Exercise testing and the ECG

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THE CLINICAL CASE
41 year old male

No past history
No risk factors
Chol 4.8 LDL 2.1
F/H - Negative
P/C – 3/12 atypical pain intermittently at exercise with chest wall tenderness
Examination – Unremarkable. ECG - Normal
Referred for exercise MIBI study
Which test?

1. Do the ex MIBI study – rest-stress
2. Do the exercise MIBI study – stress only
3. Do an exercise ECHO
4. Do stress MRI – (CE Marc 2 ESC 8/16)
5. Do CTCA
6. Do Cath
7. Do Exercise ECG
8. Do Nothing
Robert Bruce

• 20/11/16 – 12/2/04
• First published 1949
• Multistage test 1963
• Emeritus Professor of Medicine, U of Washington.
• “You would never buy a used car without taking it for a drive and seeing how the engine performed while it was running, and the same is true for evaluating the function of the heart.”
Prognosis in patients achieving ≥10 METS on exercise stress testing: Was SPECT imaging useful?

Jamieson M. Bourque et al.... JNC 4/11

Conclusion... MPI (and other testing) limited value in this group!!!!
### EXERCISE CAPACITY and CER – (n = 9000)

<table>
<thead>
<tr>
<th>Outcome (% predicted METs achieved)</th>
<th>Adjusted hazard ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI</td>
<td></td>
</tr>
<tr>
<td>• &lt;85</td>
<td>2.36 (1.55–3.60)</td>
</tr>
<tr>
<td>• 85–100</td>
<td>0.79 (0.46–1.36)</td>
</tr>
<tr>
<td>• &gt;100</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Unstable angina</td>
<td></td>
</tr>
<tr>
<td>• &lt;85</td>
<td>2.39 (1.78–3.21)</td>
</tr>
<tr>
<td>• 85–100</td>
<td>1.31 (0.94–1.81)</td>
</tr>
<tr>
<td>• &gt;100</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>CABG, PCI</td>
<td></td>
</tr>
<tr>
<td>• &lt;85</td>
<td>1.75 (1.46–2.08)</td>
</tr>
<tr>
<td>• 85–100</td>
<td>1.08 (0.90–1.31)</td>
</tr>
<tr>
<td>• &gt;100</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>All-cause mortality</td>
<td></td>
</tr>
<tr>
<td>• &lt;85</td>
<td>2.90 (1.88–4.47)</td>
</tr>
<tr>
<td>• 85–100</td>
<td>1.08 (0.90–1.31)</td>
</tr>
<tr>
<td>• &gt;100</td>
<td>1 (reference)</td>
</tr>
</tbody>
</table>

What is this?
A standard treadmill stress test was performed.
Exercise test

9 minutes Bruce
Ceased due to SOB
No chest pain
HR      Rest - 72    Peak - 162
BP      Rest - 130/75 Peak - 200/80
Normal @ rest
Normal @ stress
Clearly positive v Equivocal --- further tests!!
Nuclear v. Stress Echo v. MRI v CTCA

The Answer

Do the one that is done best in your institution!!!

P. Douglas .... Time Magazine 2006

Now .... Back to basics
The Action Potential and the ECG

Surface recording
Multiple cells summated
Action Potential moving through the heart

Single Ventricular Cell Action Potential

P: Atrium
PR: AV Node
QRS: Ventricular Depolarisation
QT: Action Potential Duration
T&U: Ventricular Repolarisation

www.textbookofcardiology.org
How does the action potential happen?

- Open Na⁺ channel
- Influx of Na⁺
- Voltage change from – to + = *Depolarisation*
- Close Na⁺ channel
- ........
- Open K⁺ channel
- Efflux of K⁺
- Voltage change from + to – = *Repolarisation*
- Close K⁺ channel

After Hodgkin & Huxley J. Physiol (1952) 117: 500-544
How are cardiac cells different from nerve cells?

• Ca channels open to prolong the action potential duration
EXERCISE TESTING

HISTORY

Feil and Seigel.. Am J Med Sci 1928
- ST depression after exercise in patients with angina
  Resolve with pain resolution + GTN

Bruce RA .. Mod Concepts Cardiovasc Dis 1956
- Exercise protocols

1970’s – Bayesian paralysis (Kligfield .. AJC 1994)
- Positive predictive value = Clinical likelihood
- Therefore test use became limited.
  Birth = other non-invasive modalities
INDICATIONS FOR Ex ECG

Clear Indications
1. Dx CAD in men with atypical symptoms
2. Assess prognosis and functional capacity in pts with known CAD
3. Assessing exercise-induced arrhythmia
4. Assessment post MI
5. Evaluation post revascularisation
INDICATION Ex ECG

