Webinar – 12th March 2024, Module 1

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Essential ECGs

ECGs that matter

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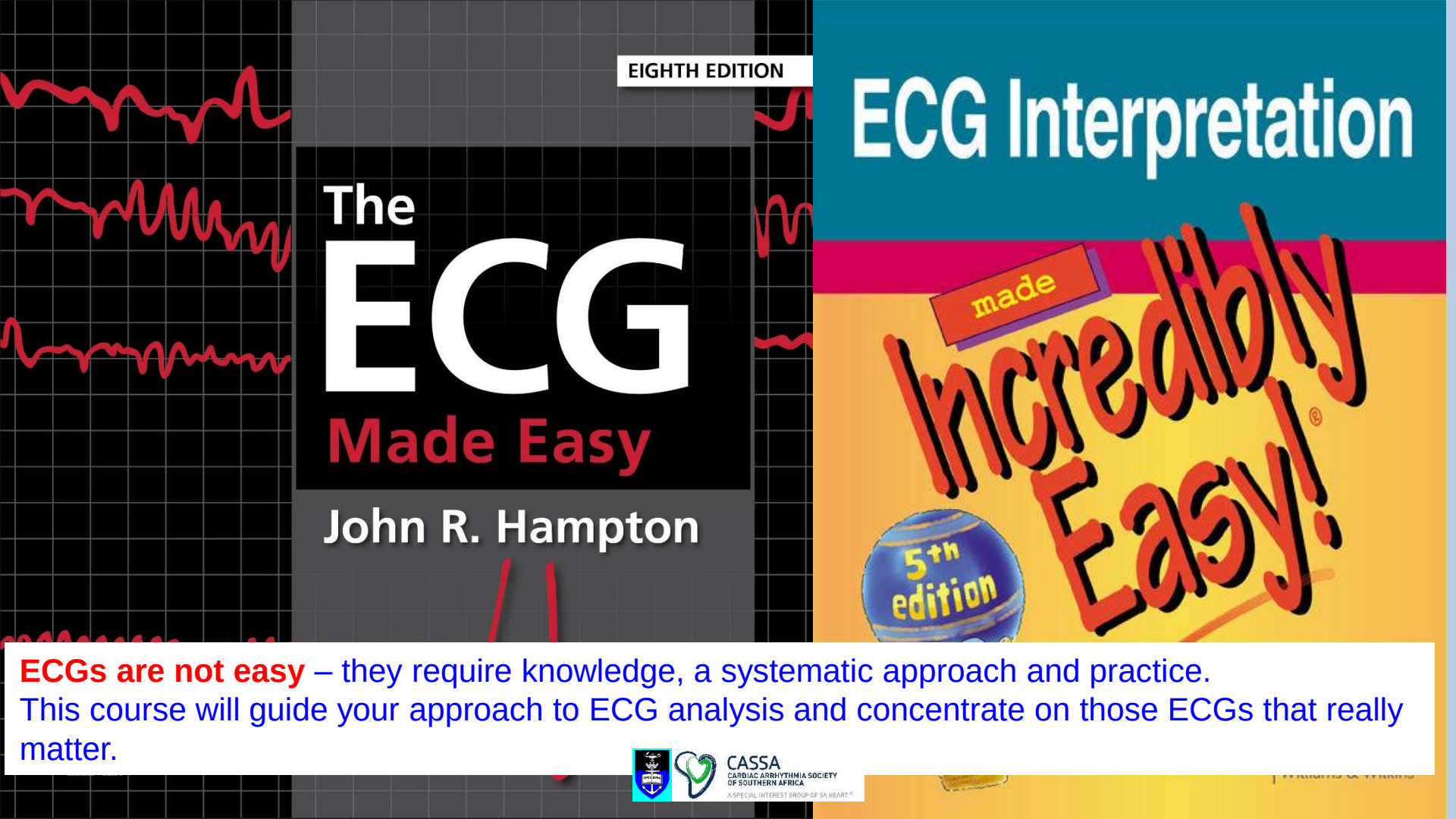
Essential ECGs – module 1

Which best describes you:

1. General practitioner?
2. Specialist physician?
3. Emergency unit doctor?
4. Anaesthetist?
5. Other medical practitioner?
6. Technologist?
7. Other?



ECGs are not easy – they require knowledge, a systematic approach and practice.
This course will guide your approach to ECG analysis and concentrate on those ECGs that really matter.

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What can you learn from an ECG?

- Rhythm
- Conduction
- Structural heart disease
  - Myocardial infarction
  - Hypertrophy
    - Atria
    - Ventricles
  - Pericarditis
- Transient abnormalities
  - Ischaemia
  - Electrolytes

- Drug effects
  - QT prolongation
- Primary ECG syndromes
  - Wolff-Parkinson-White (WPW)
  - Congenital long QT syndrome (LQTS)
  - Brugada syndrome

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Who should have an ECG?

- Acute chest pain
- Arrhythmia
- Suspected heart disease
- Chest pain
- Unexplained blackouts
- Hypertension
- Major medical/surgical illness
- Drug overdose
- Stroke
- Patients over 50
- Routine check up

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What are “Essential ECGs”?

