Exercise testing of athletes

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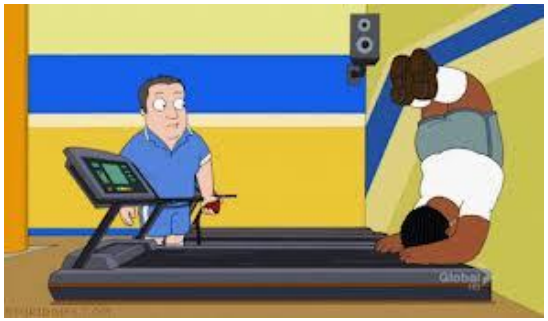
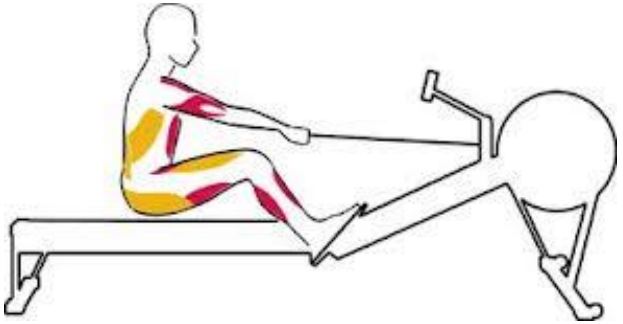
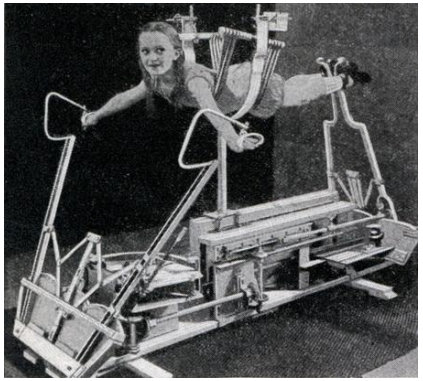
Objectives

- 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







Cardiac Risk in the Young

- 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

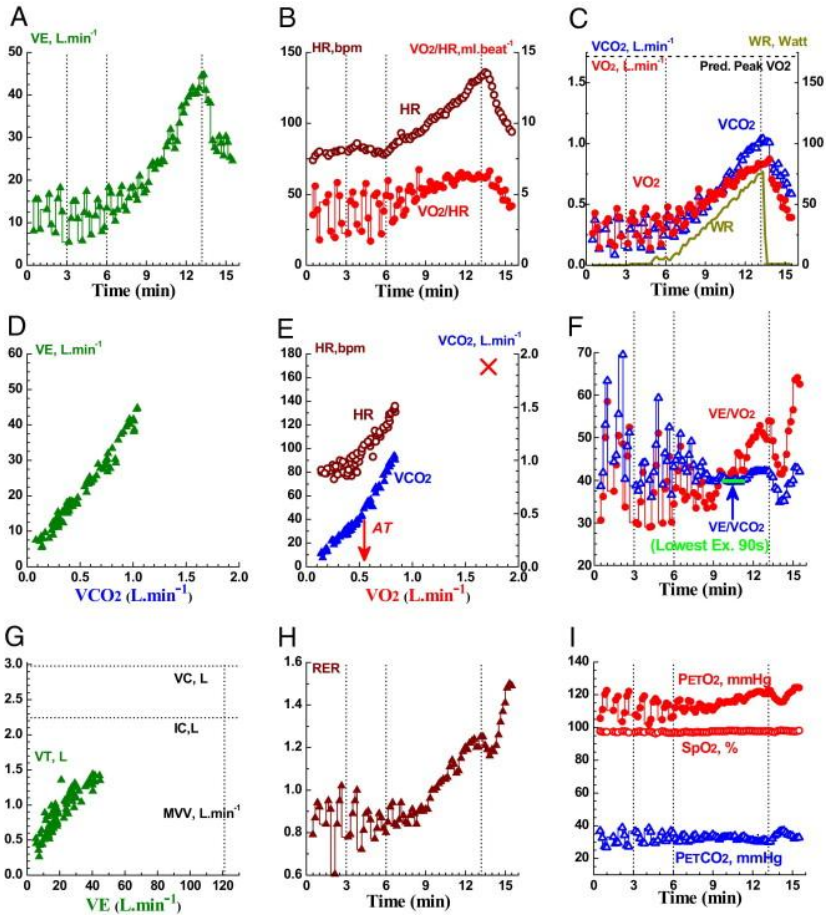
- Exercise duration & MET (surrogate to fitness)
- Provoke symptoms
  - Angina, Shortness of breath, palpitations, syncope
- ST-segment depression
- BP response to exercise
  - Hypotension or hypertension
- Chronotropic incompetence
- Heart rate recovery
- Arrhythmias
- Accessory pathways

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

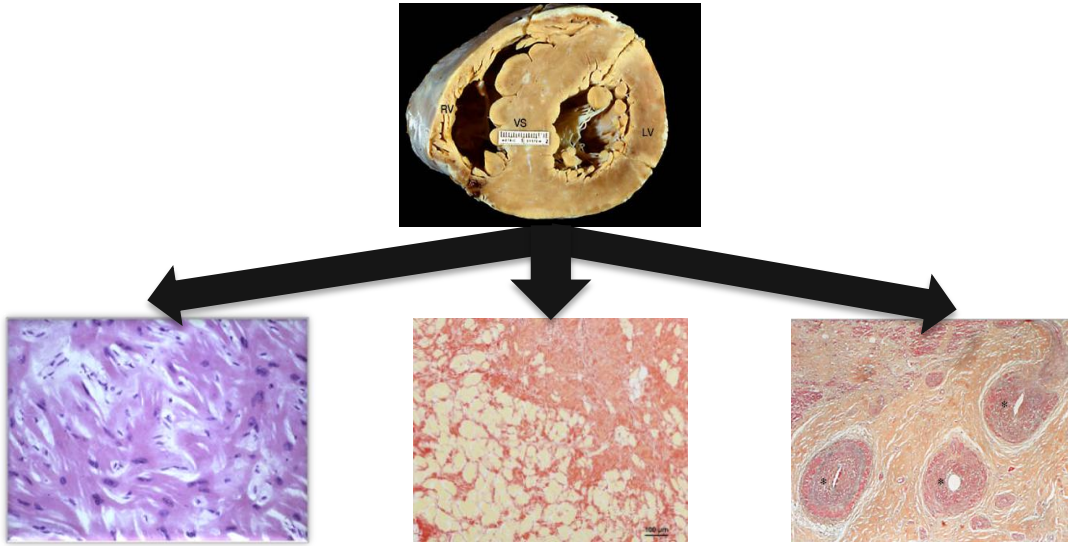


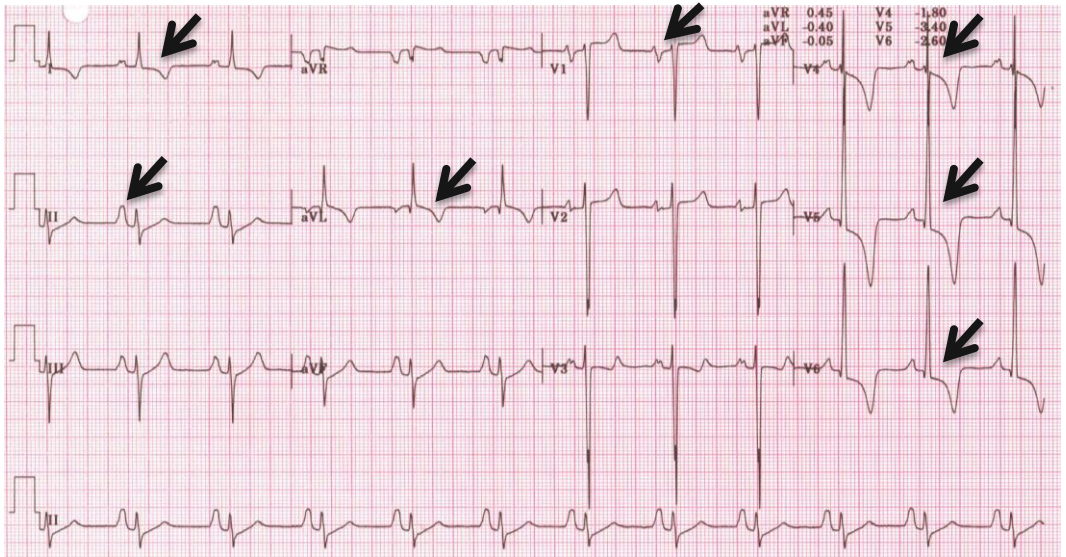
Performing an exercise stress test

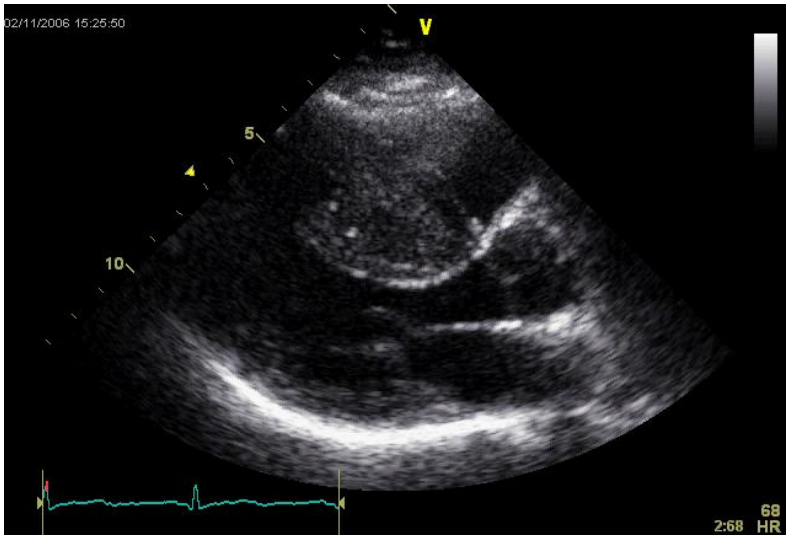
- Exercise most athletes to volitional exhaustion

- 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)

