Stress Testing for Nuclear Medicine Technologists

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Clinical Applications Specialist
GE Healthcare
Historical Perspective

• When was the first Stress Test performed?
  1928 by Feil and Seigel on 3 patients

• Who developed the treadmill protocols we use today?
  Dr. Robert Bruce in 1963
Objectives

1. Purpose of stress testing
2. The preparation
3. How is stress testing done
4. The results
5. Other measured variables
The purpose of stress testing

- To obtain diagnostic and prognostic information
- To evaluate an individual's capacity for dynamic exercise
- To provoke symptoms in a safe environment

*Nuclear Cardiology: The Basics How to Set Up and Maintain a Laboratory. Wackers FJT, Bruni W, and Zaret B. Humana Press, Totowa
Methods of Stress Testing

- Bicycle ergometer or arm ergometer
- Exercise treadmill
- Pharmacologic stress
  - Dipyridamole (Persantine)
  - Adenosine
  - Dobutamine (Not FDA Approved)
  - A₂A Adenosine Agonists (Lexiscan FDA approved 4/10/08)
Indications

- Diagnosis of Coronary Artery Disease (CAD)
- Risk assessment and prognosis in patients with symptoms or a prior history of CAD
- Post MI/ACS
- Prior to non-cardiac surgery
- Recurrent symptoms post-revascularization
- Evaluation of exercise-induced arrhythmia
- Evaluation of medical therapy

Contraindications to physical exercise testing
Contraindications - Absolute

- Acute myocardial infarction (MI) (<2 to 4 days)
- Unstable angina
- Uncontrolled arrhythmias
- Severe aortic stenosis
- Uncontrolled heart failure
- Acute pulmonary embolus
- Aortic dissection
- Acute myocarditis/pericarditis
- Severe pulmonary hypertension
- Uncontrolled hypertension (>200/110 mm Hg)
- Inability to exercise

Contraindications - Relative

• Left main coronary artery stenosis
• Moderate stenotic valvular heart disease
• Electrolyte abnormalities
• Severe arterial hypertension
• Tachyarrhythmias or bradyarrhythmias
• Hypertrophic obstructive cardiomyopathy and other forms of outflow tract obstruction
• Mental or physical impairment leading to the inability to exercise adequately
• High degree atrioventricular block
• Acute systemic illness
• No MD/resuscitation or equipment malfunction

Vasodilator Stress Indications

- Inability to exercise (~6 minutes)
- Blunted HR response (medications)
- Left Bundle-Branch Block (LBBB)
- Ventricular paced rhythm
- Evaluation of patients early after AMI (<3 days) or angioplasty/stent (< 2 weeks)

Vasodilator Stress Contraindications

- **Absolute**
  - Asthma (severe or ongoing wheezing)
  - > 1st degree heart block
  - Systolic BP < 90 mmHg
  - Dipyridamole use < 24 hours (No adenosine)
  - Xanthines (caffeine, aminophylline, etc) < 12 hrs

Vasodilator Stress Contraindications

- **Relative**
  - Severe sinus bradycardia (HR <40 bpm)
  - Known hypersensitivity to adenosine or dipyridamol
  - Unstable acute MI or acute coronary syndrome

Pre-test instructions

Nuclear Medicine Myocardial Perfusion

Pre-Procedure Instructions  Patient Name ____________________________ Procedure ____________________________

Date ____________________________ Arrival Time ____________________________

Ordering Physician ____________________________

This procedure is completed in two steps, a stress portion and a resting portion. The entire test takes approximately six hours to complete. It is important you clarify with the person scheduling your test which portion will be completed first and how long of a break will be required in between tests. Some patients who are unable to exercise will be given medications instead of exercising on a treadmill. Both portions of the test use a radiopharmaceutical that is injected in the heart muscle and allows a special camera to take pictures of how well your heart is functioning. The amount of radiation you will receive is similar to that of a chest x-ray. To make sure we protect your safety and get the most accurate test results, it is important that you follow these general instructions prior to your procedure.

☐ Do NOT eat or drink anything containing caffeine for 24 hours prior to your test. This includes coffee, decaffeinated coffee, tea, soda and chocolate. Should you have caffeine, your test may need to be rescheduled.