- **It indicates a lethal condition**
  - A missed diagnosis may be fatal
  - Appropriate treatment will save lives
  - The ECG is the only, or the principal, means of diagnosis
- **It adds important information to the clinical diagnosis**
  - Helps to make or confirm the diagnosis
  - Indicates an additional problem
  - Aids in prognosis

- **It indicates an important condition, not otherwise diagnosable**
- **It indicates an important condition, not otherwise suspected**
- **It may reassure one**

Some examples of “Essential ECGs”
ECGs critical to the diagnosis

- **Lethal conditions**
  - Complete heart block
  - Acute ST elevation myocardial infarction (STEMI)
  - Ventricular tachycardia
- **Serious consequences if not diagnosed**
  - Atrial fibrillation (stroke)
  - Atrial flutter (stroke)
- **Potentially lethal conditions**
  - Healed (old) myocardial infarction
  - Congenital long QT syndrome

- **Essential for accurate diagnosis**
  - All arrhythmias
- **It indicates an important condition, not otherwise suspected**
  - Wolff-Parkinson-White (WPW) pattern
- **Useful for prognosis**
  - Left ventricular hypertrophy
  - Bundle branch block

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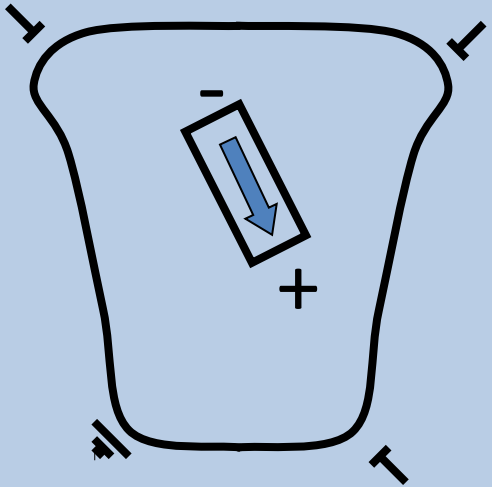
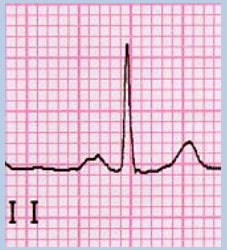
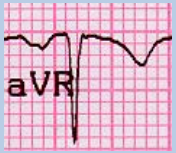
ECG recording

Vector Electrode ECG







The ECG records successive time-dependent changes in cardiac electrical potential at the body surface (vectors)

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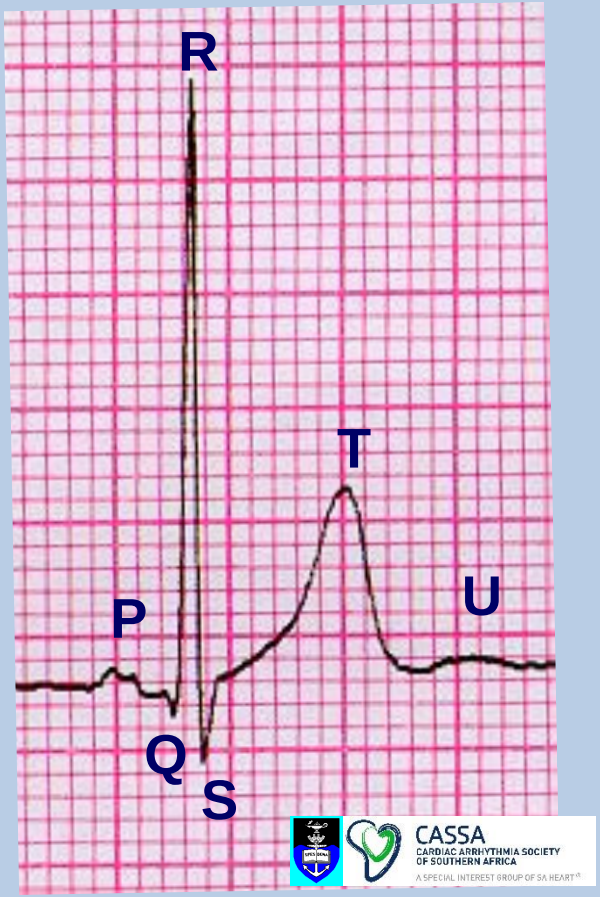
ECG waves