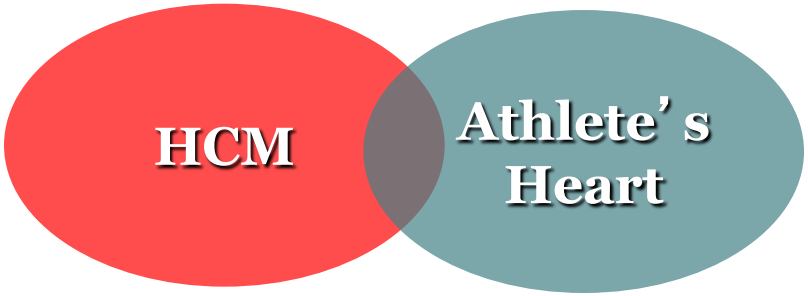






Contribution of ETT in HCM

"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

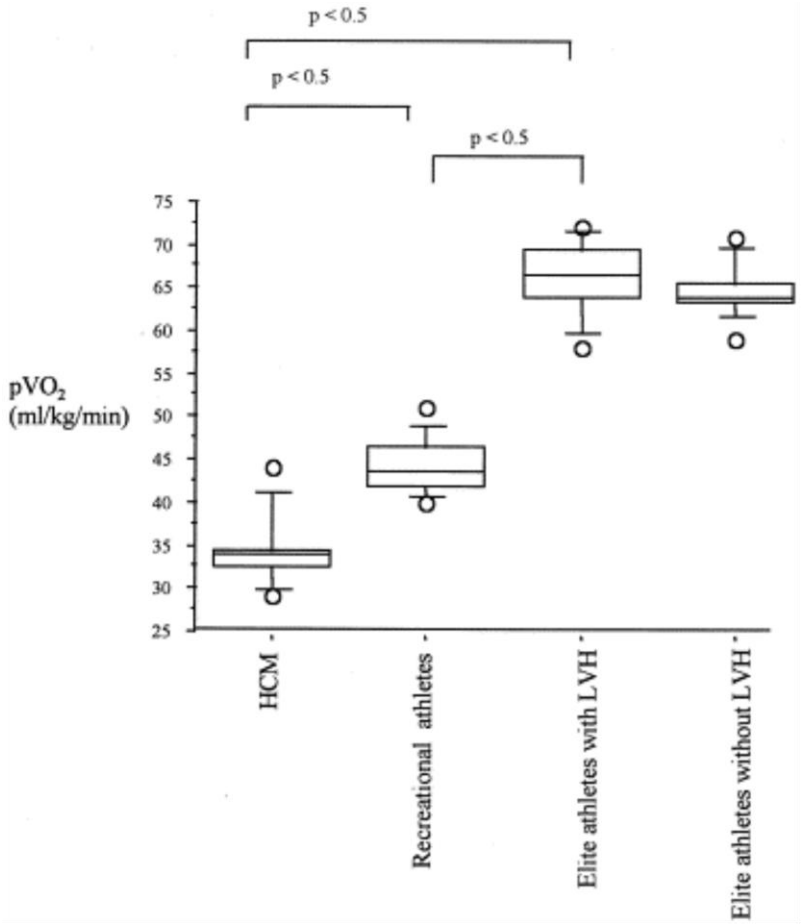
← NSVT/VT, Abnormal BP response

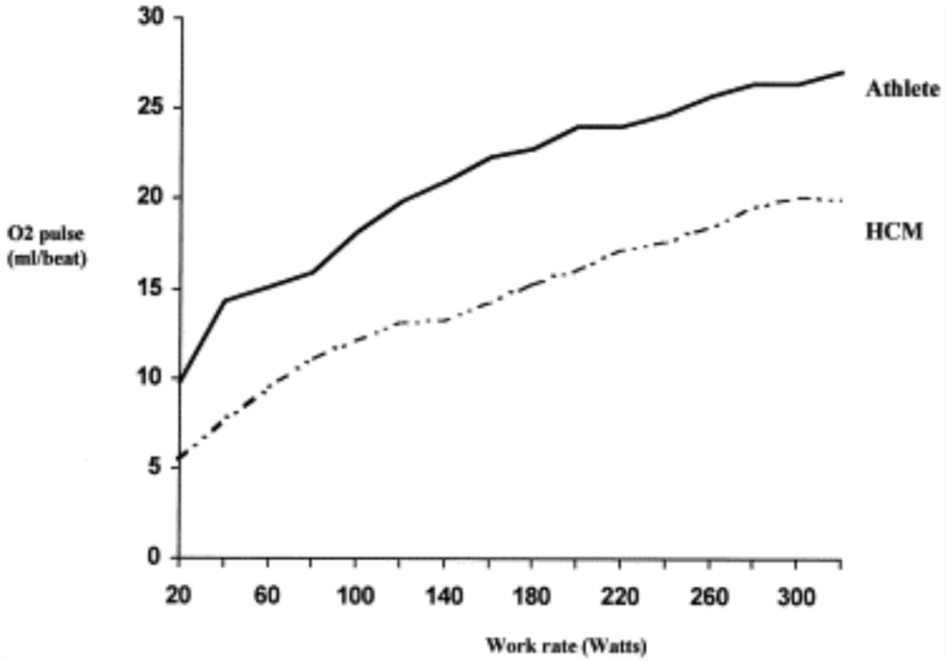
Peak VO2 >50 ml/kg/min or >120% predicted →

← CMR-delayed gadolinium enhancement

Utilising CPET to distinguish HCM vs athlete's heart

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





Sharma S et al. J Am Coll Cardiol 2000;36:864-870

Risk stratification in HCM

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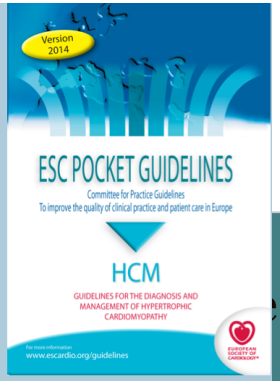
HCM Risk-SCD Calculator

Age	**Years**	*Age at evaluation*
Maximum LV wall thickness	**mm**	*Transthoracic Echocardiographic measurement*
Left atrial size	**mm**	*Left atrial diameter determined by M-Mode or 2D echocardiography in the parasternal long axis plane at time of evaluation*
Max LVOT gradient	**mmHg**	*The maximum LV outflow gradient determined at rest and with Valsalva provocation (irrespective of concurrent medical treatment) using pulsed and continuous wave Doppler from the apical three and five chamber views. Peak outflow tract gradients should be determined using the modified Bernouilli equation: Gradient= $4V^2$, where V is the peak aortic outflow velocity*
Family History of SCD	○ No ○ Yes	*History of sudden cardiac death in 1 or more first degree relatives under 40 years of age or SCD in a first degree relative with confirmed HCM at any age (post or ante-mortem diagnosis).*
Non-sustained VT	○ No ○ Yes	*3 consecutive ventricular beats at a rate of 120 beats per minute and <30s in duration on Holter monitoring (minimum duration 24 hours) at or prior to evaluation.*
Unexplained syncope	○ No ○ Yes	*History of unexplained syncope at or prior to evaluation.*

Risk of SCD at 5 years (%):	
ESC recommendation:	

Reset



Histo

ECH

t

ETT → NSVT/VT → Abnormal BP response <25mmHg

Holter → NSVT/VT

Arrhythmogenic right ventricular cardiomyopathy

ARVC Pathophysiology

Genetic defect in one of a variety of cellular adhesion proteins

↓

Failure of cellular adhesion

↓

Myocyte detachment

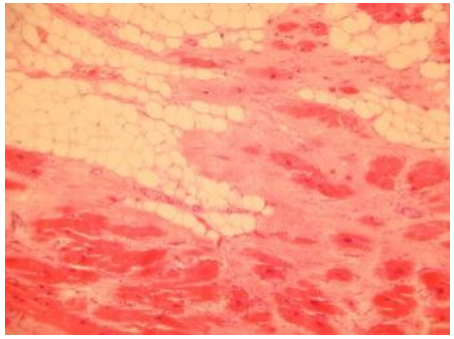
↓

Cell death

↓

Development of focal myocarditis +/- Lypmhocyte infiltration

↓



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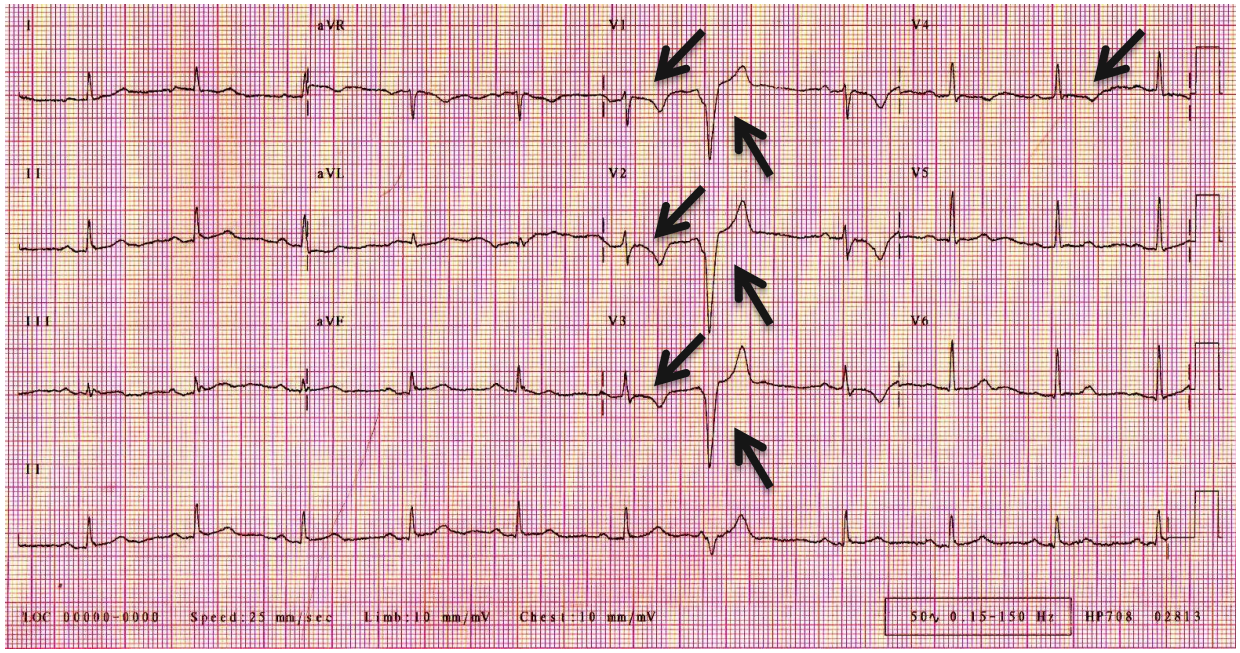
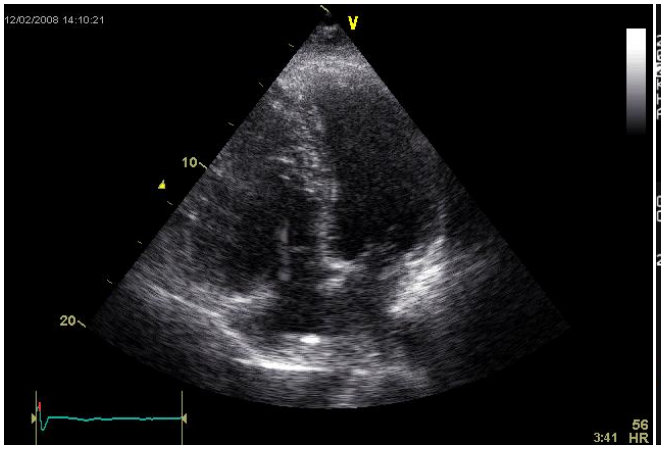
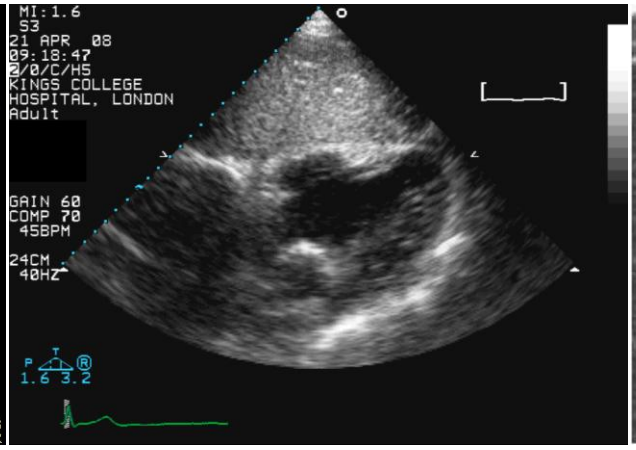
Diagnosis of ARVC







