CARDIOPULMONARY EXERCISE TESTING – INTERACTIVE CASE DISCUSSION

The Cardiologist’s point of view
Lukas Trachsel
9 – Panel – Plot (Wassermann)
9 – Panel – Plot (Wassermann)

Motivation / exercise capacity
Motivation / exercise capacity

Ventilatory mechanical relevant panels
Oxygen uptake in response to acute exercise

Wassermann, Principles of Exercise Testing, 5th Edition

\[ VO_2 = CO \times C(a-v) O_2 \]

‘Fick equation’
9 – Panel – Plot (Wassermann)

\[ \text{VO}_2 = \text{SV} \times \text{HR} \times C(a-v) \text{ O}_2 \]

\[ \frac{\text{VO}_2}{\text{HR}} = \text{SV} \times C(a-v) \text{ O}_2 \]

Motivation / exercise capacity

Ventilatory mechanical relevant panels

Cardio-circulatory relevant panels

VO2/WR-Slope
9 – Panel – Plot (Wassermann)

Cooperation / exercise capacity

Ventilatory mechanical relevant panels

Cardio-circulatory relevant panels

Gas exchange
Case Report

• 61 year old male
• 3-vessel CAD (12/2010)
  – Non-STE-MI inferior 12/2010
  – CABG 12/2010
  – Ejection fraction normal
  – Risk factors: cholesterol, BMI 30, familial history, former smoker
• Suspected exercise induced asthma 07/2012
  – Body plethysmography 20.7.2012: borderline restriction (TLC 76% predicted), dynamic lung volume normal, C0 diffusion capacity normal
• Annual ‘follow-up’:
  – Exercise intolerance for months, exertional dyspnoe (NYHA II)
**Spirometry**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Ist</th>
<th>Pred</th>
<th>% (Act1/Pred)</th>
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</thead>
<tbody>
<tr>
<td>FVC [L]</td>
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<td>MVV [L/min]</td>
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</tbody>
</table>

**Medical History**

- Last Name: [Redacted]
- First Name: [Redacted]
- Date of Birth: 10.01.1953
- Weight: 99 kg
- Height: 182 cm
- Age: 61 Years
- Sex: Male
- BSA: 2.2 m²
- Date: 09.09.2014
- Time: 10:00:48
CAD, post-CABG
Exercise intolerance, NYHA II

<table>
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<th>Ref.</th>
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<th>Pred</th>
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<td>06:05</td>
<td>13:17</td>
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<td>1.3</td>
<td>0.3</td>
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<tr>
<td>MET</td>
<td></td>
<td>1.2</td>
<td>2.9</td>
<td>5.2</td>
<td>3.4</td>
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<td>94</td>
<td>134</td>
<td>113</td>
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<tr>
<td>Pdia mmHg</td>
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<td>70</td>
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<td>12220.0</td>
<td>21440.0</td>
<td>18080.0</td>
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</table>
CAD, post-CABG
Exercise intolerance, NYHA II
CAD, post-CABG

Exercise intolerance, NYHA II

CRF 77% pred
WR 76% pred

O₂ pulse 77% pred
VO₂/WR-Slope 8.2 (> 8.6)

VE/VCO₂-Slope 35 (<30)

RER 1.15

BR 20%
QUIZ QUESTION:

What is the most likely reason for the symptoms and for the reduced exercise capacity/CRF?

a) Respiratory limitation  
b) Cardio-circulatory limitation (unspecific)  
c) Cardio-circulatory limitation (suggestive of ischemia)  
d) Limitation of peripheral muscles  
e) Others
CAD, post-CABG
Exercise intolerance, NYHA II

**Flattening of O2 pulse and VO2 as related to work rate increase**

**VE/VCO2-Slope 35 (<30)**

Cardio-circulatory limitation (suggestive of ischemia)

**RER 1.15**

**BR 20%**
PCI LAD distal LIMA-RIVA graft
15.09.2014
CAD, post-CABG
Symptoms resolved

09.09.14
Before PCI

23.09.14
After PCI
Exercise-induced myocardial ischaemia detected by cardiopulmonary exercise testing

Fig. 2 An example of \( O_2 \) pulse (a) and \( \Delta VO_2/\Delta \) work rate (b) slope in two representative patients. One had a negative ECG stress testing and a negative scan (closed circles). The other developed myocardial ischaemia during exercise, and also had a reversible myocardial defect on scintigraphy (SDS 14, SSS 15) (open circles). The dotted line indicates the onset of flattening in both \( O_2 \) pulse and \( VO_2 \) as related to work rate increase, evident only in the patient with a positive scan. Note the absence of flattening in both \( O_2 \) pulse and \( VO_2 \) as related to work rate in the patient who had no ST segment changes during exercise and a negative scan. In (b), the slope above the inflection point is flattened as compared with the slope from start to the inflection point (3.5 ml/min/W vs 9.1 ml/min/W). For details, see text. (a) Time to \( O_2 \) pulse flattening; (b) \( O_2 \) pulse flattening duration.
Exercise-induced myocardial ischaemia detected by cardiopulmonary exercise testing

