusion Scan

**Radiation:**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Radiation Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo/EKG</td>
<td>None</td>
</tr>
<tr>
<td>Chest X ray (for comparison)</td>
<td>0.1 mSv</td>
</tr>
<tr>
<td>Coronary Angiogram</td>
<td>7 mSv (~15 PCI)</td>
</tr>
<tr>
<td>Cardiac CT Angiography</td>
<td>10-16 mSv</td>
</tr>
<tr>
<td>Nuclear Stress:</td>
<td></td>
</tr>
<tr>
<td>SPECT - Tc-99</td>
<td>10-12 mSv</td>
</tr>
<tr>
<td>PET - 82 Rubidium</td>
<td></td>
</tr>
<tr>
<td>Nuclear Stress – Thallium</td>
<td>17 -29 mSv</td>
</tr>
</tbody>
</table>

Mark DB et al, JACC, 2010:55;2663-2699

**High Risk Scan Findings:**

- Multiple reversible defects
- Large perfusion defects
- Increased lung radiotracer uptake
- Transient dilatation of the left ventricle
- Depressed resting left ventricular ejection fraction
- Increased right ventricular radiotracer uptake
• HX: 69 yo man with HTN and FH of CAD, seen by Family Practice noting recent chest pain (difficult historian)

• PMH: S/P prostatectomy due to cancer

• MEDS: ASA, Enalapril, Norvasc, HCTZ

• PE: BP 170/80 mmHg, HR 66 bpm; Normal physical exam, no JVP, no murmurs, clear lungs, no leg edema
Baseline ECG

Normal resting ECG

Courtesy of Paul Lindower, MD
### Peak Exercise ECG

**Protocol:** Bruce  
**Exercise time:** 4.18 min  
**Resting HR:** 63  
**Resting BP:** 166/76  
**Peak HR:** 130  
**Chest pain:** 2/10

![ECG Image](image-url)  

2 mm infero-lateral ST depressions at peak exercise

*Courtesy of Paul Lindower, MD*
Large, severe, reversible defect involving the anterior wall, septum, apex and inferior wall -> Cath confirmed 85% mid LAD stenosis
Types of stress to provoke ischemia

Patient CAN exercise

1. Treadmill
2. Treadmill + ECHO
3. Treadmill + SPECT Nuclear stress test

Patient can NOT exercise

Exercise

Pharmacological

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- Regadenosone
- Adenosine

Beta-agonist
- Dobutamine

4. SPECT Nuclear stress test
5. PET Nuclear stress test
6. Dob ECHO

Induce vasodilation-elicited heterogeneity in induced coronary flow

↑ myocardial work and oxygen demand
Pharmacological Nuclear Myocardial Perfusion Scan

**Resting images**  **IV Vasodilator**  **1-2 min Exercise**  **Post-stress images**

**End-Point:** ECG, symptoms and coronary flow:
- Rest: >90% stenosis detection
- Stress: >50% coronary stenosis detection

- Time: <1h; STAFF: Fellow/ARNP, Nuclear tech, Cardiologist/Radiologist
- Vasodilators (adenosine, regadenoson) act to increase blood flow to normal arteries while decreasing perfusion to stenotic vessels
- Gated SPECT Tc99m agents have high photon flux which permits ECG gating
- PET has high spatial resolution; blood flow tracers 82 Rubidium/13N ammonia
- NPO, 12h prior to the test - avoid theophylline or caffeine-containing foods
- Must lie flat/stay still, able to place arms over the head

Vasodilators

Adenosine receptors:

- **A1 receptors**
  - Heart, AV node blocker
- **A2A receptors**
  - Coronary SMCs hyperemia
- **A2B and A3 receptors**
  - Bronchial SMCs

Adenosine: non-selective receptor agonist
Regadenoson: adenosine derivative; more selective A2A receptor agonist

Caffeine: **A2A receptor antagonist** – lowers hyperemic response

"12 hours or less, no pharm stress"

https://cdn.intechopen.com

Safety Considerations

Lexiscan can cause serious or fatal heart attacks, abnormal heart rhythms, cardiac arrest or serious allergic reactions. Lexiscan should not be given to patients with signs or symptoms of acute blood loss to the heart because they may be at greater risk of serious heart reactions. Trained staff should be immediately available while you are receiving Lexiscan.
Pharmacological Nuclear Myocardial Perfusion Scan