☐ CLARIFY with the person scheduling your test whether you should:
  ☐ EAT a light breakfast in the morning of the test remembering to avoid anything with caffeine.
  ☐ Do NOT eat or drink anything BUT water after midnight, the night before your test.

☐ ALWAYS drink plenty of fluids AFTER your test is completed.

☐ DO wear comfortable clothes AND shoes, as you will be exercising. DO NOT wear dresses or overalls.

☐ If you take insulin or oral diabetic medications, please take as you normally would unless instructed otherwise.

☐ DO NOT take the following medications for 12 hours prior to your test. Resume them on your normal schedule after the test is completed.

☐ DO NOT take the following medications for 24 hours prior to your test. Resume them on your normal schedule after the test is completed.

☐ DO NOT take the following medications for 48 hours prior to your test. Resume them on your normal schedule after the test is completed.

☐ DO take all your medications according to your normal home schedule. No medications require adjustment.

☐ DO bring a list of your medications with you. If you have held any medications in preparation for this test, please bring those medications with you. You may be requested to take them once the test is completed.

☐ DO notify the staff if you are or may be pregnant.

☐ Your doctor’s office will contact you with test results within 7 days. Should your test result be abnormal, someone will contact you as soon as possible.

☐ If you should need to cancel your test for any reason, we ask that you give us 48 hours notice so we may accommodate other patients.

Staff Signature: ____________________________  Staff Signature: ____________________________

 legible
Patient Preparation

NO:

- Food (4 to 6 hrs)
- Tobacco (2 to 4 hrs)
- Caffeine (12 hrs min.- 24 hrs preferred)
Patient Preparation

- Comfortable clothes and shoes
- Bring medications
- Discontinue medication
  - *Diagnostic vs. functional scan*
Medications

- Insulin – Take ½ of morning dose
- Nitroglycerin – 4 to 6 hours
- Nitrates – 12 hours
- Diuretics – 12 hours
- Bronchodilators – 24 hours
- Beta Blockers – 48 hours
- Calcium channel blockers – 24 hours
- Caffeine – 24 hours

**Beta Blockers – 48 hours**

<table>
<thead>
<tr>
<th>Beta Blockers</th>
<th>Trade Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acebutolol hydrochloride</td>
<td>Sectral</td>
</tr>
<tr>
<td>Atenolol</td>
<td>Tenormin, Tenoretic</td>
</tr>
<tr>
<td>Betaxolol hydrochloride</td>
<td>Kerlone</td>
</tr>
<tr>
<td>Bisoprolol fumarate</td>
<td>Zebeta</td>
</tr>
<tr>
<td>Labetalol hydrochloride</td>
<td>Normodyne, Trandate</td>
</tr>
<tr>
<td>Metoprolol tartrate</td>
<td>Betaloc, Lopressor, Toprol</td>
</tr>
<tr>
<td>Nadolol</td>
<td>Corgard, Corzide</td>
</tr>
<tr>
<td>Pindolol</td>
<td>Visken</td>
</tr>
<tr>
<td>Propranolol hydrochloride</td>
<td>Betachron, Inderal</td>
</tr>
<tr>
<td>Timolol</td>
<td></td>
</tr>
</tbody>
</table>
# Calcium channel blockers – 24 hours

<table>
<thead>
<tr>
<th>Drug</th>
<th>Drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amlodipine</td>
<td>Norvasc</td>
</tr>
<tr>
<td>Diltiazem</td>
<td>Cardizem, Dilacor, Tiazac</td>
</tr>
<tr>
<td>Felodipine</td>
<td>Plendil</td>
</tr>
<tr>
<td>Isradipine hyd.</td>
<td>DynaCirc</td>
</tr>
<tr>
<td>Nicardipine hyd.</td>
<td>Cardene</td>
</tr>
<tr>
<td>Nifedipine</td>
<td>Adalat, Procardia</td>
</tr>
<tr>
<td>Nimodipine</td>
<td>Nimotop</td>
</tr>
<tr>
<td>Nisoldipine hyd.</td>
<td>Sular</td>
</tr>
<tr>
<td>Verapamil hyd.</td>
<td>Calan, Isoptin, Verelan, Cardura, Lotrel, Cartia</td>
</tr>
</tbody>
</table>