R
T
U
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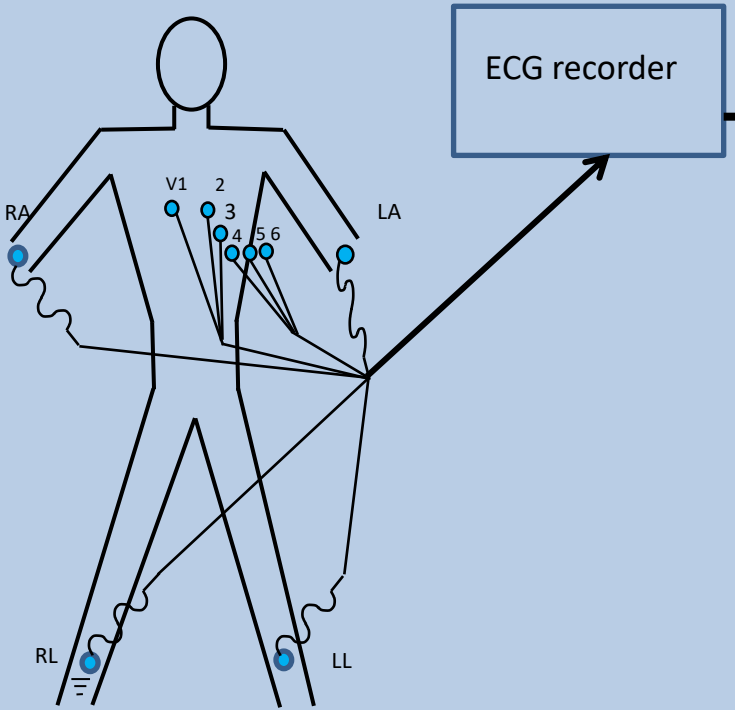
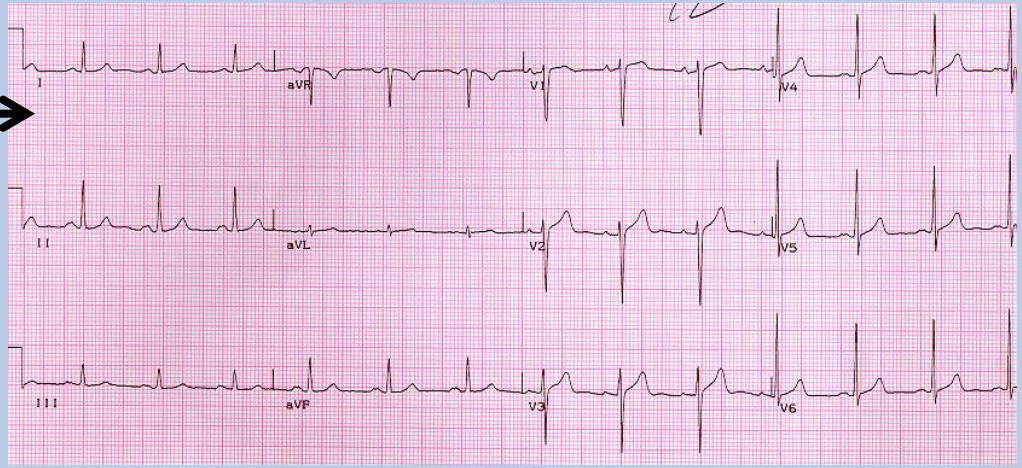
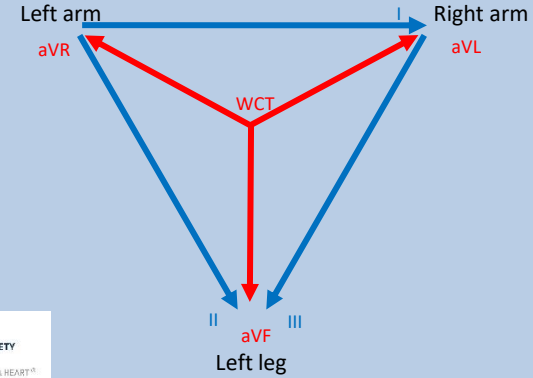
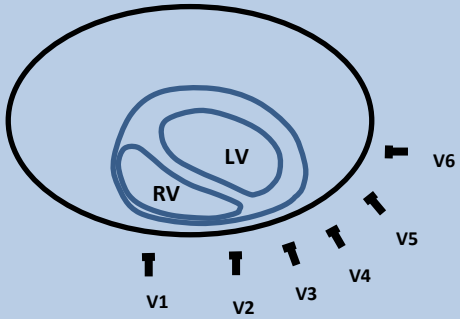
ECG recording



ECG recorder







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ECG recording

L

a **b** c

What is the correct placement of Chest lead electrodes?

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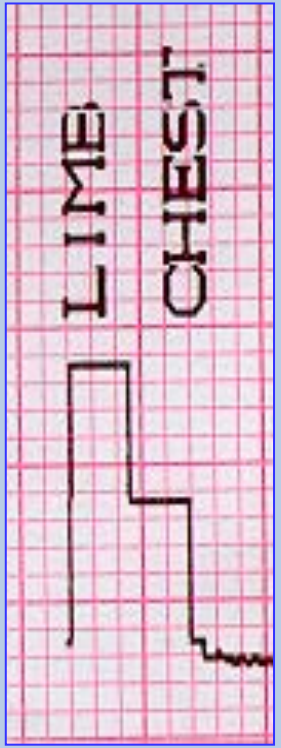
ECG recording

Chest 1/2 std
(1mv = 5mm)

25mm = 1 sec



0.04 sec = 40ms

0.2 sec = 200ms

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Initial approach to an ECG – start with the patient

- **Clinical context e.g.:**
  - Level of consciousness, chest pain, shock, no symptoms
- **First glance:**
  - Name, ID, date (without these the ECG is useless)
  - Start with the obvious:
    - Fast, slow or +- normal rate
    - Any obvious abnormality: e.g. ST elevation
- **Detailed analysis**
  - Don’t be distracted by any obvious abnormalities – avoid a “blink” diagnosis (exception: cardiac arrest)
  - Proceed to analyse systematically

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Looking at the ECG

Primary observations

- Ventricular rate:
  - Normal (60 – 100/minute)
  - Slow (<60/minute)
  - Fast (>100/minute)
- Regularity:
  - Regular
  - Irregular
- QRS width
  - Normal (≤100ms)
  - Wide (≥120ms)
    - Left bundle branch block
    - Right bundle branch block
    - Neither
    - Delta wave

Secondary observations

- P waves
  - Present or absent/not visible
  - Morphology (? Upright in II, negative aVR)
  - Rate
  - Relationship to QRS complexes
- PR interval
- QRS abnormalities
- ST segments
- T waves
- QT interval

Steps in analysing the ECG

- **Observe and measure**
  - Rate
  - Regularity
  - QRS width
  - Any obvious abnormalities
- **Systematic analysis**
  - P waves
  - PR interval
  - QRS complexes
  - ST segments
  - T waves
  - QT

- **Interpret**
  - Normal/abnormal
  - Possible mechanisms of abnormalities
  - Consider the differential diagnosis
  - Exclude the impossible
- **Conclude**
  - Rhythm
  - Structural abnormalities
  - Alternative diagnoses
  - Possible underlying pathology

Summarise

Main features
Likely diagnosis

Communicate

your findings clearly and succinctly

Beware snap (“blink”) diagnoses and hasty conclusions which lead to premature closure