Possible indications

1. Dx CAD in women with typical and atypical pain
2. RBBB, Digoxin
3. Known CAD - functional capacity, response to treatment
4. Functional capacity in some pts with valvular heart disease – Moderate to severe AS (ESC 2005)
5. Asymptomatic males > 40 or high risk job with 2+ risk factors or a sedentary pt going to begin a vigorous exercise program
Patient preparation

No eat, drink or smoke for 3 hours prior
Comfortable clothes and shoes
Off drugs, 24-48 hours, such as beta-blockers, digoxin, verapamil/diltiazem if possible ONLY
Avoid Viagra/Cialis/Levitra prior
Personnel & Equipment

2 trained people, including physician
Resuscitation gear including
  oxygen, bag, suction, etc
IV access if needed
GTN
Defibrillator
Treadmill or bicycle
12 lead ECG, BP
PROTOCOLS

- Bruce
- Modified Bruce
- Naughton
- Cornell
- Bicycle
  - Use what referring doctors are familiar with
  - 3 minutely increase in speed and incline
Another simple, effective means of inducing instantaneous, non-exercise cardiac stress. Functioning needles, in sizes shown above, are not widely available. Check your catalogue.
INTERPRETATION

Chest pain
- usual or different
- typical or atypical
- when it started, stopped

Reason to stop - fatigue, SOB, etc

Number of minutes

ECG - > 1mm ST depression 0.08 seconds after J point (Secondary = up or downsloping and speed of recovery)
INTERPRETATION

ECG - Arrhythmia
How does the patient look?
Chest auscultation
Oxygen saturation prn
Recovery - minimum 5 minutes or until symptoms resolve
INDICATIONS to STOP

1. Target HR
2. Progressive angina
3. Other limiting symptoms (e.g. SOB, dizzy, etc)
4. ST elevation > 2mm
5. ST depression > 3mm
6. Non-sustained VT > 3 beat
7. New onset AF, SVT, A.flutter, etc
INDICATION to STOP

8. Development 2nd or 3rd degree block
9. New LBBB
10. Fall BP > 10mmHg
11. Extreme elevation BP
12. Progressive drop in HR with exercise
13. Equipment problems, incl ECG signal loss
### Serious and potentially life threatening complications of cardiac stress testing: Physiological mechanisms and management strategies

**Vasken Dilsizian et al.** JNC 12/15

<table>
<thead>
<tr>
<th>complication</th>
<th>Exercise</th>
<th>Dobutamine</th>
<th>Dipyridamole MPI</th>
<th>Adenosine MPI</th>
<th>Regadenoson MPI</th>
<th>Gadolinium MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any serious complication</td>
<td>0.1–3.46</td>
<td>2.988</td>
<td>0.714–2.6</td>
<td>0.97</td>
<td>Case reports</td>
<td>NR</td>
</tr>
<tr>
<td>Death</td>
<td>0–0.25</td>
<td>Case reports</td>
<td>0.5</td>
<td>Case reports</td>
<td>Case reports</td>
<td>NR</td>
</tr>
<tr>
<td>Vfib/Vtach</td>
<td>0–25.7</td>
<td>0.6–1.35</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Acute MI</td>
<td>0.038</td>
<td>0.3–3</td>
<td>1</td>
<td>0.108</td>
<td>Case reports</td>
<td>NR</td>
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<tr>
<td>Cardiac rupture</td>
<td>Unknown</td>
<td>Case reports</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>High degree AV Block or asystole</td>
<td>Unknown</td>
<td>NR</td>
<td>Case reports</td>
<td>Case reports</td>
<td>Case reports</td>
<td>NR</td>
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<tr>
<td>Bronchospasm</td>
<td>Unknown</td>
<td>NR</td>
<td>1.5</td>
<td>0.76</td>
<td>Case reports</td>
<td>NR</td>
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<tr>
<td>Stroke/TIA</td>
<td>Unknown</td>
<td>Case reports</td>
<td>NR</td>
<td>NR</td>
<td>Case reports</td>
<td>NR</td>
</tr>
<tr>
<td>Afib</td>
<td>Unknown</td>
<td>5–40</td>
<td>NR</td>
<td>NR</td>
<td>Case reports</td>
<td>NR</td>
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<tr>
<td>Seizure</td>
<td>Unknown</td>
<td>Case reports</td>
<td>NR</td>
<td>1.5</td>
<td>Case reports</td>
<td>NR</td>
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<tr>
<td>Contrast-Induced Nephrotoxicity</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Nephrogenic Systemic Fibrosis</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>0–18%</td>
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<tr>
<td>Radiation-Induced Cancer</td>
<td>NR</td>
<td>NR</td>
<td>NR (theoretical)</td>
<td>NR (theoretical)</td>
<td>NR (theoretical)</td>
<td>NR</td>
</tr>
</tbody>
</table>
RESULTS
ST depression, ST/HR slope, QRS amplitude and size
HR and BP response, change rhythm - incl VEs
Positive, Negative, Equivocal, Non-diagnostic
Treadmill score
  e.g. DUKE score = ex duration - (5xST deviation) - (4x angina index)
0 = no angina, 1 = non-limiting, 2 = ex limited
# Risk Stratification

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>68 %</td>
<td>77 %</td>
</tr>
<tr>
<td>Multivessel</td>
<td>81 %</td>
<td>66 %</td>
</tr>
</tbody>
</table>

Weiner et al NEJM 1979...