Fig. 2  An example of $O_2$ pulse (a) and $\Delta VO_2/\Delta$ work rate (b) slope in two representative patients. One had a negative ECG stress testing and a negative scan (closed circles). The other developed myocardial ischaemia during exercise, and also had a reversible myocardial defect on scintigraphy (SRS 14, SSS 15) (open circles). The dotted line indicates the onset of flattening in both $O_2$ pulse and $VO_2$ as related to work rate increase, evident only in the patient with a positive scan. Note the absence of flattening in both $O_2$ pulse and $VO_2$ as related to work rate in the patient who had no ST segment changes during exercise and a negative scan. In (b), the slope above the inflection point is flattened as compared with the slope from start to the inflection point (3.5 ml/min/W vs 9.1 ml/min/W). For details, see text. (a) Time to $O_2$ pulse flattening; (b) $O_2$ pulse flattening duration.
Exercise-induced myocardial ischaemia detected by cardiopulmonary exercise testing

Cardiopulmonary exercise testing is more accurate than ECG-stress testing in diagnosing myocardial ischemia in subjects with chest pain

![Graphs showing relationship between oxygen pulse (O₂ pulse) and work rate](image)

Fig. 2 An example of O₂ pulse (a) and ΔVO₂/Δ work rate (b) slope in two representative patients. One had a negative ECG stress testing and a negative scan (closed circles). The other developed myocardial ischaemia during exercise, and also had a reversible myocardial defect on scintigraphy (SDS 14, SSS 15) (open circles). The dotted line indicates the onset of flattening in both O₂ pulse and VO₂ as related to work rate increase, evident only in the patient with a positive scan. Note the absence of flattening in both O₂ pulse and VO₂ as related to work rate in the patient who had no ST segment changes during exercise and a negative scan. In (b), the slope above the inflection point is flattened as compared with the slope from start to the inflection point (3.5 ml/min/W vs 9.1 ml/min/W). For details, see text. (a) Time to O₂ pulse flattening; (b) O₂ pulse flattening duration.
Case Report

• 53 year old male
• Hypertensive heart disease
• Metabolic syndrome
• Syncope 2012
• Sent for disability evaluation by the insurance (‘IV-Abklärung’)
• Symptoms: dyspnoe on exertion (NYHA II-III), periodic chest pain (at rest, on exertion)
Spirometry

<table>
<thead>
<tr>
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<tr>
<td>FVC [L]</td>
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<td>4.36</td>
<td>80.4</td>
</tr>
<tr>
<td>FEV1 [L]</td>
<td>2.71</td>
<td>3.50</td>
<td>77.5</td>
</tr>
<tr>
<td>FEV1 % FVC [%]</td>
<td>77.26</td>
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</tr>
<tr>
<td>MVV [L/min]</td>
<td></td>
<td>127.63</td>
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</table>
Hypertensive HD, metabolic syndrome
NYHA II-III
Hypertensive HD, metabolic syndrome
NYHA II-III
Hypertensive HD, metabolic syndrome

NYHA II-III

VO2/WR-Slope 8.9 (> 8.6)

CRF 64% pred
WR 54% pred

O2 pulse 59% pred

VE/VCO2-Slope 38(<30)

RER 1.29

BR 16%
QUIZ QUESTION:

What is the most unlikely reason for the reduced exercise capacity?

a) Heart failure with preserved ejection fraction
b) Subacute pulmonary embolism
c) Chronic thrombo-embolic pulmonary hypertension (CTEPH)
d) Previously undetected aortic stenosis
e) COPD
Hypertensive HD, metabolic syndrome

NYHA II-III

VO2/WR-Slope 8.9 (> 8.6)

CRF 64% pred
WR 54% pred

VE/VCO2-Slope 38 (<30)

O2 pulse 59% pred

Ventilation/Perfusion Mismatch

bath tub?

RER 1.29

BR 16%

PET Co2 32mm Hg
(Rest: >35mm Hg)
Ventilation-/Perfusion-Szintigraphy

Subsegmentary bilateral pulmonary emboli
## Technology and Guidelines

### Cardiopulmonary exercise testing and its application

K Albouaini, M Egred, A Alahmar, D J Wright

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### Table 3  American College of Cardiology/American Heart Association guidelines for cardiopulmonary exercise testing

<table>
<thead>
<tr>
<th>Class</th>
<th>Indication</th>
</tr>
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<tbody>
<tr>
<td>I (indicated)</td>
<td>1 Evaluation of exercise capacity and response to treatment in patients with heart failure who are being considered for heart transplantation.</td>
</tr>
<tr>
<td></td>
<td>2 Assistance in the differentiation of cardiac versus pulmonary limitations as a cause of exercise-induced dyspnoea or impaired exercise capacity when the cause is uncertain</td>
</tr>
<tr>
<td>IIA (good supportive evidence)</td>
<td>Evaluation of exercise capacity when indicated for medical reasons in patients for whom the estimates of exercise capacity from exercise test time or work rate are unreliable</td>
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</table>
| IIb (weak supportive evidence) | 1 Evaluation of the patient’s response to specific therapeutic interventions in which improvement of exercise tolerance is an important goal or end point  
2 Determination of the intensity for exercise training as part of comprehensive cardiac rehabilitation |
| III (not indicated) | Routine use to evaluate exercise capacity |

Adapted from ATS/ACCP Statement on Cardiopulmonary Exercise Testing.¹
“Several CPX statements have been published by well-respected organizations in both the US and Europe. Despite these prominent reports and the plethora of pertinent medical literature which they feature, underutilization of CPX persists.”
New CPX indications and algorithms:

- CPX to assess perisurgical and postsurgical risk and long-term prognosis
- CPX to assess valvular disease/dysfunction