Bronchodilators – 24 hours

Brand Name:
- Aminophylline
- Choledyl
- Aerolate, Aquaphylline
- Asmalix
- Elixophylline Slo-bid
- Slophylline
- Theo-Dur
- Theovent

Generic Name:
- aminophylline
- oxtriphylline
- theophylline

Medications containing caffeine – 24 hours

- Anacin
- Caffedrine
- Cardiotec
- Exedrin
- Fioricet
- Fiorinal
- Hycomine
- Norgesic
- Repan
- Vivarin

# Miscellaneous Medications – 24 hours

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Generic Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggrenox</td>
<td>aspirin, dipyridamole</td>
</tr>
<tr>
<td>Cafergot</td>
<td>caffeine, ergotamine</td>
</tr>
<tr>
<td>Dipyridamole</td>
<td>dipyridamole</td>
</tr>
<tr>
<td>Pletal</td>
<td>cilostazol</td>
</tr>
<tr>
<td>Trental</td>
<td>pentoxifylline</td>
</tr>
</tbody>
</table>

Miscellaneous-24 hours

- Energy Drinks
- ED (lifestyle) drugs
Pretest Evaluation

- History and Physical Exam
- Medications
- Ability to Exercise
- Informed Consent
- IV
- Baseline BP
- Baseline ECG – Supine and Standing

Components of history

- Indication for exam
- Medications
- Symptoms – type, character, duration and radiation of symptoms
- Cardiac risk factors – HTN, DM, CHOL, Fam Hx
- Prior diagnostic tests
- Prior therapeutic procedures
Components of physical exam

- Pulse
- Blood pressure (standing)
- Assessment of jugular vein distention
- Presence of edema
- Auscultation of the heart for murmurs and/or gallops
- Lung auscultation
- Gait and mobility
Explain the procedure to the patient!

"Let's try a slower speed."
CONSENT FOR EXERCISE MYOCARDIAL PERFUSION SCAN

I, ____________________________, authorize Dr. ___________________________ and his assistants to administer and conduct an exercise stress test. This test is designed to determine the presence or absence of clinically significant heart disease; to evaluate the effectiveness of my current therapy, and/or to measure my fitness for work or sport.

I understand that I will walk on a treadmill at a specific speed and grade and at three-minute intervals the speed and elevation will increase. While walking on the treadmill, my electrocardiogram and blood pressure will be monitored. Exercise will be progressively increased until I attain a predetermined end point corresponding to moderate exercise stress, or become distressed in any way or develop any abnormal response the physician considers significant, whichever of the above occurs first. Just before the test is terminated an injection of radioisotope (Tc99M Myoview) is given through an intravenous site and I am required to walk an additional minute on the treadmill to allow significant circulation and accumulation of the isotope in my heart.

Every effort will be made to conduct the test in such a way as to minimize discomfort and risk. However, I understand that just as with other types of diagnostic tests there are potential risks (approximately 2 to 3 per 10,000) associated with an exercise test. These include episodes of lightheadedness, fainting, chest discomfort, leg cramps and very rarely heart attack or sudden death. There is no risk or side effects associate with the radiisotope injection. I further understand that the laboratory is properly equipped for such situations and that its professional personnel are trained to administer any emergency care necessary. I voluntarily accept the risks associated with the above procedures.

______________________________
Signature of Patient

______________________________
Signature of Witness

_____________________________
Date
EKG Placement

1. Shave the area where the electrodes will be applied.
2. Lightly abrade the skin with fine sandpaper pads or commercial prep until skin is slightly pink.
3. Remove oil from skin with an alcohol prep pad.
4. When dry apply electrodes.
5. If possible, place the electrode on with the patient standing.
EKG Placement

1. Sites should be over soft tissue and close to the bone

2. Avoid:
   1. Thick muscles
   2. Skin folds
   3. Bony prominences
Poor prep-baseline
With stress...
Artifacts and Noise