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>76 %</td>
<td>64 %</td>
</tr>
<tr>
<td>Males</td>
<td>78 %</td>
<td>73 %</td>
</tr>
</tbody>
</table>
OUTLOOK

Good signs =

Bruce at least Stage 3.

Duke Treadmill Score high
DUKE TREADMILL SCORE

Calculation: $+ \text{mins} - 5 \times \text{ST} - 4 \times \text{angina}$

<table>
<thead>
<tr>
<th>Risk</th>
<th>Score</th>
<th>Mortality/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>$\geq 5$</td>
<td>0.25%</td>
</tr>
<tr>
<td>Interm</td>
<td>4-10</td>
<td>1.25%</td>
</tr>
<tr>
<td>High</td>
<td>$\leq -11$</td>
<td>5.25%</td>
</tr>
</tbody>
</table>

Use DUKE to:

1. Estimate if nuclear is needed after a treadmill test
2. Use the exercise and perfusion data combined to guide management
ST depression magnitude and Predictive Value
WORKLOAD AS A PREDICTOR OF DEATH

Snader CE et al, JACC, 1997;30:641-8
FIGURE 14-15. The incidence of subsequent coronary events (progression of angina, MI, and death) increases with the magnitude of the ST-segment depression only when analyzed at a light workload (3 minutes of exercise = 4 METS; time span = 6 years).
Ischaemic Cascade

- Perfusion
- Diastolic Function
- Systolic Function
- ECG changes
- Angina
Reading an ECG

- Identify the ECG: Name, Date, Time
- Check the scaling: 25mm/sec   10mm/mV
- Beware axis on exercise ECG v standard ECG!!
ECG: 12 leads – information overload!!

Look at the specific leads you need for the piece of information you want.
Reading an ECG: Rate

300/no. of large squares = 300/4 = 75

10 sec page
6 X 13 = 76
As the Action Potential (current) passes through the heart it causes an ECG deflection. Size and Direction in any LEAD depends on the orientation of the LEAD to the current.
Reading an ECG: Rhythm

Look for the P Waves: Best seen in Leads II and V1
Sinus Rhythm
Sinus Tachycardia
Sinus Bradycardia
Premature Ventricular Complex
{Premature Ectopic Extra Systole}
Premature Beat
Atrial Ectopic Complex
Extra Systole
Sinus Bradycardia: Junctional Escape
Junctional Rhythm: Retrograde P Waves
Conduction Block Level

- Sino-atrial Node & Atrium (uncommon)
- Atrio-Ventricular Node & His Bundle
  - 1\textsuperscript{st} degree: Slow conduction: Prolonged PR interval
  - 2\textsuperscript{nd} degree: Some beats not conducted
  - 3\textsuperscript{rd} degree (Complete): No beats conducted
    - Ventricular Escape Rhythm
- Purkinje System
  - R or L Bundle Branch Block
  - Hemiblocks
1st Degree AV Block: Prolonged PR
2nd degree AV Block: Some beats not conducted
Wenckebach Block = Mobitz 1 Block
= Prolonging PR interval until “dropped” (non-conducted) beat
Block at level of AV Node
2nd degree AV Block: Some beats not conducted
Mobitz 2 Block
= Constant PR interval with “dropped” (non-conducted) beat
Block at level of His Bundle
3rd degree AV Block: No beats conducted
Junctional escape rhythm (Junctional pacemaker cell): Narrow QRS
A-V dissociation
In BBB, the late wave represents the activation of the ventricle going to the side of the blocked bundle.

- **RBBB**: Late wave is positive in V1 and negative in V6.
- **LBBB**: Late wave is negative in V1 and positive in V6.
Implications for stress testing ??
Rate 129. Age not entered, assumed to be 50 years old for purpose of ECG interpretation.

Atrial flutter with predominant 2:1 AV block. A-rate 263, multiple Ps.

QRSd 154. Left bundle branch block. QRSd > 120, broad/notched R.

QT 398. ST > 0.10mV, T upright, II III aVF.

QTc 584.

