Exercise testing of athletes

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Objectives

• Exercise stress testing in athletes
  ▫ What are the information can we obtain?
  ▫ Cardiopulmonary exercise testing

• Role of exercise testing in different conditions
  ▫ Cardiomyopathies
  ▫ Ion-channelopathies
  ▫ Accessory pathway
  ▫ Post-exertional syncope
  ▫ Coronary artery anomalies
  ▫ Ischaemic heart disease (Master athletes)
Different modes of exercise testing
• Advantages of treadmill
  ▫ Attain higher VO2
  ▫ More functional

• Advantages of cycle ergometer
  ▫ Cheaper
  ▫ Requires less space
  ▫ Less ECG noise
  ▫ Easier BP recording, blood draw, ECHO
  ▫ Little training needed
  ▫ Safer
  ▫ Direct power calculation
    ▫ Independent of weight
    ▫ Holding bars has no effect
Garbage in - Garbage out

- Good skin preparation
- Placement of your leads
- Good ECG trace
  - PR isoelectric line
- Test BP cuff
- Clear instructions to the athlete
Value of exercise stress testing

- Exercise duration & MET (surrogate to fitness)
- Provoke symptoms
  - Angina, Shortness of breath, palpitations, syncope
- ST-segment depression
- BP response to exercise
  - Hypotension or hypertension
- Chronotropic incompetence
- Heart rate recovery
- Arrhythmias
- Accessory pathways
Cardiopulmonary exercise testing

Variables

- VO2max/VO2 peak
- Anaerobic threshold
- Peak heart rate
- Heart rate reserve
- Peak work
- O2 pulse (VO2/HR)
- Ventilatory reserve
- Respiratory frequency
- VE/VCO2 (at AT)
- VD/VT
- P(A-a)O2

Wasserman 9-panel plot
Performing an exercise stress test

- Exercise most athletes to volitional exhaustion
- 12-lead ECG and BP recordings every minute
- Continue recording 3-5 mins into recovery
- When to stop an exercise test!
  - Athlete becomes symptomatic
  - ECG ischaemic changes and arrhythmias
  - Systolic BP drop (>20mmHg)
Hypertrophic cardiomyopathy (HCM)
Contribution of ETT in HCM

“Grey zone”
LVWT 13-16 mm
T-wave inversion

Female gender & Family history of HCM

**ECG**
- Isolated Sokolow-Lyon LVH
- ST-segment depression/Deep T-wave inversion inferolateral leads

**ECHO**
- LV cavity <54mm
- Bizarre patterns of LVH, LA >50mm, SAM, LVOT obstruction,
  Impaired systolic or diastolic function

**Exercise stress testing/ECG monitor**
- NSVT/VT, Abnormal BP response
- Peak VO2 >50 ml/kg/min or >120% predicted
- CMR-delayed gadolinium enhancement
Utilising CPET to distinguish HCM vs athlete’s heart

- Peak VO2 >50ml/kg/min or >120% predicted

Risk stratification in HCM

**HCM Risk-SCD Calculator**

- **Age**
- **Maximum LV wall thickness (mm)**
- **Left atrial size (mm)**
- **Max LVOT gradient (mmHg)**
- **Family History of SCD**
- **Non-sustained VT**
- **Unexplained syncope**
- **Risk of SCD at 5 years (%)**
- **ESC recommendation**

**History**
- Aborted SD
- Unexplained syncope
- FH of premature SCD

**ECHO**
- ETT
- NSVT/VT
- Abnormal BP response <25mmHg

**ETT**
- NSVT/VT

**Holter**
- NSVT/VT
Arrhythmogenic right ventricular cardiomyopathy

Pathophysiology

Genetic defect in one of a variety of cellular adhesion proteins

Failure of cellular adhesion

Myocyte detachment

Cell death

Development of focal myocarditis +/- Lymphocyte infiltration

ARVC
Diagnosis of ARVC
Contribution of ETT in ARVC

Symptoms
- RV dilatation, Inverted T waves V1-V3
- Epsilon waves
- Ventricular extrasystoles of LBBB morphology

Family history
- NSVT/VT

Impaired RV function

Impaired LV function

Asymptomatic

Voltage criteria for LVH on ECG

LV dilatation and preserved function

Good RV function
Risk pyramid in ARVC

- Aborted SCD
- VT with haemodynamic compromise
- Unheralded syncope
- Young age/Early disease progression
- Reduced RV systolic function
- Asymptomatic sustained VT on antiarrhythmics

ICD
Serial exercise tests to monitor response to treatment

- 33-year-old, Caucasian, tri-athlete
- Palpitations and paraesthesia on exertion
- Diagnosis of ARVC
- Commenced athlete on beta-blocker
### Long-QT syndrome - Schwartz score