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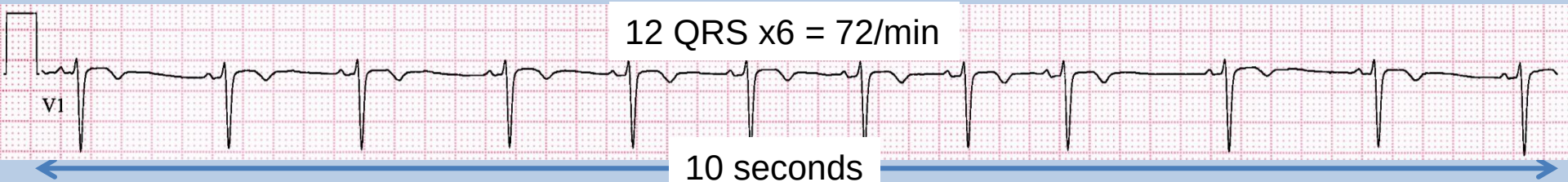
Look beyond the obvious – analyse systematically

Ventricular rate

Rate = number of QRS complexes x6

Normal (60-100/min)



Slow(<60/min)

Fast(>100/min)

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Regularity

Regular – sinus rhythm (may be irregular, due to respiratory sinus arrhythmia)

Group beating – ventricular bigeminy

Group beating – 4:3 Wenckebach AV block

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Regularity

Intermittent pauses during otherwise regular rhythm

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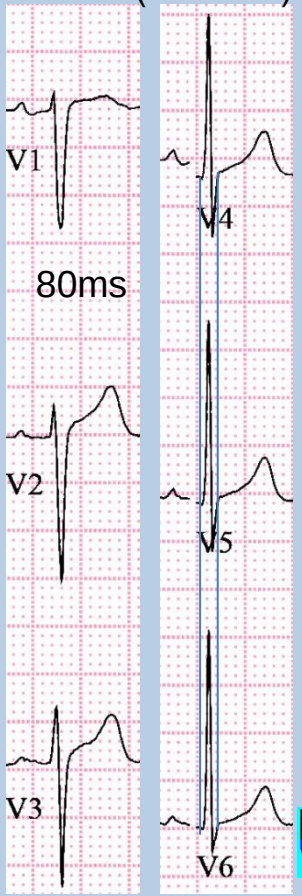
Random irregularity – due to atrial fibrillation

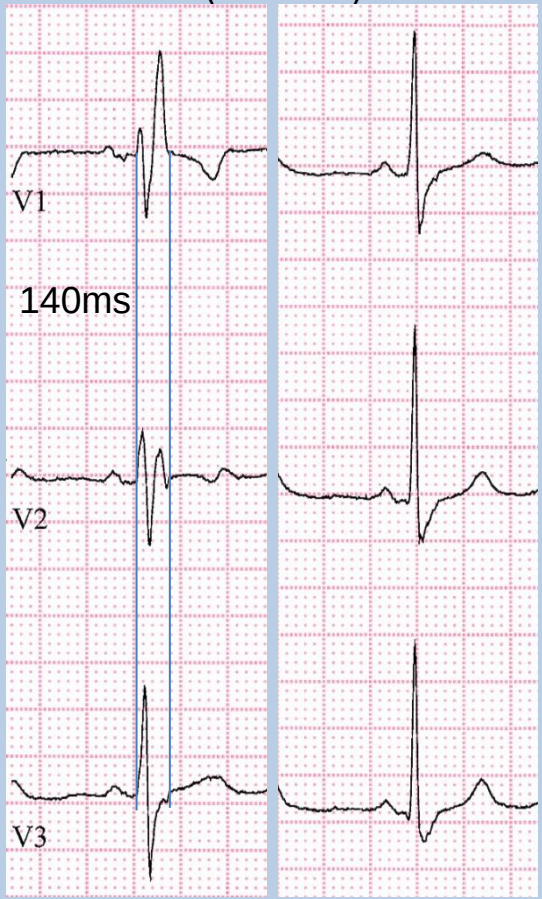
QRS width (adults)

Normal (≤100ms)



Best measured in the chest leads

Wide (≥120ms)



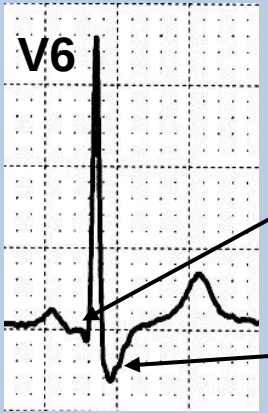
QRS duration is difficult because the difference between the upper limit of normal (100ms) and wide (120ms) is only half a small block.

Typical patterns of right & left bundle branch block

RBBB

V1 & V2 positive
rSR' in V1

Broad *terminal* R in V1

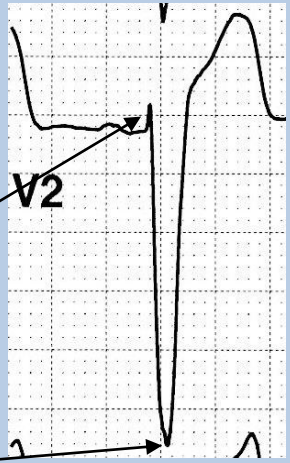


Normal left ventricular activation (septal q, rapid R upstroke in V6)

Small, broad terminal s in V6

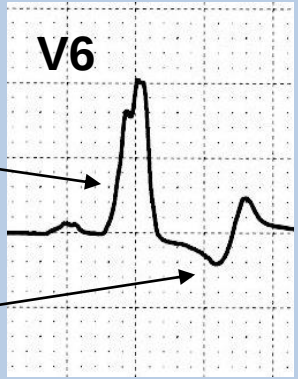
LBBB

V1 & V2 negative
V5 & V6 positive



Initial *sharp* deflection V1 & V2 (< 40 ms)