Contribution of ETT in ARVC

Symptoms

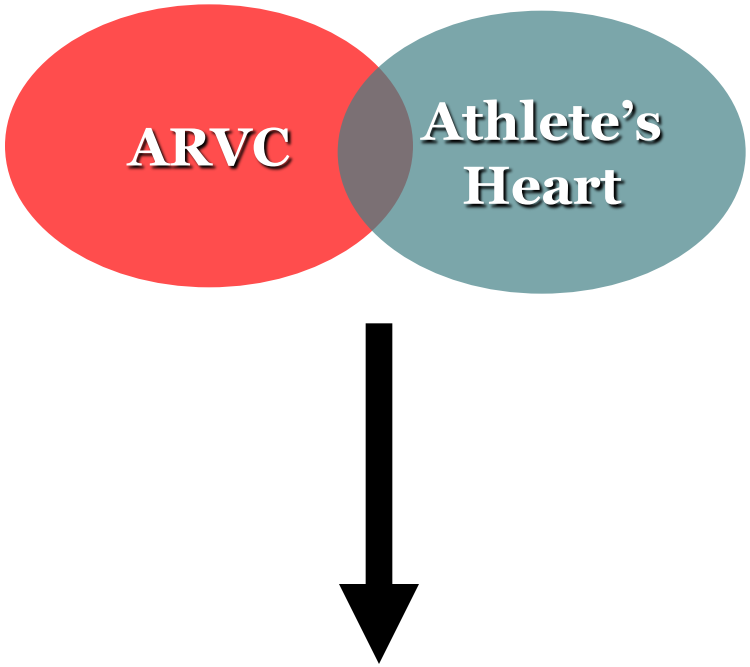
Family history

Impaired RV function

Impaired LV function

Epsilon waves

NSVT/VT



Asymptomatic

Voltage criteria for LVH on ECG

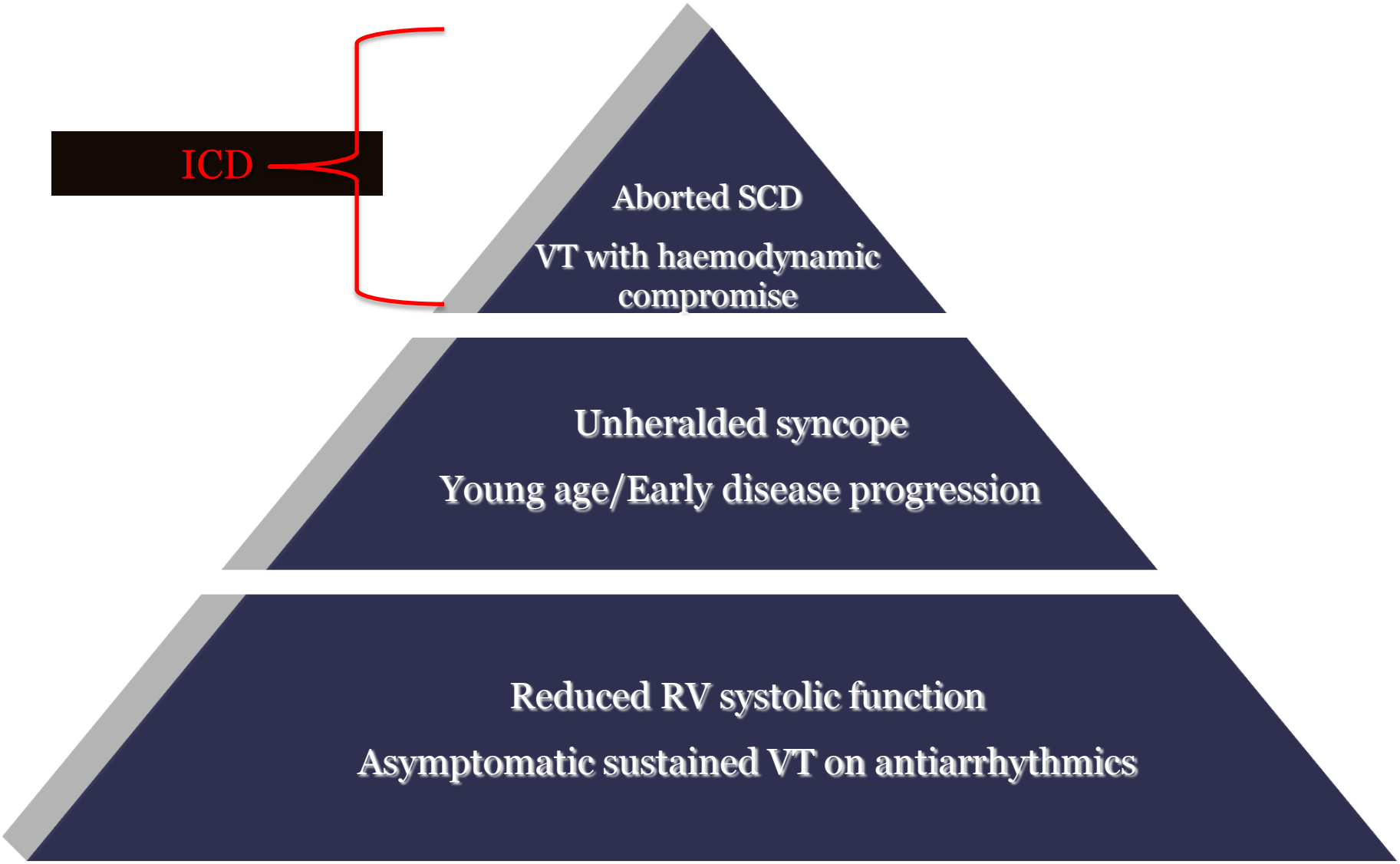
LV dilatation and preserved function

Good RV function

RV dilatation, Inverted T waves V1-V3

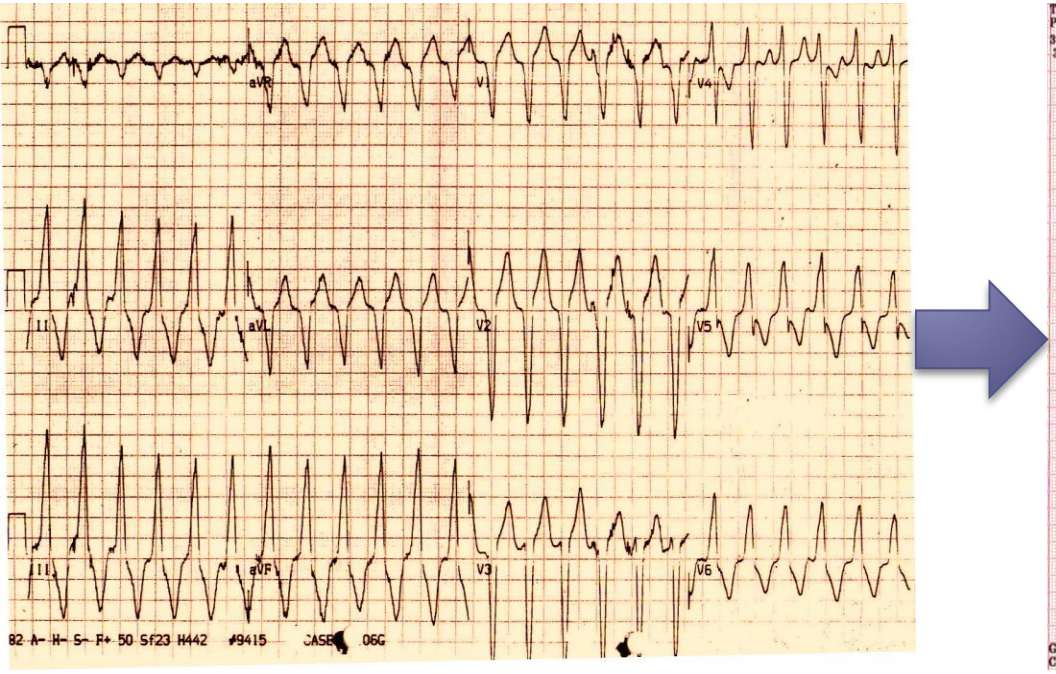
Ventricular extrasystoles of LBBB morphology