• Inadequate skin prep
  • Repeat preparation of skin and replace electrodes
• Patient motion/tight grip on handle bar
  • No excessive arm movements
  • Hands should rest lightly on top of the handle bar
• Inflation of blood pressure cuff
  • Do not measure blood pressure while the ECG machine is printing

*Nuclear Cardiology: The Basics How to Set Up and Maintain a Laboratory. Wackers FJT, Bruni W, and Zaret B. Humana Press, Totowa, NJ, 2004*
Muscle Tremor Artifact

Muscle Tremor (somatic)

Electrical interference caused by the patient's tensed muscles.
Equipment

- ECG continuous monitoring system
- Blood pressure monitoring equipment
- Cardiac defibrillator
- Emergency equipment and medications
- **BLS –in room**
- **ACLS certification-on site**
- **Physician-in building**
Emergency Equipment

- Defibrillator (portable)
- Oxygen tank (portable)
- Nasal cannula, ventimask, nonrebreathing mask, O₂ mask
- Airways (oral)
- Bag-valve-mask hand respirator (Ambu bag)
- Syringes, needles, IV catheters
- Intravenous tubing, solutions, and stand
- Adhesive tape
- Suction apparatus and supplies i.e. gloves, tubing

Emergency Drugs and Solutions

- Atropine
- Isoproterenol
- Lidocaine
- Bretylium
- Adenosine
- Sublingual NTG
- Epinephrine
- Procainamide
- Verapamil
- Dopamine
- Dobutamine

Intravenous fluids:
- Normal saline (0.9%)
- D5W

Methodology

1. Explanation and demonstration
2. Warm up
3. Start protocol
4. Monitor
5. **Symptom limited peak exercise >85% MPHR or at least 5 METS**
6. Inject radiopharmaceutical
7. **Walk additional 1.5-2 minutes**
8. Cool down
Maximum Predicted HR

\[ = 220 - \text{Age (years)} \]

For example: \( 220 - 43 = 177 \text{ bpm} \)

85% of the MPHR

\[ = \text{MPHR} \times 0.85 \]

For example: \( 177 \times 0.85 = 150 \text{ bpm} \)
# Exercise Protocols: Bruce Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Speed (mph)</th>
<th>Elevation (%)</th>
<th>METS</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>2.5</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
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<td>3.4</td>
<td>14</td>
<td>10</td>
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<tr>
<td>3</td>
<td>3</td>
<td>4.2</td>
<td>16</td>
<td>13</td>
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<tr>
<td>6</td>
<td>3</td>
<td>6.0</td>
<td>22</td>
<td>23</td>
</tr>
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</table>
## Exercise Protocols: Modified Bruce Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Speed (mph)</th>
<th>Elevation (%)</th>
<th>MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1.7</td>
<td>0</td>
<td>1.7</td>
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<tr>
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<td>10</td>
<td>5</td>
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<tr>
<td>4</td>
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<td>2.5</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>3.4</td>
<td>14</td>
<td>9-10</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>4.2</td>
<td>16</td>
<td>13-14</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>5.0</td>
<td>18</td>
<td>16.7</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>5.5</td>
<td>20</td>
<td>19-20</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>6.0</td>
<td>22</td>
<td>23</td>
</tr>
</tbody>
</table>
## Exercise Protocols: Naughton Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Speed (mph)</th>
<th>Elevation (%)</th>
<th>METS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1.0</td>
<td>0</td>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2.0</td>
<td>0</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2.0</td>
<td>3.5</td>
<td>3.0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>2.0</td>
<td>7.0</td>
<td>4.0</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2.0</td>
<td>10.5</td>
<td>5.0</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2.0</td>
<td>14</td>
<td>6.0</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2.0</td>
<td>17.5</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Resting Data

- Standard 12-lead in the supine and standing positions
- Blood pressure (supine and standing)
- Heart rate (supine and standing)
Monitoring

- Heart rate
  - Continuously during the test

- Blood pressure
  - Measured every 3 minutes during the last minute of the stage

- ECG
  - Continuously during the test
  - Recorded each minute during exercise
  - Peak exercise
  - Recovery