Unconfirmed Diagnosis:

>>>Acute MI<<<
Sinus tachycardia v SVT
5-Dec-1952  Male
Vent: rate 67 bpm
PR interval 7 ms
QRS duration 75 ms
QT/QTc 0.420 ms
P-R T axis * 84.69

Technician: hp
Narrow QRS Tachycardia

• Sinus Tachycardia
  – P waves, Context
• Atrial Fibrillation
  – Irregular, No P waves
• Atrial Flutter
  – Flutter waves usually in 2,3,avF
• Atrial Tachycardia
  – Unusual P waves usually in V1
• “SVT”: AVJRT or AVRT
  – No (or hard to see) P waves
Wide QRS Tachycardia

• Ventricular Tachycardia
  – Nearly always, even if young or conscious
  – “Rule” out VT until proven otherwise
  – Adenosine may revert some VT’s
  – Treat as VT – will also treat SVT
  – DC Shock should be used early (GA required!)

• SVT with aberrant conduction
  – Bundle Branch Block or Accessory Pathway
And of course .............

ISCHAEMIA !!!!
BED 2: 54 y.o. smoker previous inferior infarct. 3 days pain. 3 hours severe pain

ST elevation in II, III, aVF

ST depression in aVL, V2, V3
BED 3: 80 y.o. man with 3 hours of chest pain
ST elevation in inferior and anterior leads
Anterior Infarcts

Left Anterior Descending Artery
  – ST ↑ in V1, V2, V3

Proximal LAD
  – ST ↑ in aVL, ST ↓ in aVF
  – ST ↑ in V1 or new RBBB with Q
  – ST ↑ in aVR (before 1st septal)

Distal LAD (beyond 1st diagonal)
  – ST → or ↑ in 2, 3, aVF
On a stress test, 1 mm ST depression 0.08 seconds after J point = positive
Basic Life Support

Dangers?

Responsive?

Send for help

Open Airway

Normal Breathing?

Start CPR
- 30 compressions : 2 breaths
  if unwilling / unable to perform rescue breaths continue chest compressions

Attach Defibrillator (AED)
  as soon as available and follow its prompts

Continue CPR until responsiveness or normal breathing return

But ……

Do Advanced Life support training!!
If with MPI

You must .....  
Incorporate an ECG component to the report  

Use the Ex ECG data and MPI data together in your conclusion. The referring doctor will use BOTH components together with age and pt’s clinical state/symptoms to alter his/her management  

e.g. Mild ischaemia at high workload  
Moderate ischaemia at low workload  
Moderate ischaemia at high workload
Guidance and Recommendations for the Implementation of Nuclear Cardiology in Developing Countries

Dear reader, please note that this document is the result of a Technical Meeting on: “Evidence-based Nuclear Cardiology in Ischemic Heart Disease” held in Vienna on February 21-25, 2011. It reflects the contributions of participants to the meeting and has been further expanded and updated to be published as an IAEA Human Health Series.

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RADIOPHARMACEUTICAL: 99mTc Sestamibi, [ ] Mbq (Rest) / 99mTc Sestamibi, [ ] Mbq (Stress)

CLINICAL INDICATION

TECHNICAL PROCEDURE AND RESULTS

Stress test:

| Protocol - Bicycle | Duration - [ ] mins.
|--------------------|-----------------------
| Peak workload - [ ] watts. | Work - [ ] kJ.
| Heart rate (bpm): Rest - [ ] | Peak - [ ] ([]% MHR)
| BP: Rest - [ ] | Peak - [ ]
| Reason for termination: [ ]
| Chest pain - [ ]
| ECG Changes - [ ]

Myocardial Perfusion Scan:

Tomographic images of myocardial perfusion were performed following the injection of 99mTc-Sestamibi at rest and again, following the injection of 99mTc-Sestamibi after stress.

Nitrate administered prior to rest injection - [ ]

OVERALL IMPRESSION

............. at a ....... workload.
**Imaging algorithm 2016**

Clinical – Hx, exam, ECG

Asymptomatic – ca score (???), exercise ECG (???) , other (???) v. nothing

Low risk – exercise ECG

Low-intermediate risk – Stress echo, cardiac CT (?stress MRI)

Intermediate to Intermediate – high – Stress nuclear MPI

  Negative – risk factor control
  Equivocal – another test – CT v. functional v. cath
  Positive – medical (mild ischaemia) v. cath (mod-large ischaemia)
  This depends on test result, symptoms and clinical status!!!

High probability – Cath – if equivocal lesion – Stress nuclear / echo or FFR
CONCLUSION

The exercise test is still here, either alone or with imaging

Know how to do it.

Interpret ischaemia, infarction and arrhythmia yourself

Keep up to date with Advanced Life support

Incorporate stress test in your report .... It WILL influence management !!

1 more message  !!!!!
I’ve shown you my lab, but now see the Stress ECGs at Joao’s lab ….