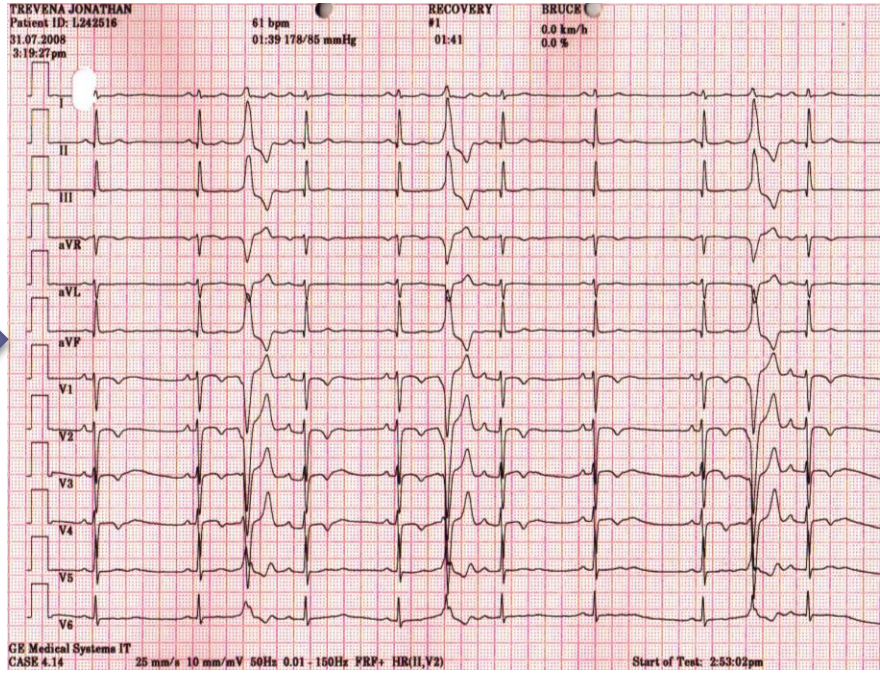
Risk pyramid in ARVC



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



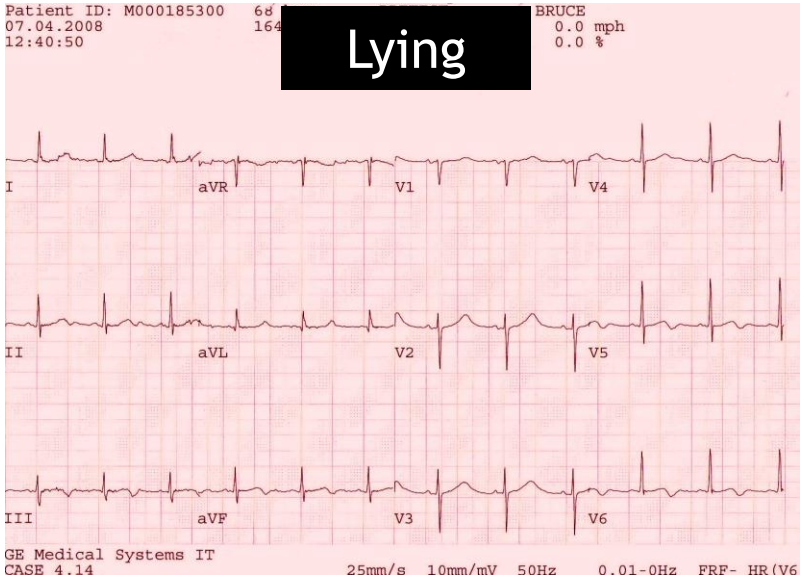


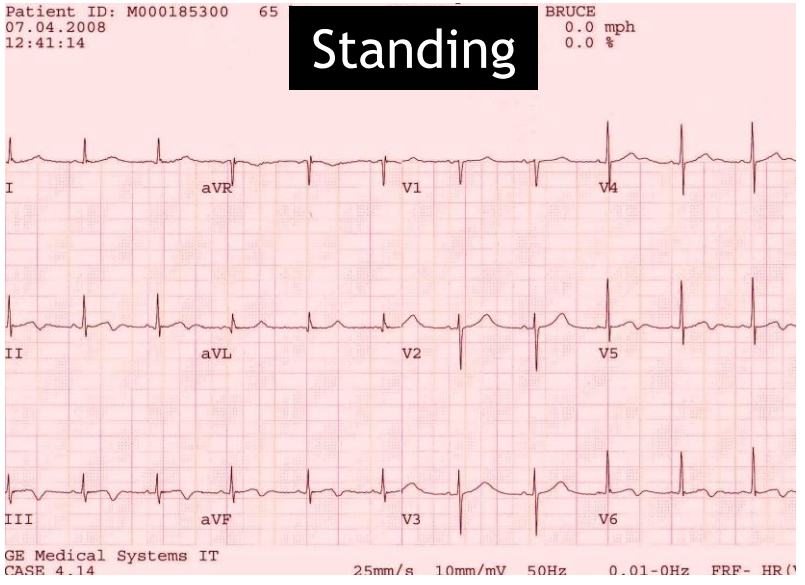
Long-QT syndrome - Schwartz score

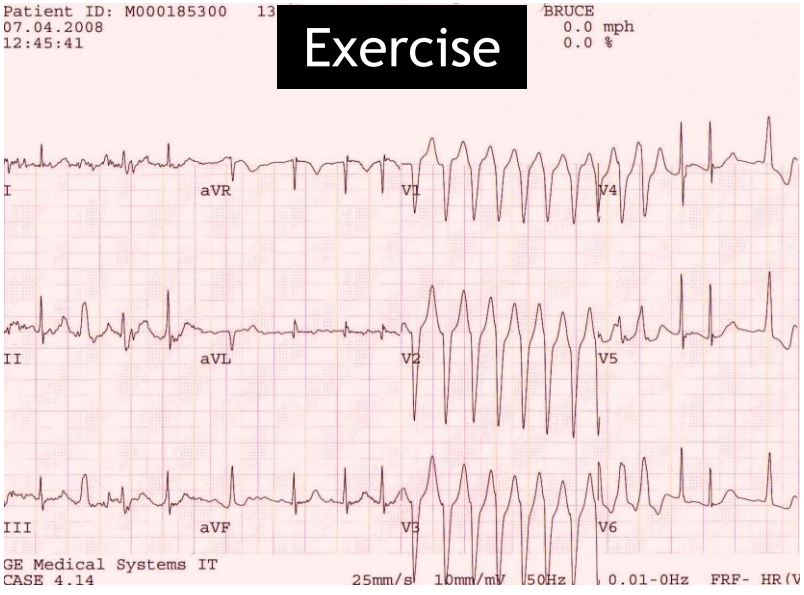
Probability of LQTS
≤1: low
1.5–3: intermediate
≥3.5: high

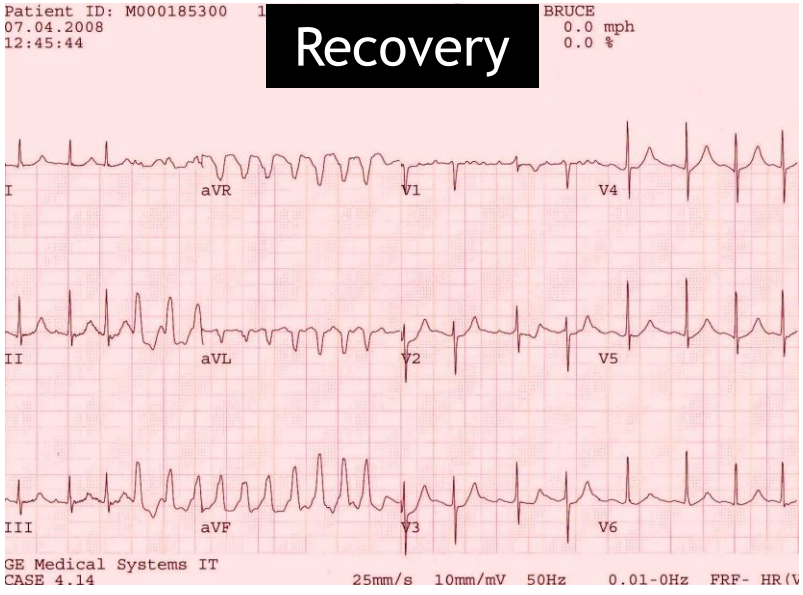
Criterion		Points
ECG		
QTC (ms)	>480	3
	460-479	2
	450-459 (males)	1
QTc ≥480ms at 4th min of recovery from ETT		1
Torsades de pointes		2
T-wave alternans		1
≥3 leads notched T-waves		1
Bradycardia for age		0.5
Clinical History		
Syncope	With Stress	2
	Without Stress	1
Congenital Deafness		0.5
Family history with definite LQTS		1
Unexplained sudden death in 1st-degree family member <30 years		0.5