Onset to nadir of S wave < 70ms



Slurred R wave

Absent septal q wave

Inverted T wave

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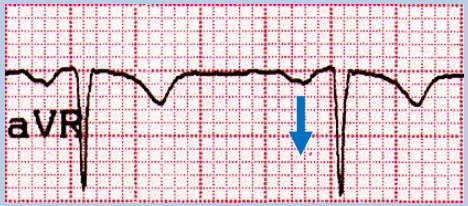
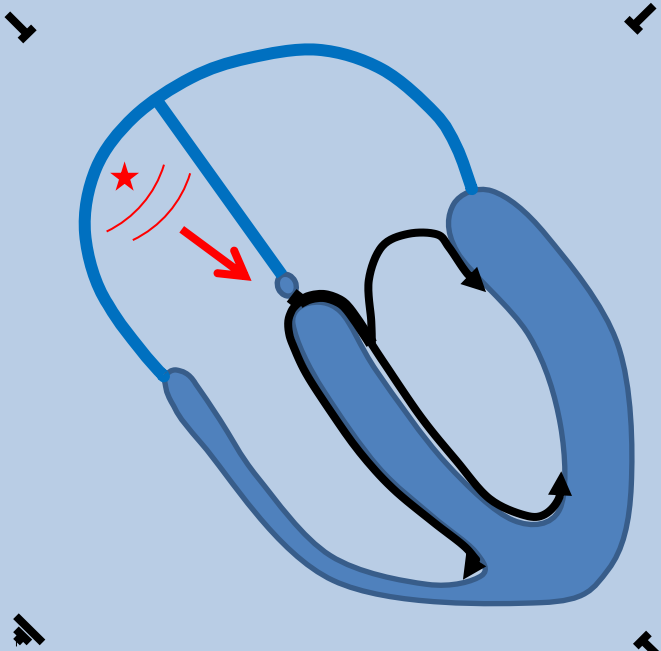
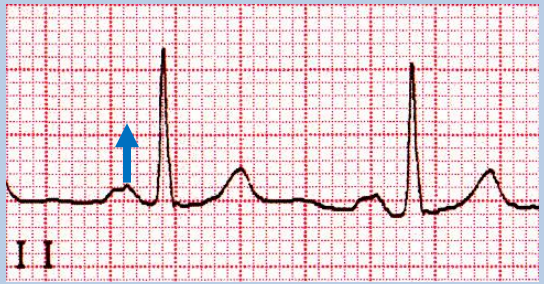
P waves





The sinus node encircles the entrance of the superior vena cava into the right atrium. Sinus P waves therefore are negative in aVR (moving away) and positive in Lead II (moving towards).



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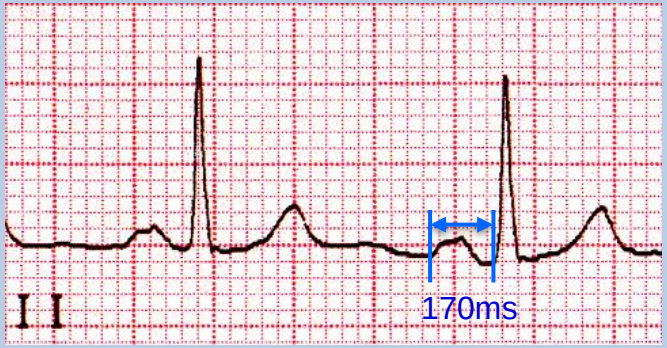
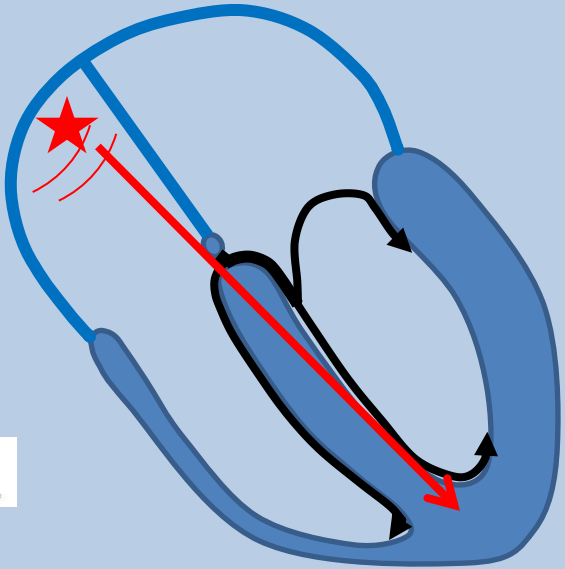
PR interval

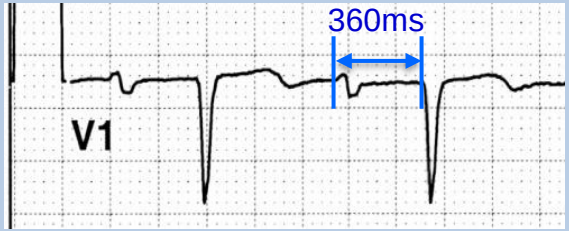


The time from the beginning of the P wave to the beginning of the QRS complex (normally 120-200ms)



The PR can be prolonged with slowing of conduction in the AV node and/or His Purkinje system