**Indications:**
- Abnormal baseline ECG: Atrial fibrillation, LBBB, paced, LVH etc
- Unable to exercise adequately
- Patients with prior revascularization
- Patients with a higher likelihood for disease
- Poor Echo acoustic window

**Advantages:**
- After successful PCI, to evaluate symptoms suggesting new disease
- Ischemia assessment after CABG
- Prior to intermediate or high risk non-cardiac surgery
- PET has higher sensitivity for CAD detection, in women and obese

**Disadvantages:**
- Risk of drug-specific adverse events: bronchospasm in COPD, AV block
- Global reductions in myocardial perfusion (i.e. left main or 3V CAD), can result in balanced reduction ischemic burden
- Radiation

Determinants of Risk and its Temporal Variation in Patients With Normal Stress Myocardial Perfusion Scans

What Is the Warranty Period of a Normal Scan?
Rory Hachamovitch, MD, MSc, FACC,* Sean Hayes, MD,† John D. Friedman, MD, FACC,†
Ishac Cohen, PHD,† Leslee J. Shaw, PHD,‡ Guido Germano, PHD, MBA, FACC,†
Daniel S. Berman, MD, FACC†
Los Angeles, California; and Atlanta, Georgia

7,376 patients; MACE: Death and MI 0.6% /year

Patients with reversible defects are at greater risk for perioperative ischemia than are those with fixed defects

Normal scan: Negative Predictive Value = 96% - 100%
Ischemia detected: Positive Predictive Value = 4% - 20%

Raiker K et al, One-year prognosis of patients with normal planar or single-photon emission computed tomographic technetium 99m-labeled sestamibi exercise imaging. Journal of Nuclear Cardiology, 1994, 449-456

• HX: 44 yo M, BMI 39, new onset chest pain and hypertensive urgency

• PMH: DM 2 diagnosed 2 weeks ago, HTN, Asthma

• MEDS: ASA, amlodipine, atorvastatin, metformin, sertraline

• PE: BP 179/113 mmHg, HR 86 bpm; Normal physical exam, no JVP, no murmurs, clear lungs, no leg edema

• Labs: cr 1.2, Trop T 0.05, Glc 421, Tch 303, HDL 34, TG 202, LDL 229
Baseline ECG

NSR, nonspecific STT changes
Large-sized area of severely decreased uptake in the inferoseptal wall. This defect is almost fully reversible on rest images, EF 44%.
Coronary Angiography

Right Coronary Artery stenosis

Left Coronary Arteries

Right Coronary Artery
Types of stress to provoke ischemia

- **Exercise**
  - 1. Treadmill
  - 2. Treadmill + ECHO
  - 3. Treadmill + SPECT Nuclear stress test

- **Pharmacological**
  - Vasodilator
    - Regadenosone
    - Adenosine
  - Beta-agonist
    - Dobutamine
  - 4. SPECT Nuclear stress test
  - 5. PET Nuclear stress test
  - 6. Dob ECHO

Induce vasodilation-elicited heterogeneity in induced coronary flow

Patient CAN exercise

Patient can NOT exercise

↑ myocardial work and oxygen demand
**Dobutamine Stress Echocardiogram**

**End-Point:** HR, ECG, Symptoms and ECHO images, Wall motion abnormalities (demand state), PEAK stress LVEF

**Dobutamine:** Beta-agonist: ↑ Heart Rate, ↑ Inotropy

**Target HR:** 220 - patient’s age (SD: 10-12 beats/min) x 0.85

- **Time:** 1.5-2h; **STAFF:** sonographer, ECG tech/cardiac rehab, RN, fellow, cardiologist
- **A graded Dob infusion starting at** 5 - 10 - 20 - 30 - 40 μg/kg/min, q 3 min
- **Achieve 85% max predicted HR (220-age), for an optimal test**
- **Beta-blocker should be held for 24-48h (Beta blocker ↔ Beta agonist)**
- **Patient can eat breakfast**
Dobutamine Stress Echocardiogram

**Application:**
- Reactive airway disease, severe COPD
- Second degree AV block
- Caffeine consumption within 24 h

**Advantages:**
- Used for risk-stratifying patients prior to vascular surgery
- Preferred over vasodilator nuclear test for assessment of regional wall motion
- At low-dose stages allows viability and ischemia assessment in segments with abnormal function at rest
- No radiation

**Disadvantages:**
- Small risk of drug-specific adverse events: VT/VF and MI (1:2,000)
- Poor image quality (patients with advanced lung disease)
- May need Atropine (max 2mg) to augment HR
- Intolerable symptoms: palpitations, nausea, headache, tremor, anxiety