Ventricular tachycardia during exercise testing

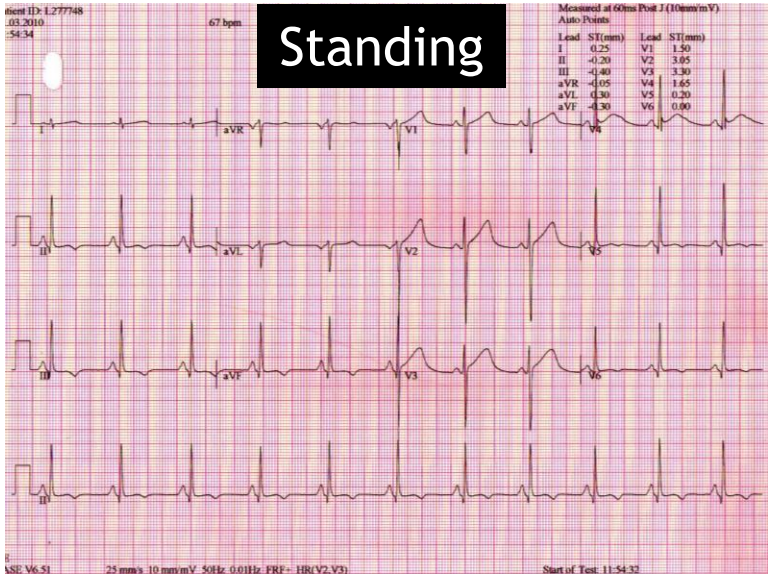


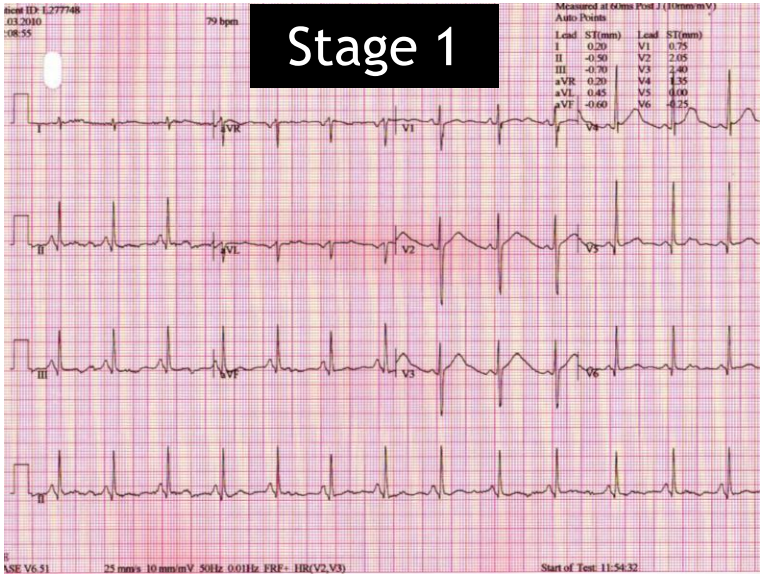


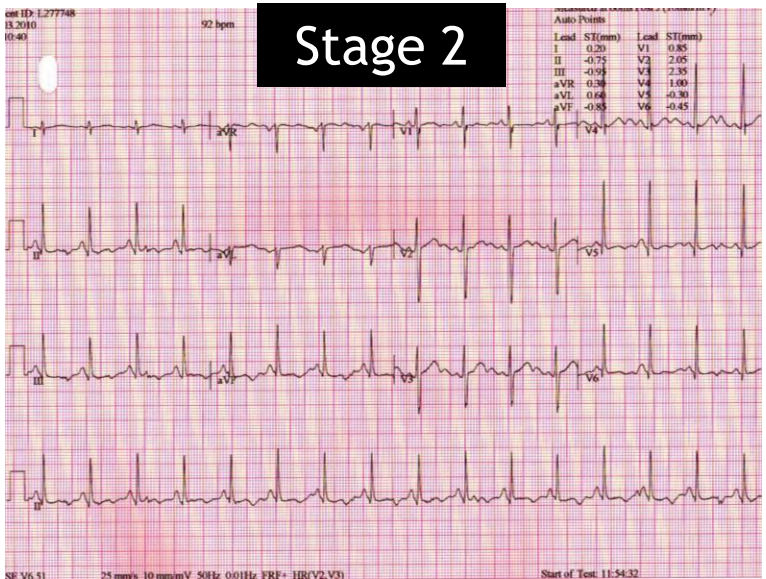


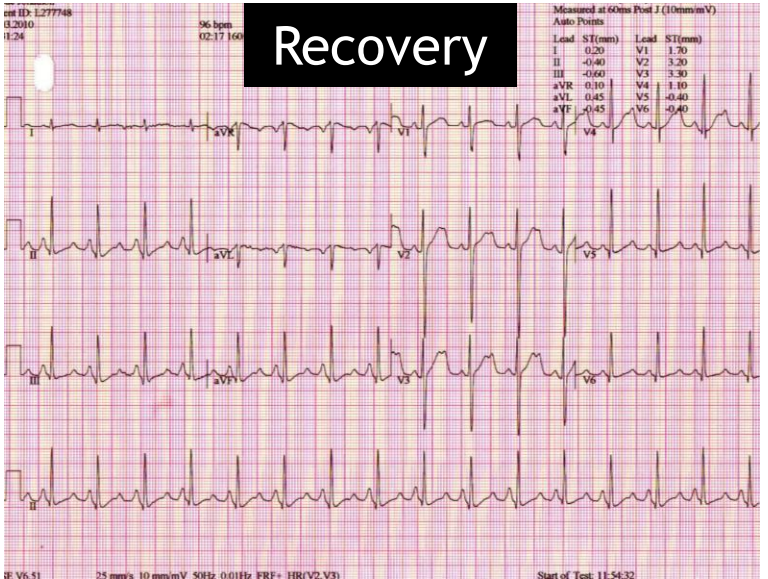


Paradoxical prolongation of the QT interval





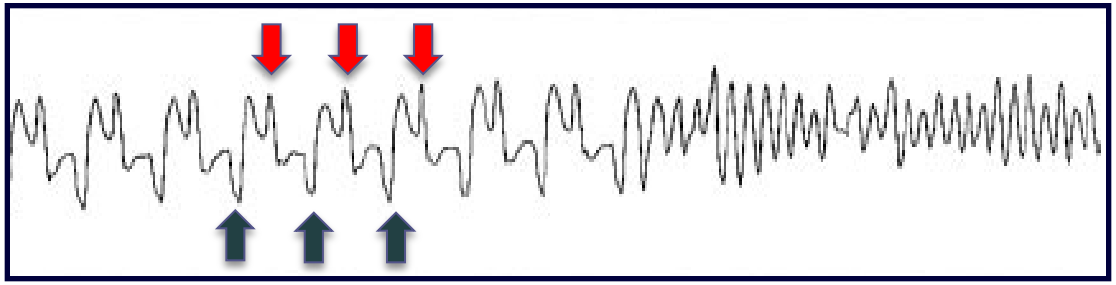


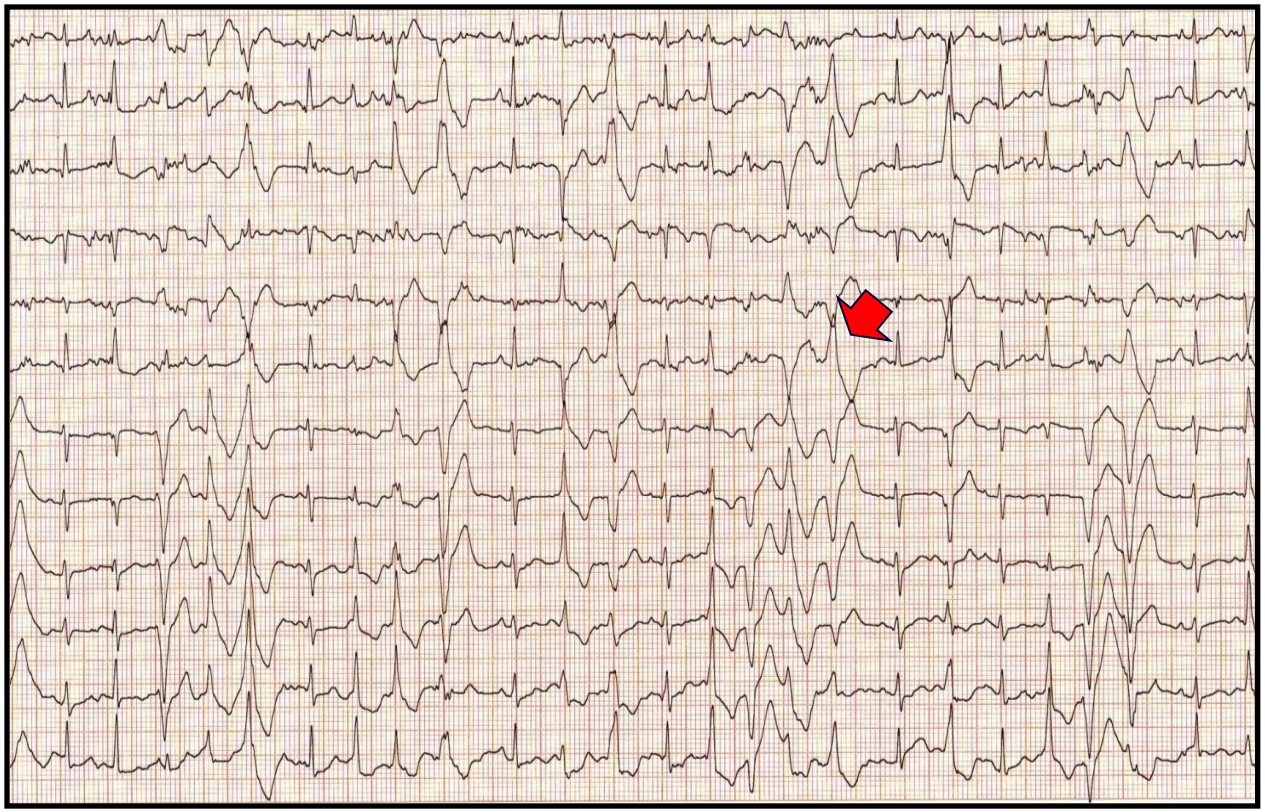


Cathecholaminergic Polymorphic Ventricular Tachycardia (CPVT)