1st degree AV block



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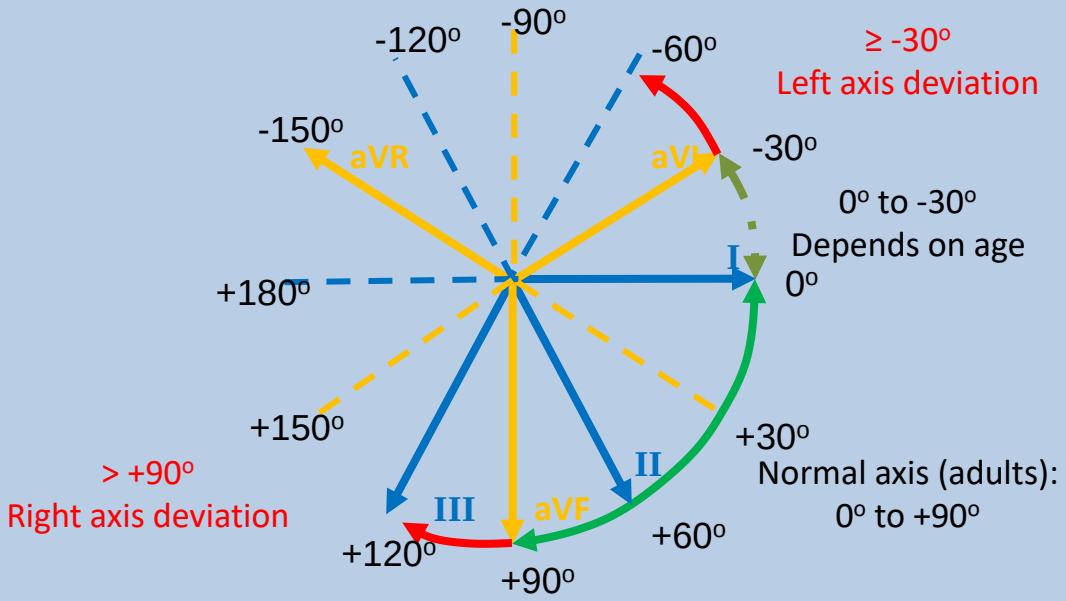
QRS complexes

- **Width**
  - Normal (≤100ms)
  - Wide (≥120ms)
- **Mean frontal plane axis**
  - Normal – 0 to +90º
  - Borderline – 0 to -30º (depends on age – normal in older adults)
- **Size**
  - S in V1 + R in V5 ≤ 35mm (3,5Mv)
  - R : S ratio in V1 <1
- **Q waves**
  - Normal in aVR, V5-6 (small septal q)
  - <40ms wide and <25% of QRS height in limb leads



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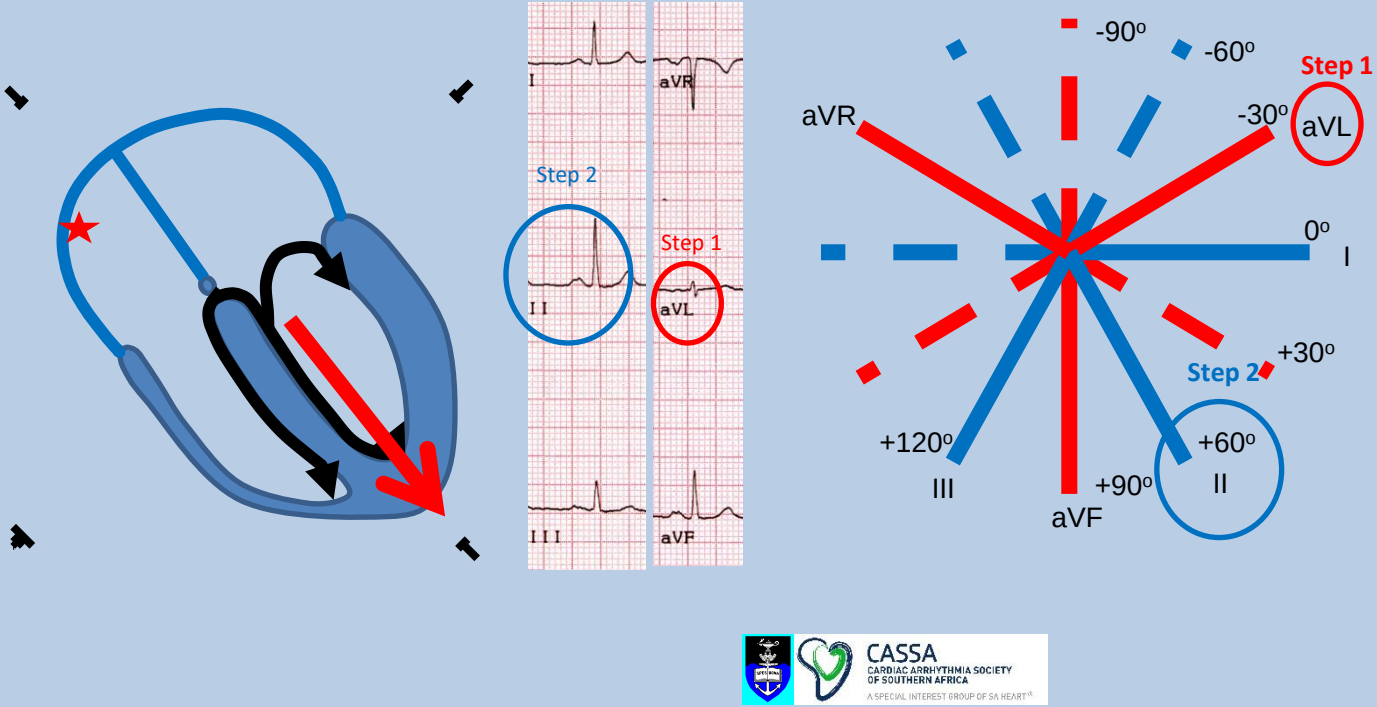
Mean frontal plane QRS axis



aVL is equiphasic, therefore the axis is perpendicular to aVL

Lead II is at 90º to aVL; the axis is therefore parallel to II. II is positive, therefore the axis is +60º.