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECG</strong></td>
<td></td>
</tr>
<tr>
<td>QTC (ms)</td>
<td></td>
</tr>
<tr>
<td>&gt;480</td>
<td>3</td>
</tr>
<tr>
<td>460-479</td>
<td>2</td>
</tr>
<tr>
<td>450-459 (males)</td>
<td>1</td>
</tr>
<tr>
<td><strong>QTc ≥480ms at 4th min of recovery from ETT</strong></td>
<td>1</td>
</tr>
<tr>
<td>Torsades de pointes</td>
<td>2</td>
</tr>
<tr>
<td>T-wave alternans</td>
<td>1</td>
</tr>
<tr>
<td>≥3 leads notched T-waves</td>
<td>1</td>
</tr>
<tr>
<td>Bradycardia for age</td>
<td>0.5</td>
</tr>
</tbody>
</table>

| **Clinical History**                                                      |        |
| Syncope                                                                   |        |
| With Stress                                                               | 2      |
| Without Stress                                                            | 1      |
| Congenital Deafness                                                       | 0.5    |
| Family history with definite LQTS                                         | 1      |
| Unexplained sudden death in 1st-degree family member <30 years           | 0.5    |

**Probability of LQTS**

- ≤1: low
- 1.5–3: intermediate
- ≥3.5: high
Ventricular tachycardia during exercise testing

Lying  
Standing  
Exercise  
Recovery
Paradoxical prolongation of the QT interval

Standing

Stage 1

Stage 2

Recovery
Cathecholaminergic Polymorphic Ventricular Tachycardia (CPVT)

- Genetic disorder (dominant or recessive)
- Disruption of the intracellular calcium regulation
- Presentation
  - Sudden death or syncope on exertion
  - Palpitations on exertion
- Polymorphic ventricular tachycardia
- Treatment
  - \( \beta \)-blockers
  - ICD
Exercise testing is the primary diagnostic tool.
The “slow” heart rate

- Athletes exhibit
  - Increased vagal tone
  - Reduced intrinsic sinus pacemaker rate
  - Reverses on detraining

- More likely to exhibit
  - Sinus bradycardia
  - Junctional rhythm
  - 1\textsuperscript{st}-degree heart block (PR-interval ≥200ms)
  - Mobitz type-I (10% of athletes)

- Mobitz type-II and 3\textsuperscript{rd}-degree heart block
  - Rare and shouldn’t be considered a normal finding
17-year-old swimmer
# Nodal versus infra-Hissian AV block

<table>
<thead>
<tr>
<th></th>
<th>Nodal AV Block</th>
<th>Infra-Hissian AV Block</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level of block</strong></td>
<td>AV Node (Extrinsic/Autonomic)</td>
<td>Infranodal (Intrinsic)</td>
</tr>
<tr>
<td><strong>Association</strong></td>
<td>Documented episodes 1st degree &amp; Mobitz I, occurs with sinus brady</td>
<td>Broad QRS, abnormal axis (interventricular conduction delay)</td>
</tr>
<tr>
<td><strong>Response to increased sinus rate</strong></td>
<td>Increased conduction</td>
<td>Increased block</td>
</tr>
<tr>
<td><strong>Environmental precipitants</strong></td>
<td>Vagal</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td><strong>Physiological</strong></td>
<td><strong>Pathological</strong></td>
</tr>
</tbody>
</table>
Post-exertional syncope

- Exercise testing can make the diagnosis

- Benign
  - Augmented vagal tone in young athletes
  - Increased parasympathetic release post exertion
  - Post-exercise peripheral vasodilation

Is all post-exertional syncope benign?

- Genetic sodium ion channel disorder
- Ventricular fibrillation
- Exercise is NOT considered to be a risk factor
- Most sudden deaths at rest/during sleep
- 10% of deaths occur post-exertion
- 56-year-old referred after the sudden death of his son
  - Exercising on a regular basis

<table>
<thead>
<tr>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-ETT Standing</td>
<td>Peak exercise</td>
<td>Recovery period</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>01:20</td>
<td>02:57</td>
</tr>
</tbody>
</table>
ST-segment elevation on recovery of ETT as a predictor of cardiac events in BrS

• 93 patients with BrS
  ▫ 22 documented VF, 35 syncope, 36 asymptomatic

• 102 healthy controls

• 37% of BrS but none of the controls
  ▫ exhibited ST elevation 1-4 min into recovery
  ▫ ≥0.05 mV in V1 to V3