- 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
  - β-blockers
  - ICD

Exercise testing is the primary diagnostic tool

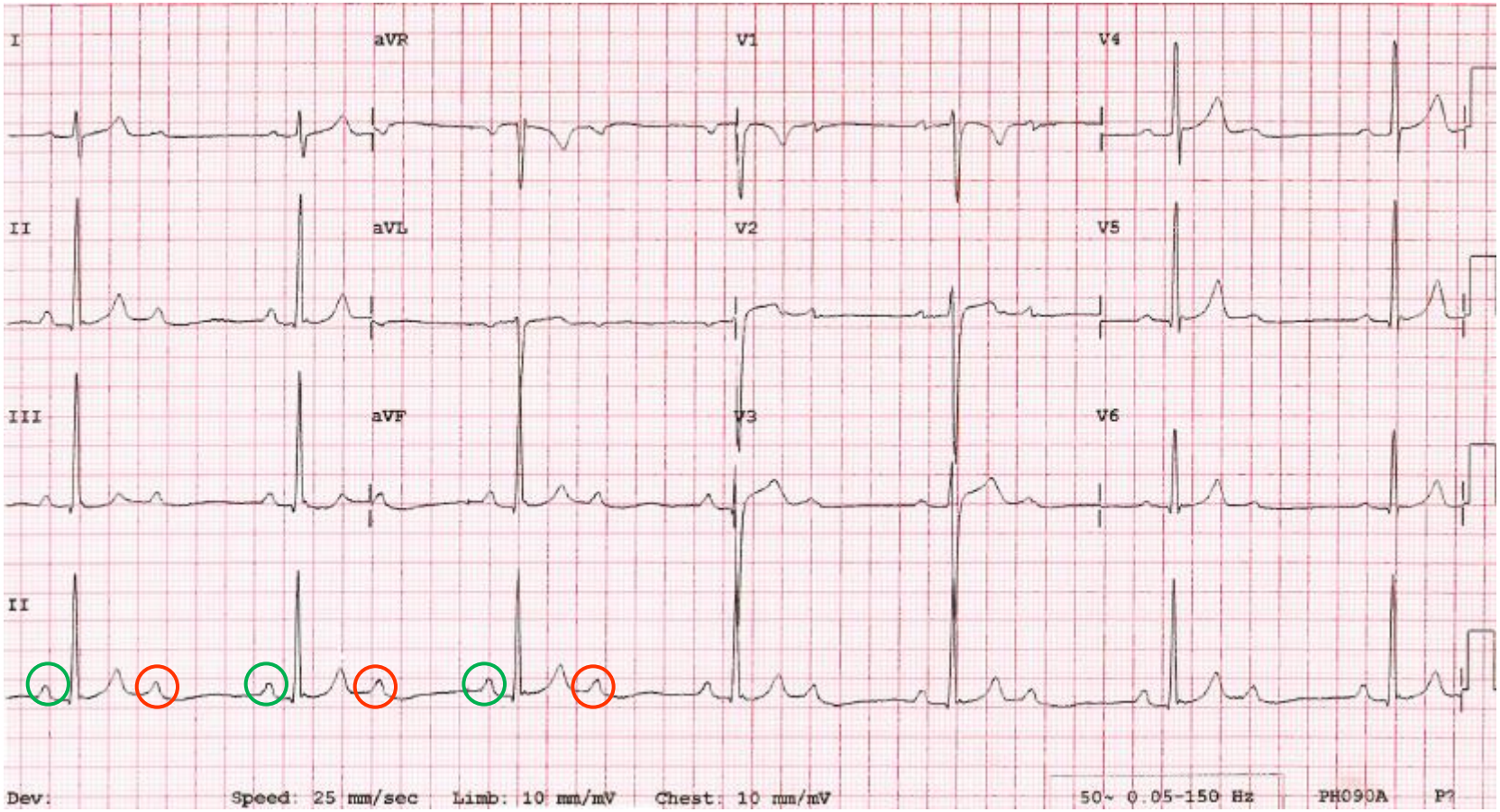




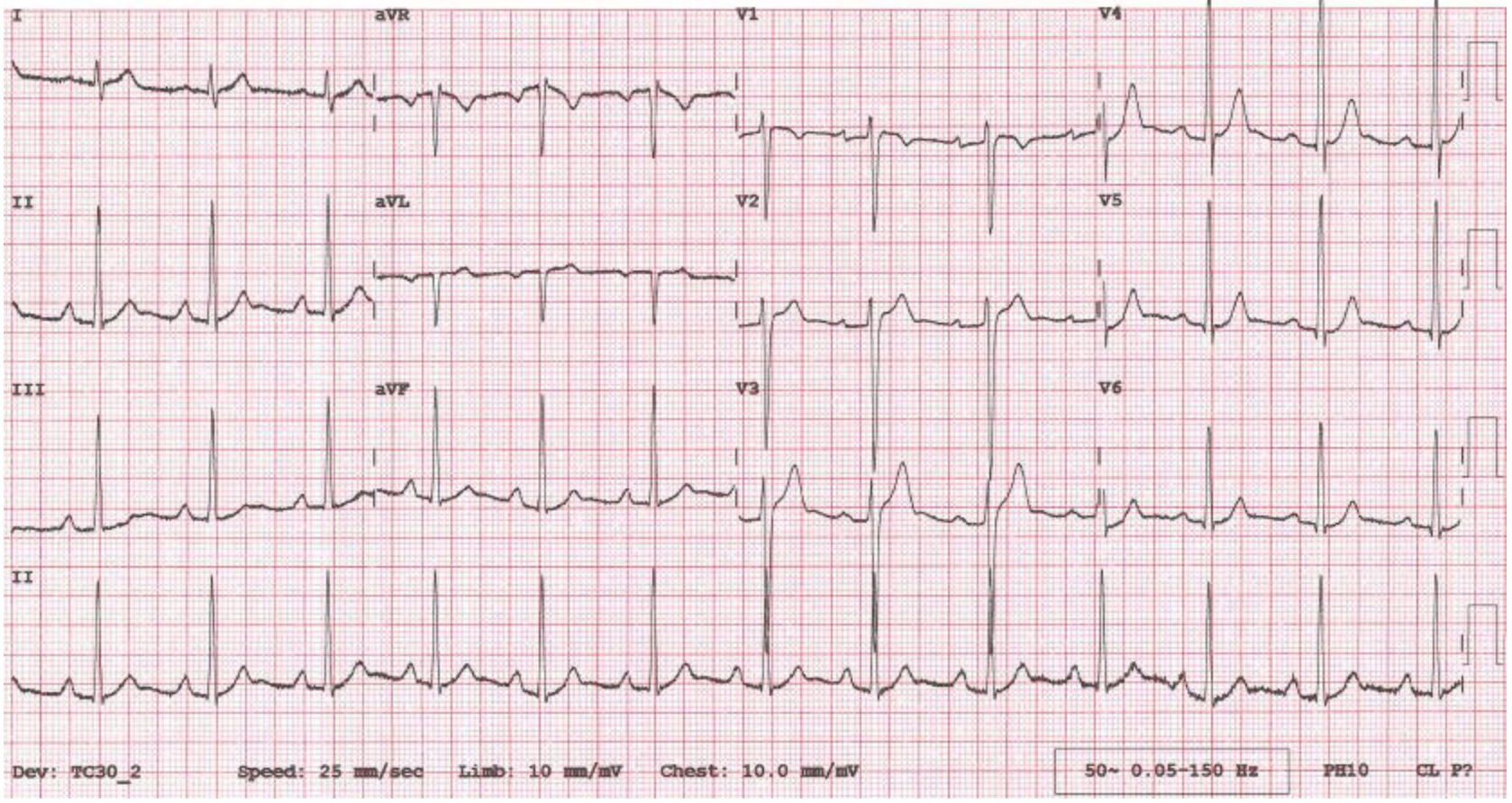
The “slow” heart rate

- Athletes exhibit
  - Increased vagal tone
  - Reduced intrinsic sinus pacemaker rate
  - Reverses on detraining
- More likely to exhibit
  - Sinus bradycardia
  - Junctional rhythm
  - 1st-degree heart block (PR-interval ≥200ms)
  - Mobitz type-I (10% of athletes)
- Mobitz type-II and 3rd-degree heart block
  - Rare and shouldn’ t be considered a normal finding

17-year-old swimmer




II
III
aVF

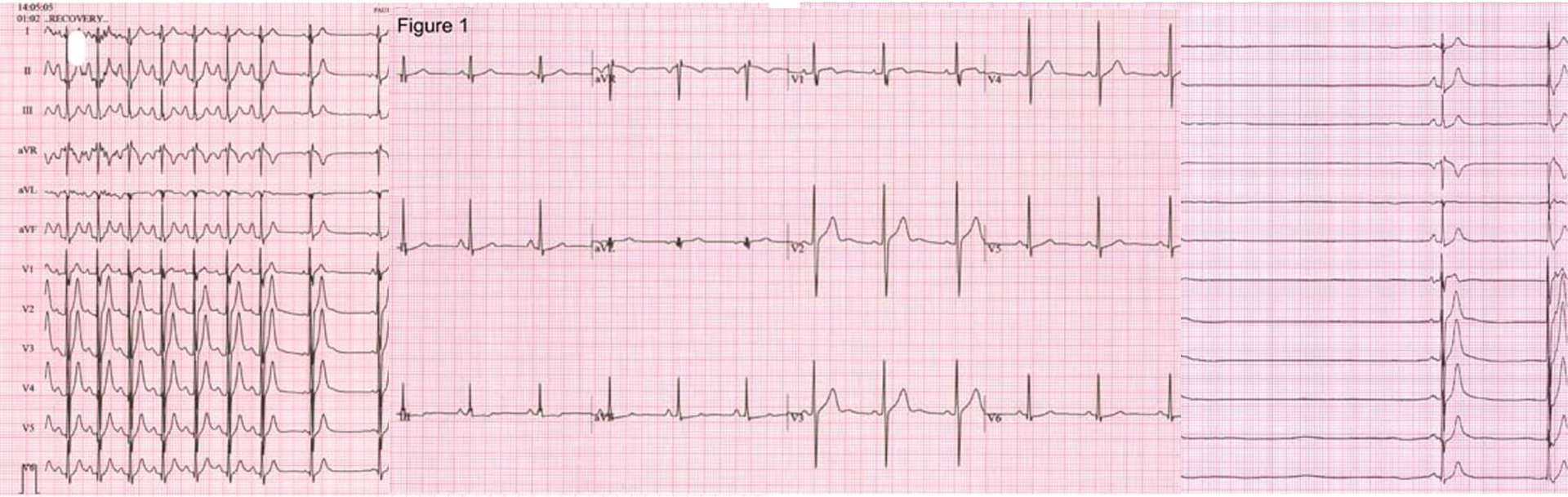

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
Dev: TC30_2
Speed: 25 mm/sec
Limb: 10 mm/mV
Chest: 10.0 mm/mV
50~ 0.05-150 Hz
PH10
CL P?

Nodal versus infra-Hissian AV block

	Nodal AV Block	Infra-Hissian AV Block
Level of block	AV Node (Extrinsic/Autonomic)	Infranodal (Intrinsic)
Association	Documented episodes 1st degree & Mobitz I, occurs with sinus brady	Broad QRS, abnormal axis (interventricular conduction delay)
Response to increased sinus rate	Increased conduction	Increased block
Environmental precipitants	Vagal	None
	Physiological	**Pathological**

Post-exertional syncope

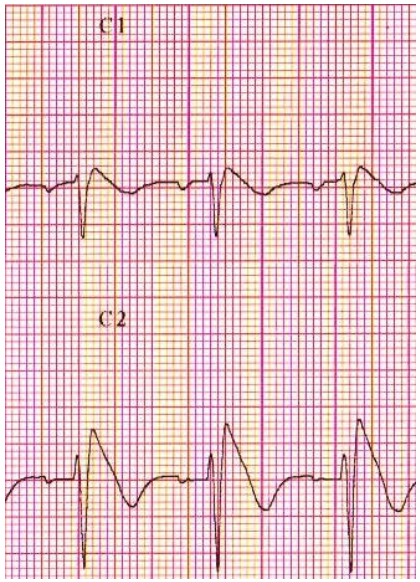
- Exercise testing can make the diagnosis
- Benign
  - Augmented vagal tone in young athletes
  - Increased parasympathetic release post exertion
  - Post-exercise peripheral vasodilation



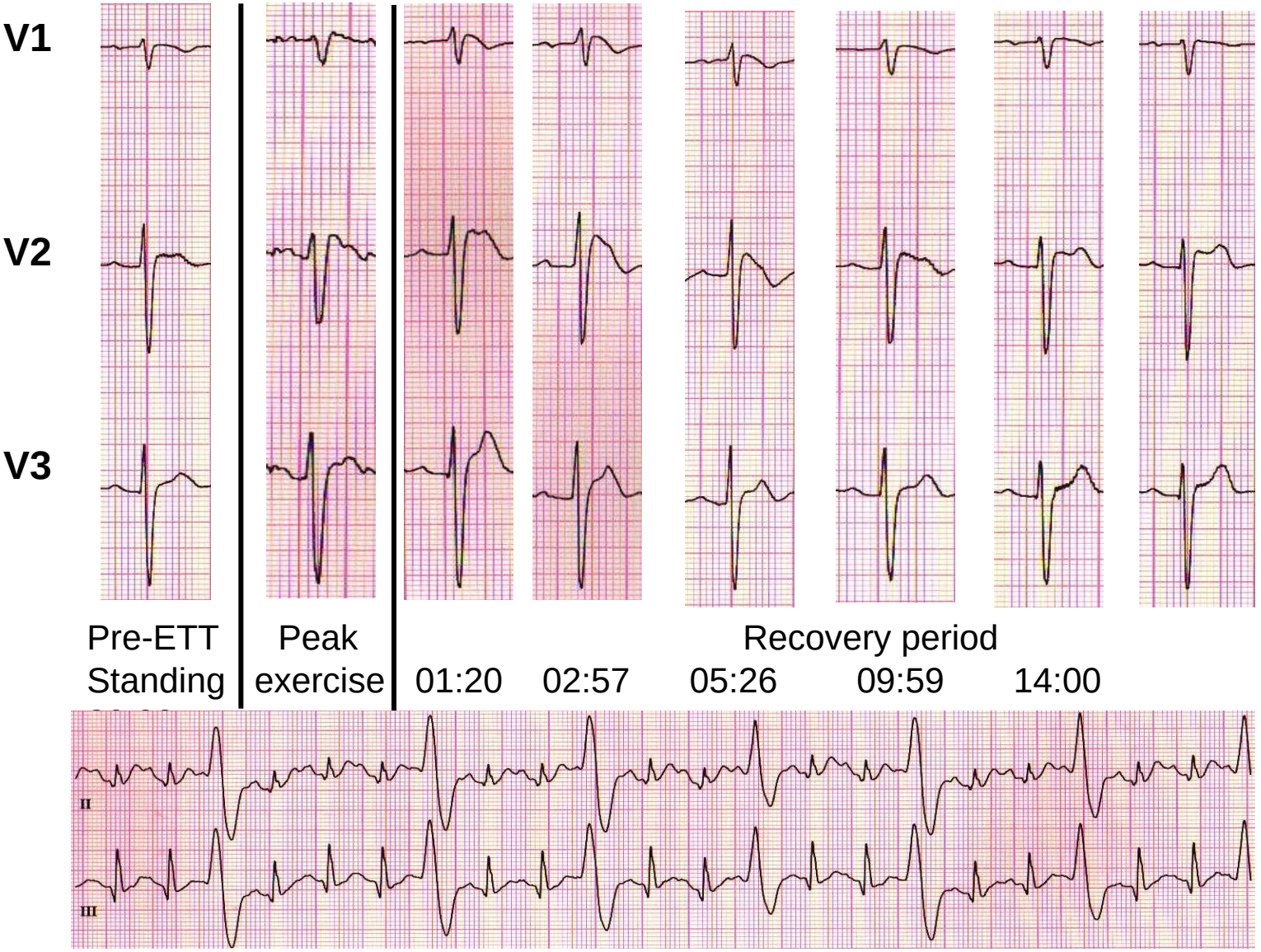
Whitaker J et al. BMJ Case Reports 2011;2011:bcr.11.2010.3519

Is all post-exertional syncope benign?