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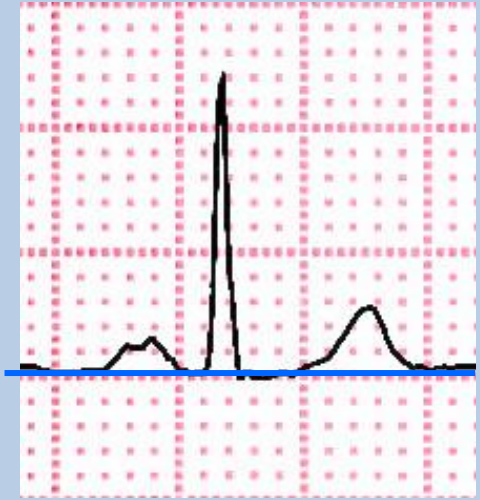
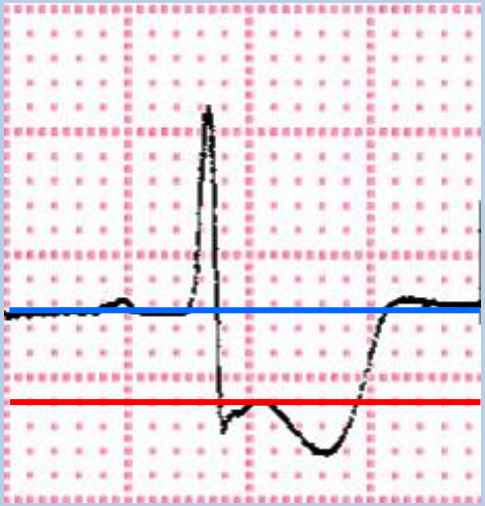
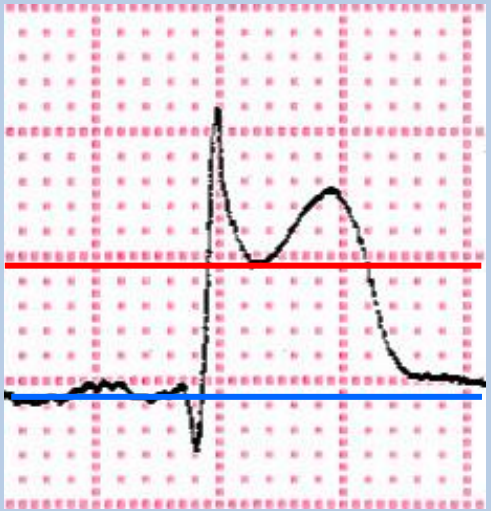
ST segments



Normal



Depressed

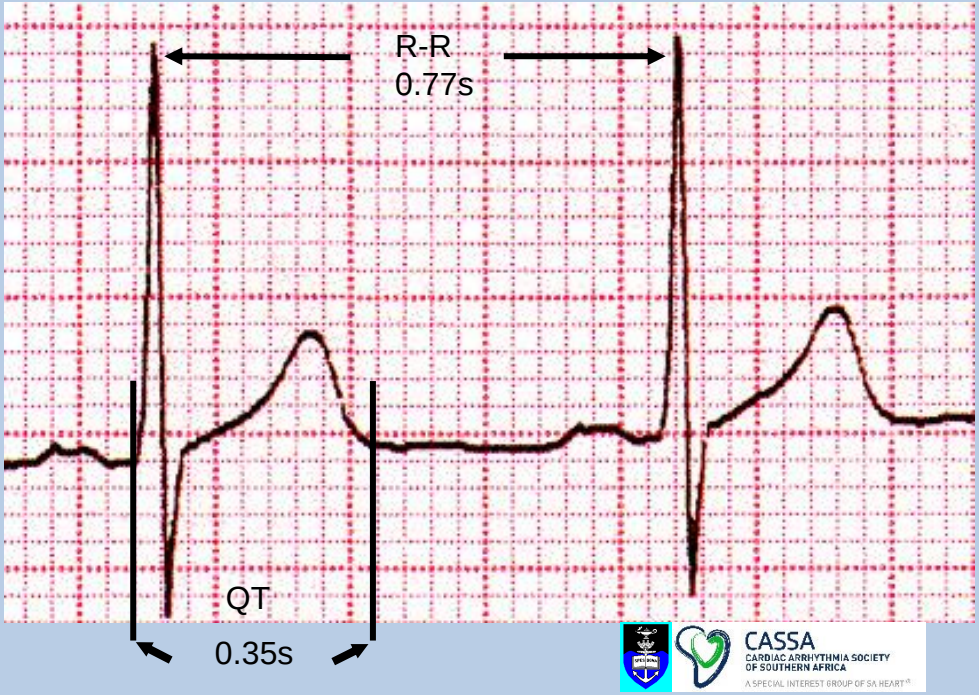


Elevated

QT interval

Q-T: measure from beginning of the QRS to the end of T wave

Measure the longest QT – usually V2 – V4



Correct using Bazett's formula - measurements in seconds

$$QTc = \frac{Q\text{-}T}{\sqrt{R\text{-}R}}$$

$$\frac{0.35s}{\sqrt{0.77s}} = 0.39s$$

Normal QTc:
≤ 0.44s (440ms) – males
≤ 0.46s (460ms) - females

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What is a normal ECG?

- Normal sinus rhythm
- Normal PR interval
- QRS normal
  - Duration
  - Size
  - Axis
  - No pathological q waves
- Normal ST segments and T waves
- Normal QT interval
- Minor deviations are usually benign