- Symptoms
  - Every stage

- Relative Perceived Exertion (RPE) (optional)
Hemodynamic Response

- Systolic BP $\uparrow$
- Diastolic BP $= \text{or} \downarrow$ slightly
- Heart rate $\uparrow$
- Ventilation $\uparrow$
- Oxygen consumption $\uparrow$
- Cardiac output $(SV \times HR) \uparrow$
Suboptimal test

"Wadda ya mean you're exhausted? All you did was step up onto the treadmill!"
Suboptimal Exercise

Effects of heart rate response during exercise stress testing on sensitivity with myocardial perfusion imaging

<table>
<thead>
<tr>
<th>% Maximal heart rate</th>
<th>One Vessel</th>
<th>Two Vessel</th>
<th>Three Vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 85%</td>
<td>74%</td>
<td>88%</td>
<td>98%</td>
</tr>
<tr>
<td>&lt;85%</td>
<td>52%</td>
<td>84%</td>
<td>79%</td>
</tr>
</tbody>
</table>

Endpoints of Exercise

- Chest pain
- Extreme fatigue
- Arrhythmias
- Systolic BP changes
- ST segment changes
- >85% MPHR or 5 METS
- *Inject radpharm 1.5-2 minute prior to end of exercise*
Reasons for early termination

- Cardiac symptoms e.g. chest pain, marked dyspnea, extreme fatigue, dizziness, ataxia, confusion, gait problems, cyanosis, pallor, leg cramps, claudication
- > 2 mm ST segment depression
- > 1 mm ST elevation in leads without diagnostic Q waves
- Ventricular or supraventricular tachycardia
- Other arrhythmias such as PVCS, triplets, heart block or bradyarrhythmias
Reasons for early termination

- Decrease in systolic BP $\geq 20$ mm Hg below starting BP

- Markedly abnormal BP elevation (systolic $\geq 250$ mm Hg or diastolic BP $\geq 130$ mm Hg).

- Technical difficulties with the ECG, IV or BP equipment

- Subjects desire to stop
Recovery

• Patient should be monitored for at least 3-5 minutes post exercise
  Or
• Patient should be monitored until heart rate, blood pressure and ECG have returned to near baseline levels
  Or
• Patient should be monitored until significant symptoms have resolved
EKG
Lead Placement

V1: 4th Intercostal space, right sternal border
V2: 4th Intercostal space, left sternal border
V3: ½ way between V2 and V4
V4: 5th Intercostal space left mid clavicula line
V5: 5th Intercostal space, anterior axillary line
V6: 5th Intercostal space, mid axillary

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Frontal and Horizontal Plane Lead

V1: right 4th intercostal space
V2: left 4th intercostal space
V3: halfway between V2 and V4
V4: left 5th intercostal space, mid-clavicular line
V5: horizontal to V4, anterior axillary line
V6: horizontal to V5, mid-axillary line
EKG Interpretation

Normal parameters
- P-wave: 1-3 sm blocks
- PR Interval: 3-5 sm blocks
- QRS Complex: 1-3 sm blocks
- ST segment
  - lies on isoelectric line
Components of an EKG

Normal parameters
- P-wave: 1-3 sm blocks
- PR Interval: 3-5 sm blocks
- QRS Complex: 1-3 sm blocks
- ST segment - lies on isoelectric line
**ECG Intervals and Waves**

- **P wave** = atrial activation
- **PR interval** = the time from onset of atrial activation to onset of ventricular activation
- **QRS complex** = ventricular activation
- **QRS duration** = duration of ventricular activation
- **ST-T wave** = ventricular repolarization
- **QT interval** is the duration of ventricular activation and recovery
Cardiac Conduction

Cardiac Conduction System

- Sinoatrial Node (SAN)
- Right Atrium
- Atroventricular Node (AVN)
- Right Bundle Branch (RBB)
- Left Atrium
- HIS Bundle
- Left Bundle Branch (LBB)
- Left Posterior Fascicle (LPS)
- Left Ventricle
- Left Anterior Fascicle (LAF)
- Purkinje Fibers (PF)
Electrical and Mechanical Events
Normal ECG

Corresponding Heart Walls

- LAD (Anterior Wall)
- Inferior Wall
- RCA
- LAD/RCA
- Septal Wall
- Lt Cx (Lateral Wall)

