Cardiopulmonary Exercise Testing in Cystic Fibrosis

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Cardiopulmonary Exercise Testing

• Cardiopulmonary Exercise Testing (CPET)
  • What? Why? How?
• Key Parameters
  • $VO_2$, $VCO_2$, HR, $V_E$, RER
• Applicability to Clinical Settings
• Demonstration
Energy Systems

[Graph showing energy systems over time.]

- Phosphagen
- Glycolytic
- Oxidative
Energy Systems

Diagram showing the interconnection of energy systems:
- Mitochondria
- Oxygen consumption
- Carbon dioxide production
- Pulmonary arteries
- Circulation
- Systemic arteries
- Inspired air
- Ventilation
- Expired air
Cardiopulmonary Exercise Testing

• CPET allows the simultaneous study of the functional capabilities of the respiratory, cardiovascular and muscular systems
• This can at rest and during the transition to a maximal metabolic rate (aerobic capacity – VO$_{2\text{max}}$)
• Allow the assessment of exercise capacity and causes of fatigue
• Allows reserve capacity of the body to be stressed, particularly in terms of its ability to deliver oxygen to peripheral muscles
• Many diagnostic tests are done at rest – why?
Cardiopulmonary Exercise Testing

• Bike v Treadmill
  – Bike allows for an easier quantification of work-rate and is better for extremely dyspnoeic or uncoordinated patients
  – Treadmill may elicit a higher VO$_2$max
Cardiopulmonary Exercise Testing

• Two-Phase Ramp Test
  – Intensity increases as a linear function of time
  – Verification via 110% of maximal workload from first test

![Diagram of Two-Phase Ramp Test]

~ 10 mins
Cardiopulmonary Exercise Testing

• Why?
  • Many ‘secondary characteristics’ are invalid
  • Heart Rate
  • RER
  • Lactate
  • RPE/RPE
  • Can result in early termination of test
Cardiopulmonary Exercise Testing
Cardiopulmonary Exercise Testing

• Measures
  – Gaseous Exchange, via means of a facemask
    • $\text{VO}_2$, $\text{VCO}_2$
    • Heart Rate
Key Measures

• **VO\textsubscript{2}**
  • The volume of oxygen utilised in metabolism
  • **VO\textsubscript{2max}** is the maximum rate that ATP can be synthesised aerobically
  • Ranges from 35-43 ml/kg/min in healthy UK children
  • Range from 24-44 ml/kg/min in CF children
  • High VO\textsubscript{2max} is associated with a decreased risk of mortality

*Armstrong et al. 1991; Saynor et al. 2013; Nixon et al. 1992*
Key Measures

• $VCO_2$
  – Volume of $CO_2$ exhaled
  – Extreme exercise results in anaerobic metabolism, with lactic acid produced as a by-product (acidemia)
  – When plotted against $V_E$, we obtain a $V_E/VCO_2$ ratio
    • Poor $V_E/VCO_2$ implies ventilation is wasted on dead space, possibly due to poor perfusion at the alveoli
    • May also indicate a low $PaCO_2$ driving diffusion i.e. hyperventilation in cardiac patients

*Tumminello et al. 2007*
Key Measures

• Heart Rate
  – During CPET, patients should be reaching 80% of their age-predicted maximum
    • 220 – Age in years = Max HR
  – HR will rise at differing rate depending upon cardiac function
    • Poor LV function will result in rapid HR increase
  – Heart Rate Reserve (HRR) will be high if a patient fails to reach 80% of their predicated maximum. Exercise may be limited by something other than cardiac function, i.e. peripheral vascular disease
9 plot display highlighting cardiovascular, ventilatory and metabolic responses to exercise
Peak VO₂

Normal
≥ 85% predicted
- Anxiety
- Obesity
- Mild Disease

Low
< 85% predicted
- Anaerobic Threshold
  - Normal
  ≥ 40% predicted PKVO₂
    - Breathing Reserve
  - Low
  < 40% predicted PKVO₂
    - Breathing Reserve

Normal
≥ 30%
- Poor Effort
- Deconditioning

Low
< 30%
- Coronary Disease
- Ventilatory Impairment

Normal
≥ 30%
- Circulatory Impairment

Low
< 30%
- Mixed Lesions
Applicability

• A CPET is useful in the following situations:
  – Differential Diagnosis
    • If cause of dyspnoea is unknown, CPET can serve to define specific limiting organ system
  – Disability Evaluation
    • Provides objective assessment of exercise capacity and impairment
  – Rehabilitation
    • Allows for prescription of appropriate exercise intensity
  – Assessing Preoperative Risk
    • Provides objective assessment about cardiopulmonary reserve during heightened metabolic stress
Applicability in CF

- A CPET is useful in the following situations:
  - Prognosis
  - Risk of hospitalisation
  - Indicator of QoL
Applicability

• Why CPET instead of other tests?
  – Sub-maximal exercise tests are common in clinical settings
    • Shuttle-Walk Test
    • 6-Minute Walk Test
  – Correlation approximately 50-65%
  – Can under predict VO$_2$$_{\text{max}}$ by 6 ml/kg/min (up to ~ 35% error)
  – Discrete results
    • These tests can be ‘beaten’
    • CPET cannot be ‘beaten’

Singh et al. 1994, Selvadurai et al. 2003
Applicability

• CPET is considered the ‘Gold Standard’ in terms of exercise testing
  – “CPET complements other clinical and diagnostic modalities, and by directly quantitating work capacity improves the diagnostic accuracy of impairment/disability evaluation”
    • American Thoracic Society
  – “Direct measures of VO\textsubscript{2} are reliable and reproducible and provide the most accurate assessment of functional capacity”
    • American Heart Association
  – “Unequivocal evidence...is not yet available, and for this reason we cannot make a formal recommendation for this practice. However...exercise testing can provide guidance on prognosis and individual patient counselling inpatients 10 years and older”
    • European Cystic Fibrosis Society
Cessation

• When to stop a CPET?
  • CPET is done to fatigue
  • UNLESS....
    – Severe desaturation with an $\text{SpO}_2 \leq 80\%$ when accompanied by symptoms and signs of severe hypoxemia
    – Other signs of respiratory failure
    – Chest pain suggestive of pneumothorax or cardiac ischemia
    – Hemoptysis
    – Sudden pallor
    – Systolic blood pressure exceeding 250 mm Hg
    – Decrease in systolic blood pressure by more than 20 mm Hg or increase in diastolic pressure above 120 mm Hg
    – Loss of coordination, Mental confusion, Dizziness or faintness, Complex cardiac ectopy, Second- or third-degree heart block

Demonstration