*Pellikka PA et al, ASE Recommendations for Performance, Interpretation, and Application of Stress Echocardiography. JASE 2007; 1021*
Prediction of Mortality Using Dobutamine Echocardiography

Thomas H. Marwick, MBBS, PhD, FACC,* Colin Case, MS,* Stephen Sawada, MD, FACC;† Curtis Rimmerman, MD, FACC,‡ Patricia Brenneman, BA,‡ Roxanne Kovacs, MSN,‡ Leanne Short, BS,* Michael Lauer, MD, FACC†
Queensland, Australia; Cleveland, Ohio; and Indianapolis, Indiana

- 3,156 patients, 9 years follow up
- MACE event risk after a normal Dobutamine Echo: 1-2%
- The risk increases with the extent of abnormal wall motion at rest and stress
- High risk is most reliable when ischemia is detected in the LAD territory; less reliable in patients with DM

53 yo M with severe PVD and claudication, new onset chest pain
Test terminated due to 9/10 chest and current of injury

Peak dobutamine infusion: infero-lateral ST segment elevations on ECG
Apical dyskinesis + chest pain -> 3 vessel CAD, 100% RCA \(\rightarrow\) medical management
Questions to consider when ordering a stress test:

1. Patient’s pre-test probability of CAD?
2. Reason for ordering stress test? Hold Beta-blocker or not?
3. Advantages and limitations of different stress testing modalities?
4. Ability to exercise?
5. Normal or abnormal resting ECG?
6. Female (consider adding imaging) or male gender
7. Comorbidities i.g. severe COPD on oxygen (Dobutamine)?

Cost:
Treadmill EKG < Stress echo < SPECT < PET < Cath
### How to order a stress test?

<table>
<thead>
<tr>
<th>After visit</th>
<th>Name</th>
<th>Test Description</th>
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<tr>
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<td><strong>ECG-EXERCISE EKG (TREADMILL)</strong></td>
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<tr>
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<td><strong>ECHO ADULT - EXERCISE STRESS ECHOCARDIOGRAM</strong></td>
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<td><strong>NUC MYOCARD PERFUSION REST &amp; TREADMILL STRESS, SPECT (78452)</strong></td>
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<td><strong>NUC MYOCARDIAL PERFUSION REST &amp; PHARM STRESS, SPECT (78452)</strong></td>
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<td><strong>PET MYOCARDIAL PERFUSION REST &amp; STRESS (78492)</strong></td>
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<td><strong>ECHO ADULT - DOBUTAMINE ECHOCARDIOGRAM</strong></td>
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</tbody>
</table>
CASE 1.

A 70 yo M with DM, HTN, severe COPD on home oxygen at 4 L/min (quit tobacco 2014), who was recently evaluated by Family Medicine for worsening shortness of breath for the past 2 weeks.

Which stress test is most appropriate?

A. Treadmill Exercise  
B. Treadmill + Stress ECHO  
C. Treadmill + Nuclear myocardial perfusion scan  
D. Pharmacological Nuclear myocardial perfusion scan  
E. Dobutamine Stress Echo  
F. Coronary angiography
CASE 2.

A 62 yo M with HTN, hypercholesterolemia and atypical chest pain that sometimes happens during exercise, but also at rest. He has known chronic and poorly controlled atrial fibrillation in the setting of LBBB, recently underwent pacemaker implantation.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
CASE 3.

A 58 yo policeman with medically treated 65% mid LAD stenosis (cath 2011), recently noticed some chest pain while exercising at the gym.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
CASE 4.

A 49 yo F with strong family history of premature CAD, BMI 30, HTN, 3 weeks ago joined weight loss exercise program and started having chest pressure with exertion. Baseline ECGs show T wave inversions in leads II, III, aVF and V5-V6.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
CASE 5.

A 68 yo M with DM2, CKD, HTN, LDL 123, reports having L sided chest pressure with minimal exertion for the past 2 months, getting worse with multiple daily episodes within the past week. Last night woke up at 3AM due to 7/10 chest pain. ECG shows LBBB.

Which stress test is most appropriate?

A. Treadmill Exercise
B. Treadmill + Stress ECHO
C. Treadmill + Nuclear myocardial perfusion scan
D. Pharmacological Nuclear myocardial perfusion scan
E. Dobutamine Stress Echo
F. Coronary angiography
Thank you

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