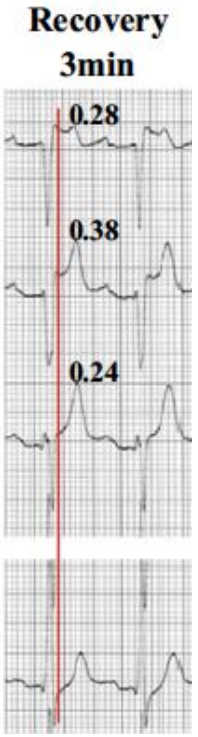
- Genetic sodium ion channel disorder
- Ventricular fibrillation
- Exercise is NOT considered to be a risk factor
- Most sudden deaths at rest/during sleep
- 10% of deaths occur post-exertion



- 56-year-old referred after the sudden death of his son
  - Exercising on a regular basis



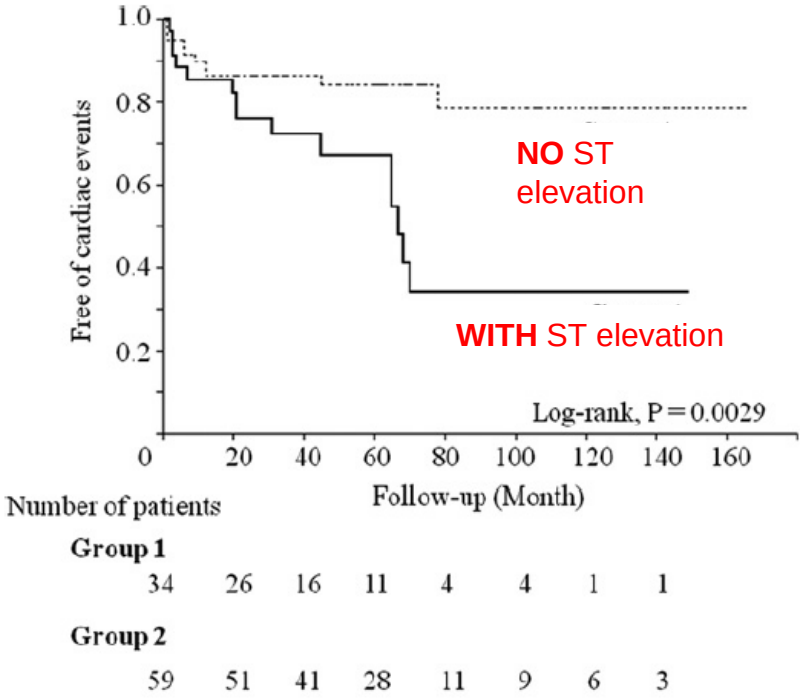
ST-segment elevation on recovery of ETT as a predictor of cardiac events in BrS