Corresponding Arteries

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Normal Sinus Rhythm

<table>
<thead>
<tr>
<th>Heart Rate</th>
<th>Rhythm</th>
<th>P Wave</th>
<th>PR interval (in seconds)</th>
<th>QRS (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-100 bpm</td>
<td>Regular</td>
<td>Before each QRS, identical</td>
<td>.12 to .20</td>
<td>&lt;.12</td>
</tr>
</tbody>
</table>
Sinus Rhythms

Normal sinus arrhythmia
- Small, slow variation of the R-R interval
- i.e. variation of the normal sinus heart rate with respiration, etc.

Sinus Tachycardia
- Defined as sinus rhythm with a rate > 100 beats per minute (BPM)
- QT interval decreases as the rate increases. Normally QT < 40% of RR interval.
- Maximum heart rate in sinus rhythm is usually (220 – age) BPM
ST segment depression

- Nonspecific abnormality
- Must be evaluated in the clinical context in which it occurs
- In a patient with angina pectoris ST depression usually means subendocardial ischemia
- Is not localizing to a particular coronary artery lesion.
ST segment depression

- Downsloping ST
- Upsloping ST
- Horizontal ST

The J point occurs at the end of the QRS complex. The ST segment begins at the J point and extends to a user defined interval.
ST Depression
ST elevation
ST elevation
Ventricular Tachycardia

- Ventricular tachycardia occurs when electrical impulses originating either from the ventricles cause rapid ventricular depolarization (140-250 beats per minute).
Ventricular Tachycardia

Ventricular Tachycardia

- Most frequent life-threatening arrhythmia
- Due to irritated focus of activity within ventricular tissues.
- Defined as a series of three or more wide-QRS complexes. Rate can be between 100 and 250 BPM.
- T waves inverted.
- Found in ventricular ischemia, infectious or inflammatory conditions, or with congenital defects (e.g. Long-QT).
- VT may degrade into fibrillation.
AV Block

- The PR progressively lengthens until a nonconducted P wave occurs
- The PR gets longer by smaller and smaller increments
- This results in gradual shortening of the RR intervals

Yanowitz, M.D., copyright 1997
First Degree AV Block

1° AV Blockade

- An increased conduction delay in the AV node (but no real block).
- PR interval > 200 ms.
- Usually asymptomatic.
- May be caused by ischemia, drugs, electrolyte imbalance, vagal tone.
# 2nd Degree AV Block

## Second Degree AV Block • Mobitz 1 (Wenckebach)

<table>
<thead>
<tr>
<th>P Wave</th>
<th>PR Interval (in seconds)</th>
<th>QRS (in seconds)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduction intermittent</td>
<td>Increasingly Prolonged</td>
<td>&lt;.12</td>
<td>QRS dropped in a repeating pattern</td>
</tr>
</tbody>
</table>

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Frank G. Yanowitz, M.D., copyright 1997
Bundle Branch Block (BBB)

- Block of either the right or left excitation bundles that branch from the Bundle of His.
- Excitation spreads to that portion of the heart via conduction through the ventricular muscle.
- In right BBB, right heart activation follows left. In left BBB, left follows right.
- Often associated with wide, double-peaked QRS complexes.
- T-wave often inverted due to altered timing of repolarization.
Left Bundle Branch

- QRS duration >0.12s
- monophasic R waves in I and V6
- terminal QRS forces oriented leftwards and posterior
- The ST-T waves should be oriented opposite to the terminal QRS forces
LBBB
Indications of a High Risk Stress Test

- Exercise time $< 6$ METS
- Limiting angina
- BP
  - Failure to increase systolic BP $\geq 120$ mm Hg
  - Sustained decrease in systolic BP $> 10$ mm Hg or below resting levels
- ST elevation ($\geq 1$ mm in leads except aVR)
- Reproducible VT or VT associated with ischemic changes
- Blunted HR response in absence of $\beta$-blockers
- ST depression
  - $\geq 2$ mm at low workload
  - ST depress in more than 5 leads
  - ST depression lasting $\geq 5$ minutes into recovery
Reasons for non-diagnostic test