• During 76 ± 38 months of follow-up
  ▫ 44% with ST elevation vs. 17% without exhibited VF (p=0.004)

Makimoto H et al. J Am Coll Cardiol 2010;56:1576-1584
ST-segment elevation on recovery of ETT as a predictor of cardiac events in BrS

- Previous episodes of VF
- SCN5a mutation
- Spontaneous type-1 pattern
- Late potential
- Inducibility in EPS
- Family history of SCD or BrS

HR 3.25; 95% CI: 1.4-7.3, p=0.007

- Important predictor amongst asymptomatic patients
  - 20% with ST elevation vs. 0% without exhibited VF (p=0.04)

Makimoto H et al. J Am Coll Cardiol 2010;56:1576-1584
Assessment of ventricular arrhythmias

- Utilised to assess significance of ventricular ectopy

- Data from general & athletic populations indicate
  - Athletes with increased VE/complexity during exercise are more likely to exhibit cardiac pathology
  - General population

Risk stratification in WPW

- **Low-risk features**
  - **Non-invasive**
    - Intermittent pre-excitation
    - Block in the accessory
      - During exercise
      - During drug challenge
  - **Invasive**
    - Anterograde refractory period of the accessory pathway >270ms
Sudden block in the accessory pathway during exercise testing
• 15-year-old, Afro-Caribbean, male, football player
• Three episodes of “pressure like” chest discomfort on exertion
• Associated with dizziness, No syncope
• No PMH or FH of note
• Normal examination
• 12-lead ECG
• Normal ECHO
Exercise stress testing

• Exercised for 13 minutes and 30 secs (Completed - Stage 4 Bruce protocol)
• Max HR 181 (88% age predicted)
• BP 122mmHg ⇒ 170mmHg
• No ST segment shift or arrhythmias
• Asymptomatic
Coronary artery anomalies

• A coronary artery originating from the wrong aortic sinus occurs in 1%
• Majority of individuals asymptomatic
• Most deaths during exercise & <30 years of age
  • One of the commonest causes of SCD in athletes
• High risk anomalies
  ▫ Arising from opposite coronary sinus (Left>Right)
  ▫ Course running between great vessels
Exercise testing and ischaemic heart disease

- Veteran athletes
- Referees, coaches, other personnel
- Amateur athletes
  - Master athletic federation
  - Leisure-time physical activity

- Age
- CV risk factors
- Intensity of exercise
- Habitual exercise
ACTIVE
Adult/senior

What activity?

Low intensity activity

Moderate intensity activity

High intensity activity

Assessment of risk (self- or by non physician)

Negative

Eligible for low intensity physical activity

Eligible for moderate/high exercise training

Further evaluation, appropriate treatment and individually prescribed PA

Positive

Screening by physician
- History
- Phys. Exam.
- Risk SCORE
- Rest ECG

Negative

Max exercise testing

Positive

Negative

Positive
Limitations of exercise testing as a screening tool for ischaemic heart disease

- Substantial number of false results
  - Particularly if asymptomatic, low risk, female

- NICE guidelines for individuals with CP

- Use of ETT recommended ONLY in patients with established CAD
  - CT calcium score ± CTCA (10%-29%)
  - Functional imaging (30%-60%)
  - Coronary angiography (61%-90%)
Prognostic Value of ETT

- Development of angina
- ST-segment depression
- Exercise duration
- Exercise hypotension or hypertension
- Chronotropic incompetence
- Heart rate recovery
- Ventricular ectopy
# Two exercise tests

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Athlete A</th>
<th>Athlete B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting BP (mmHg)</td>
<td>120/80</td>
<td>120/80</td>
</tr>
<tr>
<td>Resting heart rate (beats/min)</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Peak heart rate (beats/min)</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Chest pain during exercise</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Exercise ST-segment depression (mm)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Duration (minutes, Bruce protocol)</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Limiting symptoms</td>
<td>Fatigue</td>
<td>Dyspnoea</td>
</tr>
<tr>
<td>Peak exercise BP (mmHg)</td>
<td>210/70</td>
<td>140/60</td>
</tr>
<tr>
<td>Heart rate 1 min into recovery (beats/min)</td>
<td>138</td>
<td>162</td>
</tr>
</tbody>
</table>
Conclusion

- **Exercise testing in athletes can be utilised to:**
  - Assess & improve cardiopulmonary fitness
  - Evaluation of athletes with cardiac symptoms
  - Diagnostic purposes
  - Risk stratification of athletes with established disease
  - Monitoring/Response to treatment

- **False reassurance**
  - Young athlete with exertional chest pain and syncope
  - Accessory pathways
  - Pseudonormalisation of T-waves
  - Endurance athletes