- 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

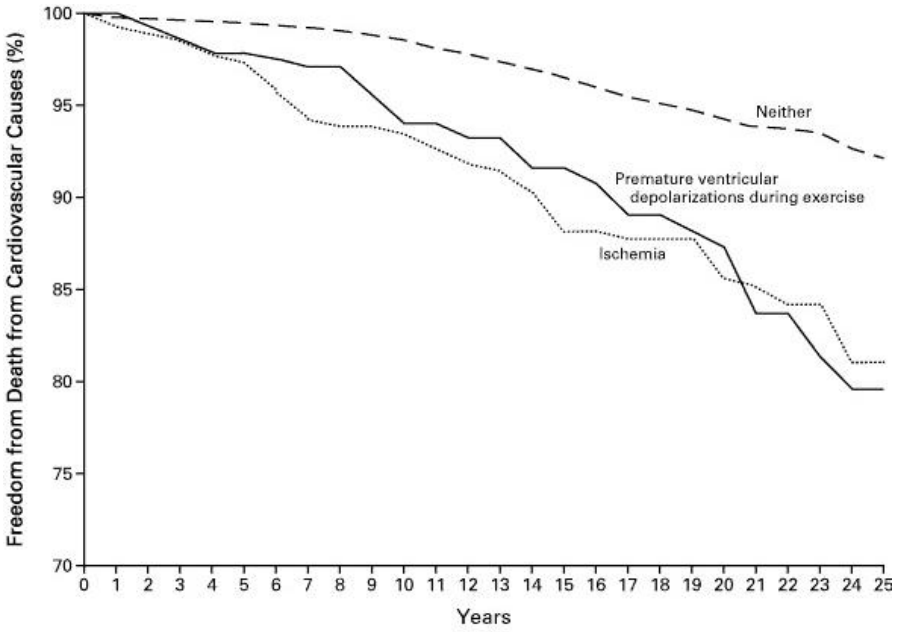
HR 3.25; 95% CI: 1.4-7.3, p=0.007

- 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

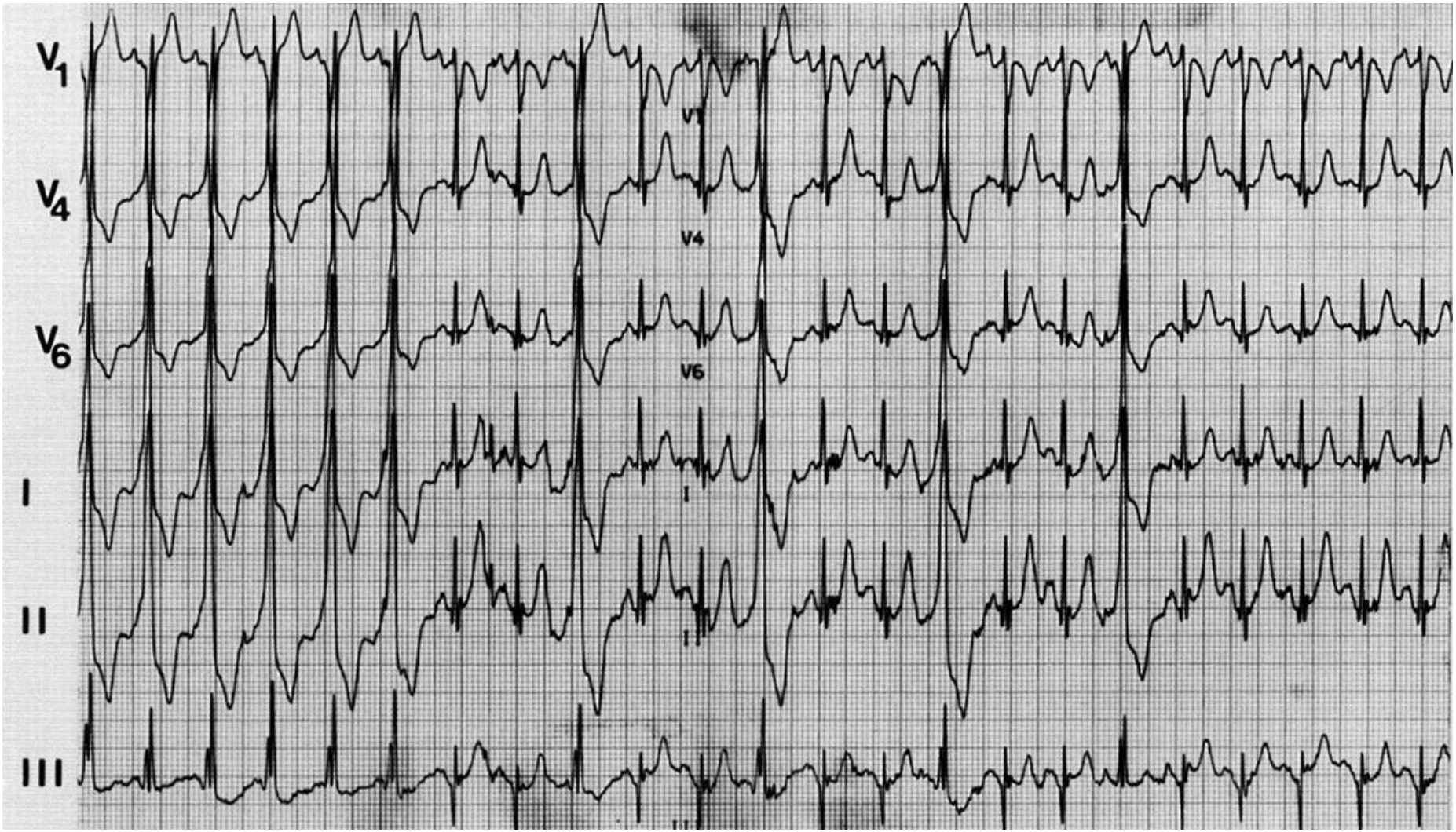


Jouven X et al. N Engl J Med 2000;343:826-833

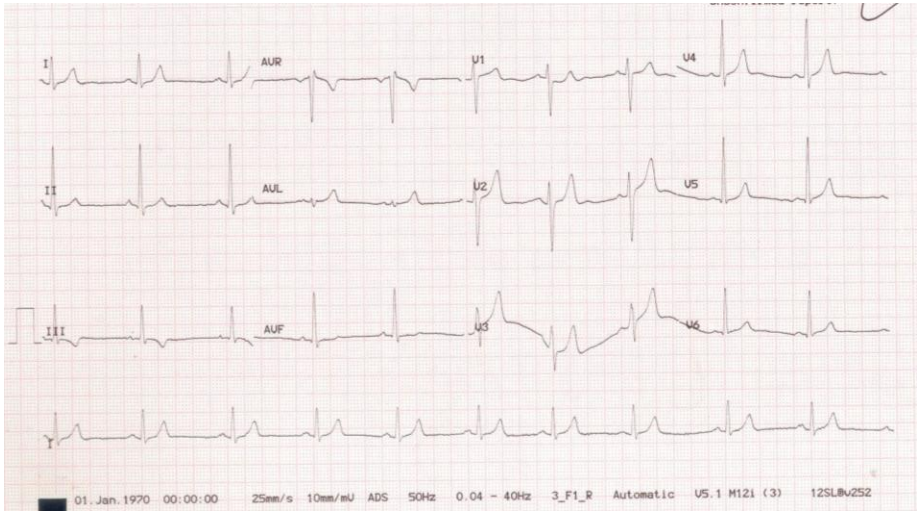
Risk stratification in WPW

- 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

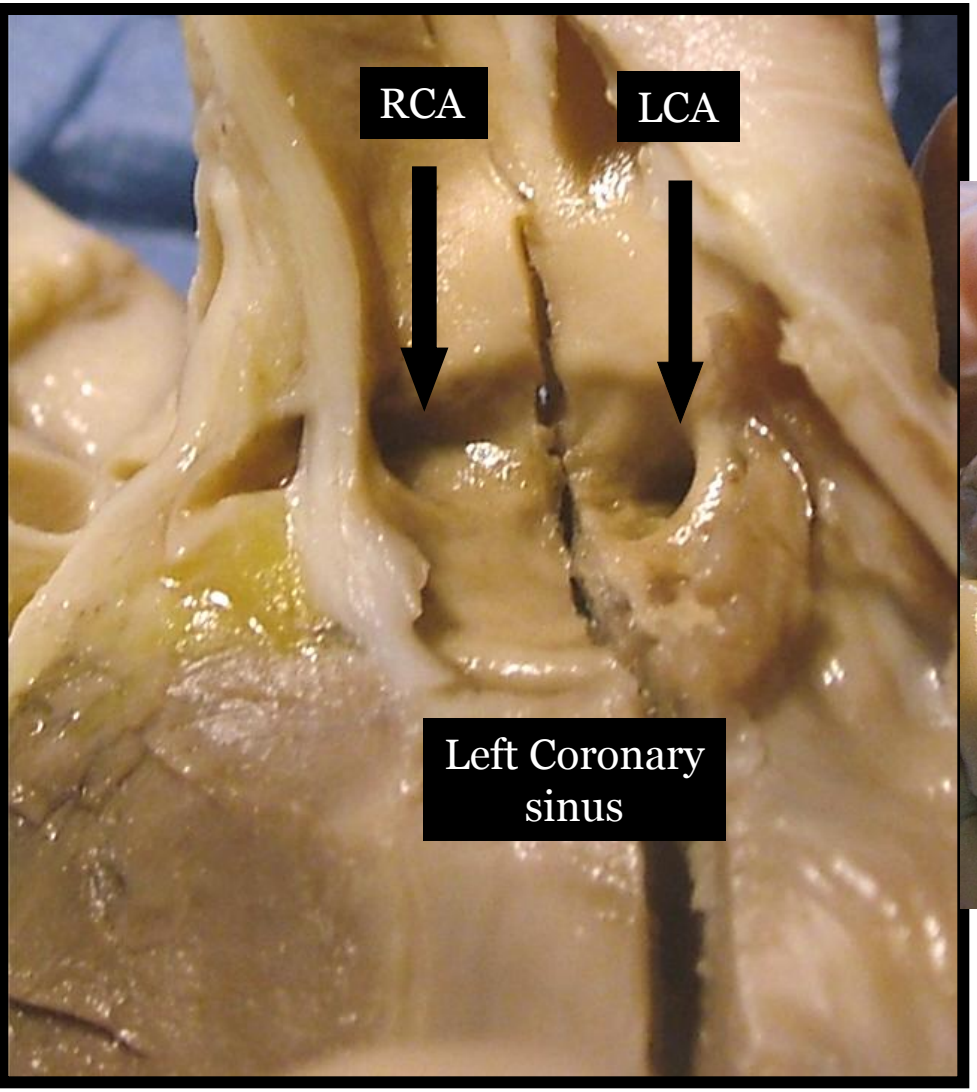


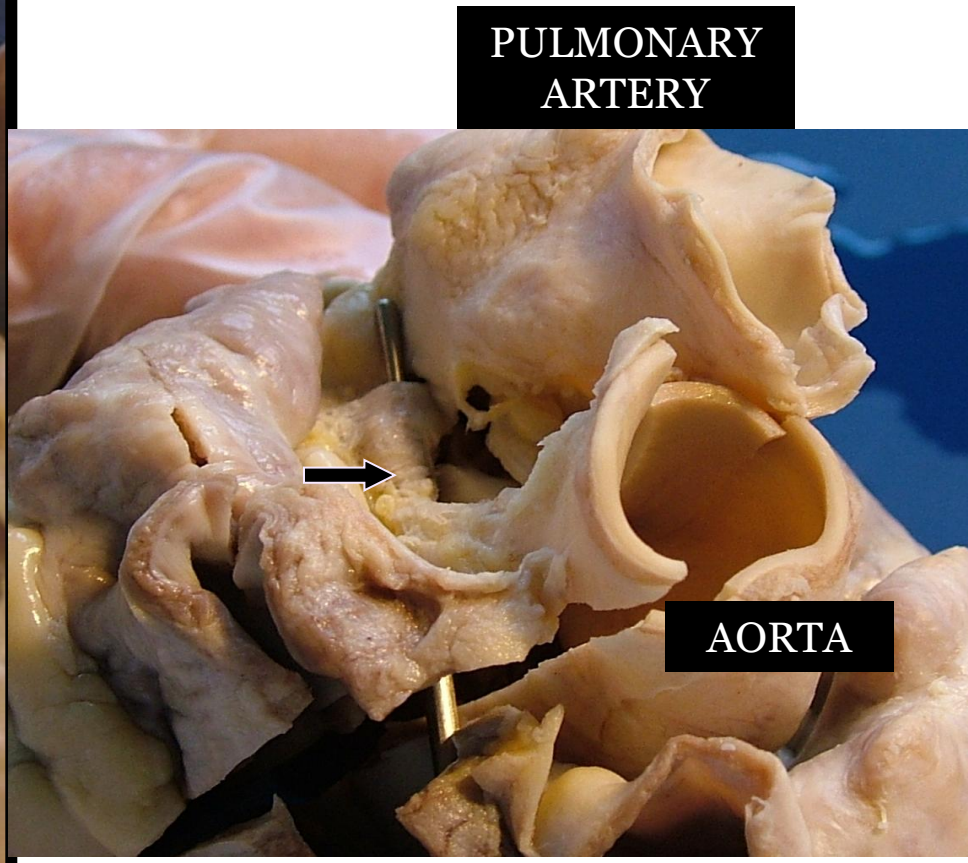
- 15-year-old, Afro-Caribbean, male, football player
- Three episodes of “pressure like” chest discomfort on exertion
- Associated with dizziness, No syncope
- No PMH or FH of note
- Normal examination
- 12-lead ECG
- Normal ECHO



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


RCA
LCA
Left Coronary sinus

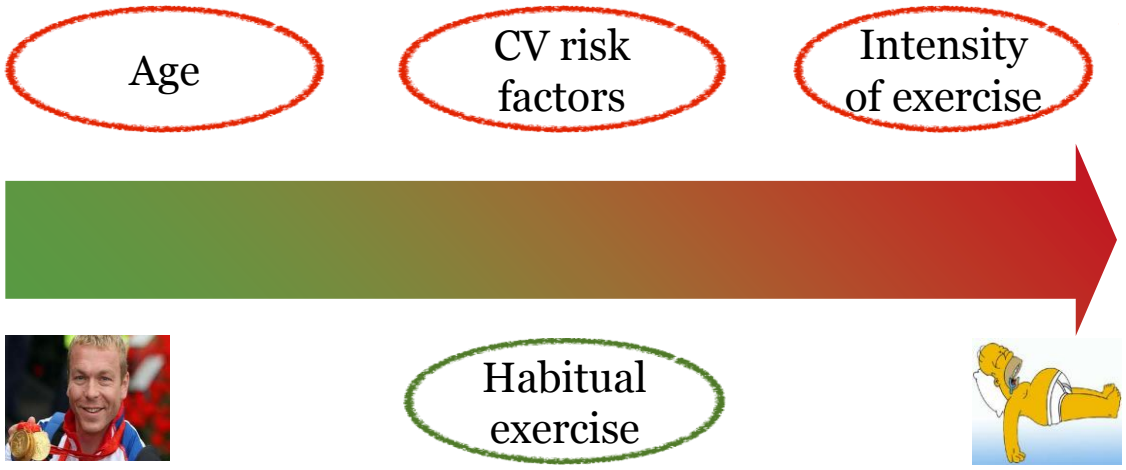

PULMONARY ARTERY
AORTA

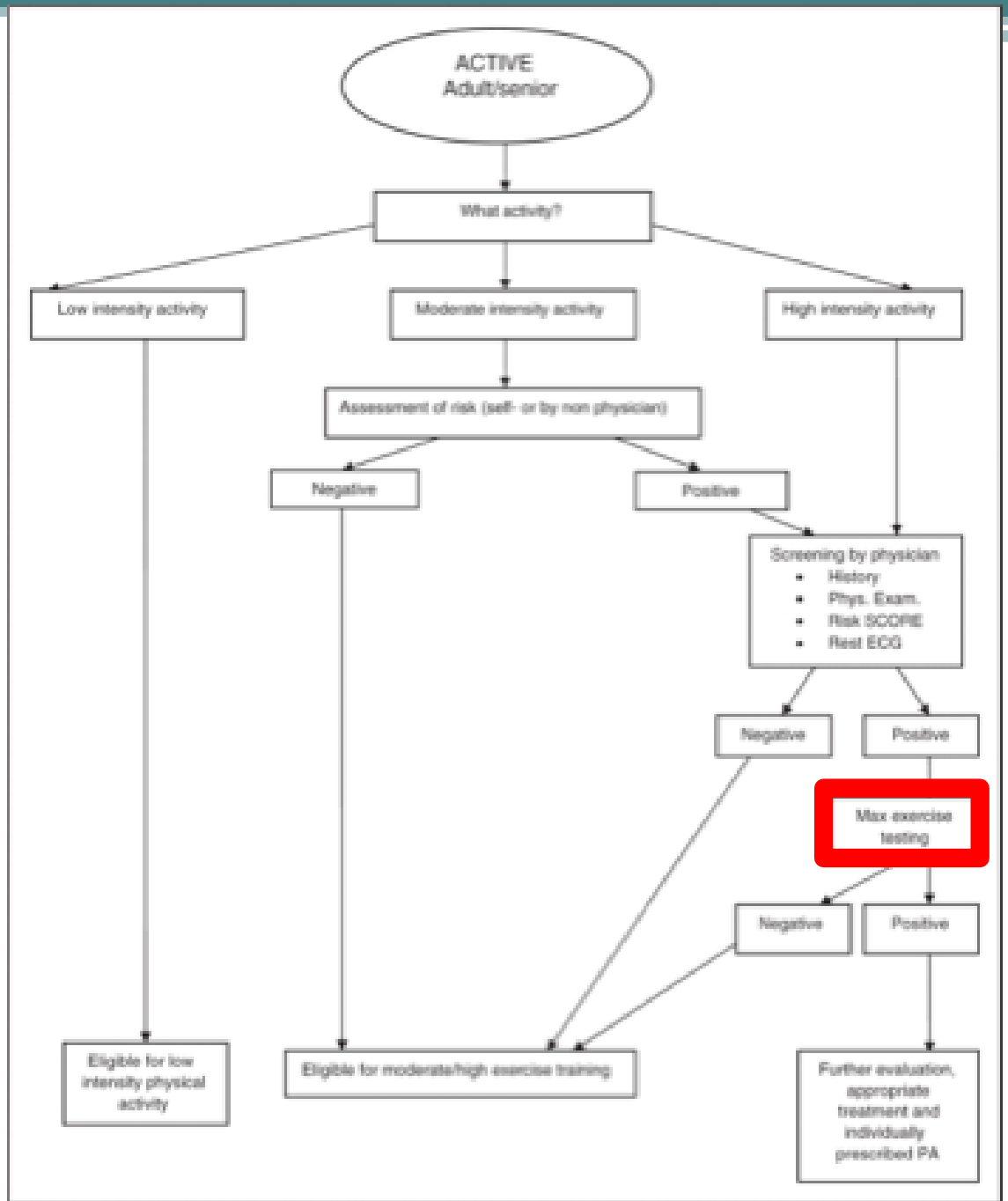
Coronary artery anomalies

- 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




ACTIVE
Adult/senior
What activity?
Low intensity activity
Moderate intensity activity
High intensity activity
Assessment of risk (self- or by non physician)
Negative
Positive
Screening by physician
History
Phys. Exam.
Risk SCORE
Rest ECG
Negative
Positive
Max exercise testing
Negative
Positive
Eligible for low intensity physical activity
Eligible for moderate/high exercise training
Further evaluation, appropriate treatment and individually prescribed PA

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

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

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