• Baseline ECG with
  • ST depression with resting
  • Left Ventricular Hypertrophy
  • Left Bundle Branch Block
  • Wolf Parkinson White
  • Non-specific Interventricular Conduction Delay
  • Digoxin therapy
  • Paced rhythm
  • ST-T wave abnormalities
  • Female

• Failure to reach 85% of the MPHR
False Positives

- Pre-existing abnormal resting ECG
- LVH or hypertrophic cardiomyopathy
- Pericardial disorders
- Mitral valve prolapse
- Pectus excavatum
- Hyperventilation
- Vasospasm
- Hypokalemia
False Negatives

- *Failure to reach 85% MPHR*
- Medications that affect myocardial oxygen requirements (pre-load & after load)
- Single vessel disease
- Good collateral circulation
- Artifact
Other things measured

- METS (metabolic equivalents)
- Rate pressure product (Double product)
- Relative Perceived Exertion (RPE)
- Duke Treadmill Score
METS

- Compares exercise capacity regardless of protocol. A way of measuring physical activity intensity.
- 1 MET = the amount of energy expended during 1 minute of rest.
- ~3.5 ml O₂/kg/min
- Each stage or workload progression approximates a multiple of the O₂ consumption at rest.
## Bruce Protocol

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Speed (mph)</th>
<th>Elevation (%)</th>
<th>METS</th>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>2.5</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
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<td>18</td>
<td>17</td>
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<tr>
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<td>5.5</td>
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<tr>
<td>7</td>
<td>3</td>
<td>6.0</td>
<td>22</td>
<td>23</td>
</tr>
</tbody>
</table>
Energy requirements of common daily activities

- Reading – 1.5 MET
- Walking (2 mph) – 2.5 METs
- Swimming (slow) – 4.5 METs
- Walking (4 mph) – 4.5 METS
- Downhill skiing – 6.8 METs
- Jogging (10 min mile) – 10.2 METs
Rate pressure product

- = Peak systolic BP x peak heart rate
- * Should be >25,000

- Gives an estimation of LV chamber pressure and is useful to evaluate medical RX for hypertension
<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>7</td>
<td>Very, very light</td>
</tr>
<tr>
<td>8</td>
<td>Very light</td>
</tr>
<tr>
<td>9</td>
<td>Fairly light</td>
</tr>
<tr>
<td>10</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>11</td>
<td>Hard</td>
</tr>
<tr>
<td>12</td>
<td>Very hard</td>
</tr>
<tr>
<td>13</td>
<td>Very, very hard</td>
</tr>
</tbody>
</table>
Duke Treadmill Score

- Risk stratification method for ETT
- Uses 3 variables
  - Duration of exercise
  - Angina
  - EKG ST depression

Categorizes myocardial event risk as low, intermediate or high
DTS Formula

Calculation of the Duke Treadmill Score (DTS)

\[
\text{Duke Treadmill Score (DTS)} = \frac{\text{Exercise Time} - (5 \times \text{ST deviation})}{(4 \times \text{treadmill angina})}
\]

**Definitions**

- **Exercise Time** = measured in minutes
- **ST deviation** = largest net deviation (either depression or elevation in any lead except aVR)

**Treadmill angina scale**

- 0 = no angina during exercise
- 1 = non-limiting angina during exercise
- 2 = exercise-limiting angina

**Interpretation**

Typically observed range for the DTS:

- Highest risk = -25
- Lowest risk = +15

*Distinction between exercise-induced angina and non-anginal chest pain is based on the clinical judgement of the physician supervising the stress test. Emphasis is placed on reproducing the patient's usual presenting symptoms and the classic features of typical angina.*
DTS Risk Stratification

DTS Risk

<-10 High (79% 4-year survival)

-10 to +4 Moderate (95% 4-year survival)

≥ +5 Low (99% 4-year survival)
Example

DTS = Ex time – (5 x ST dev) – (4 x Angina score)
= 9 min – (5 x 1mm ST) – (4 x 2)
=-4
= Moderate risk for major coronary events
Stress Testing

- Diagnosis
- Risk Stratification
- Prognosis
Thank You!