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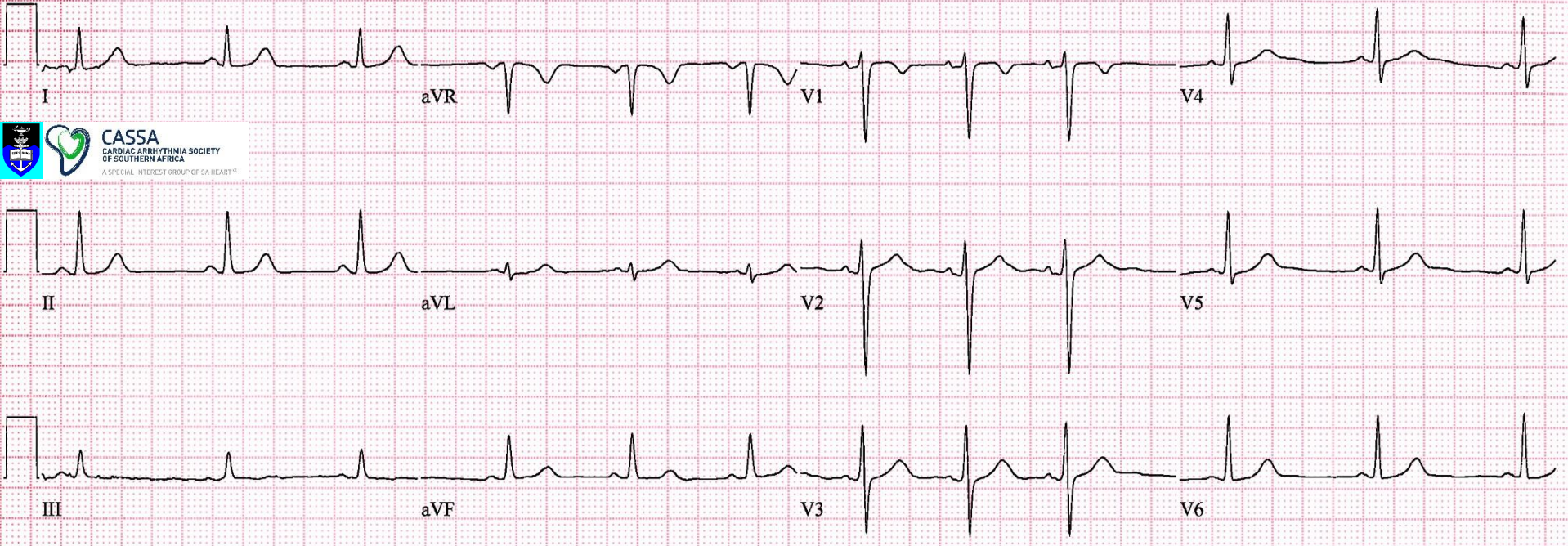
ECG 1



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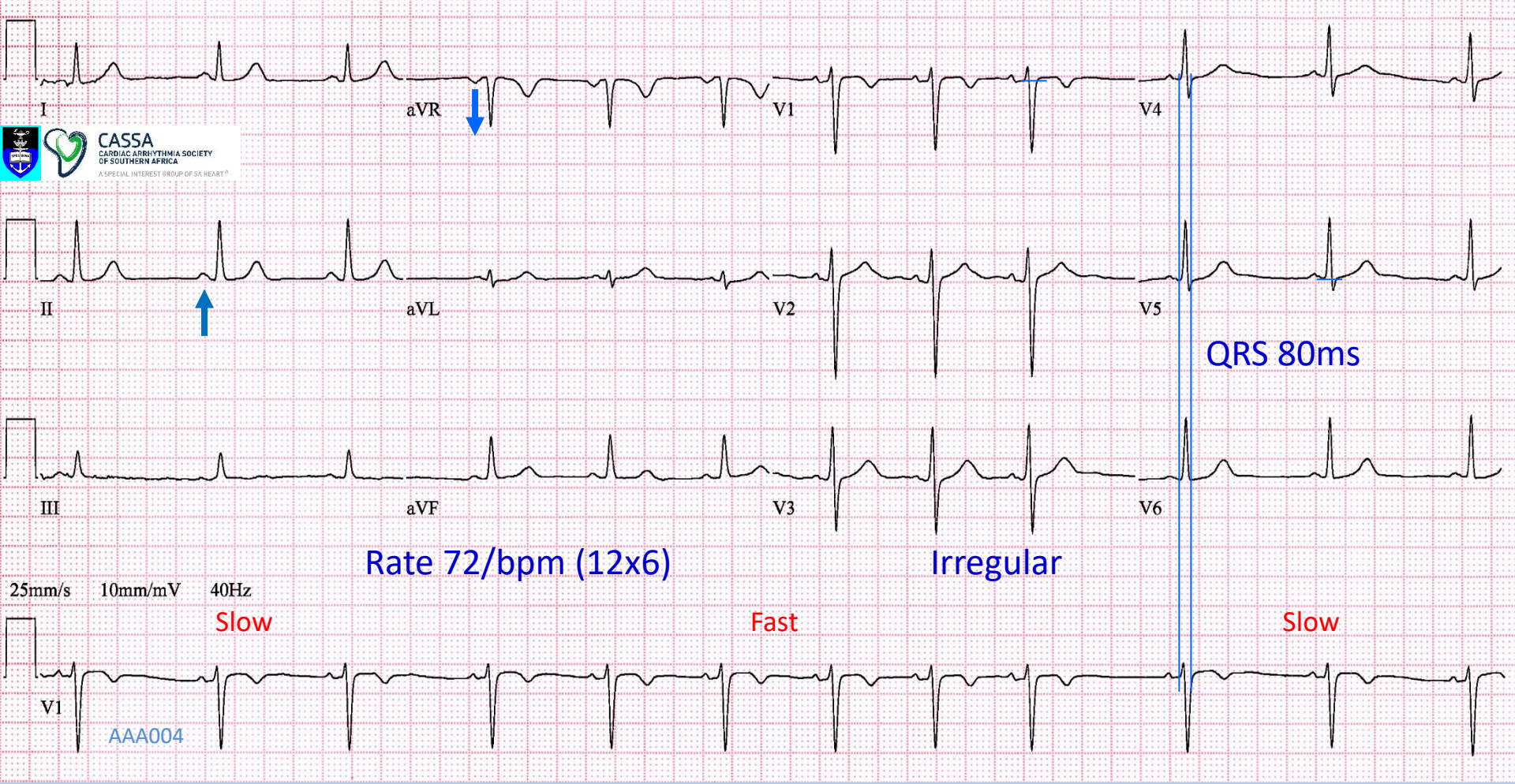
Is this ECG:

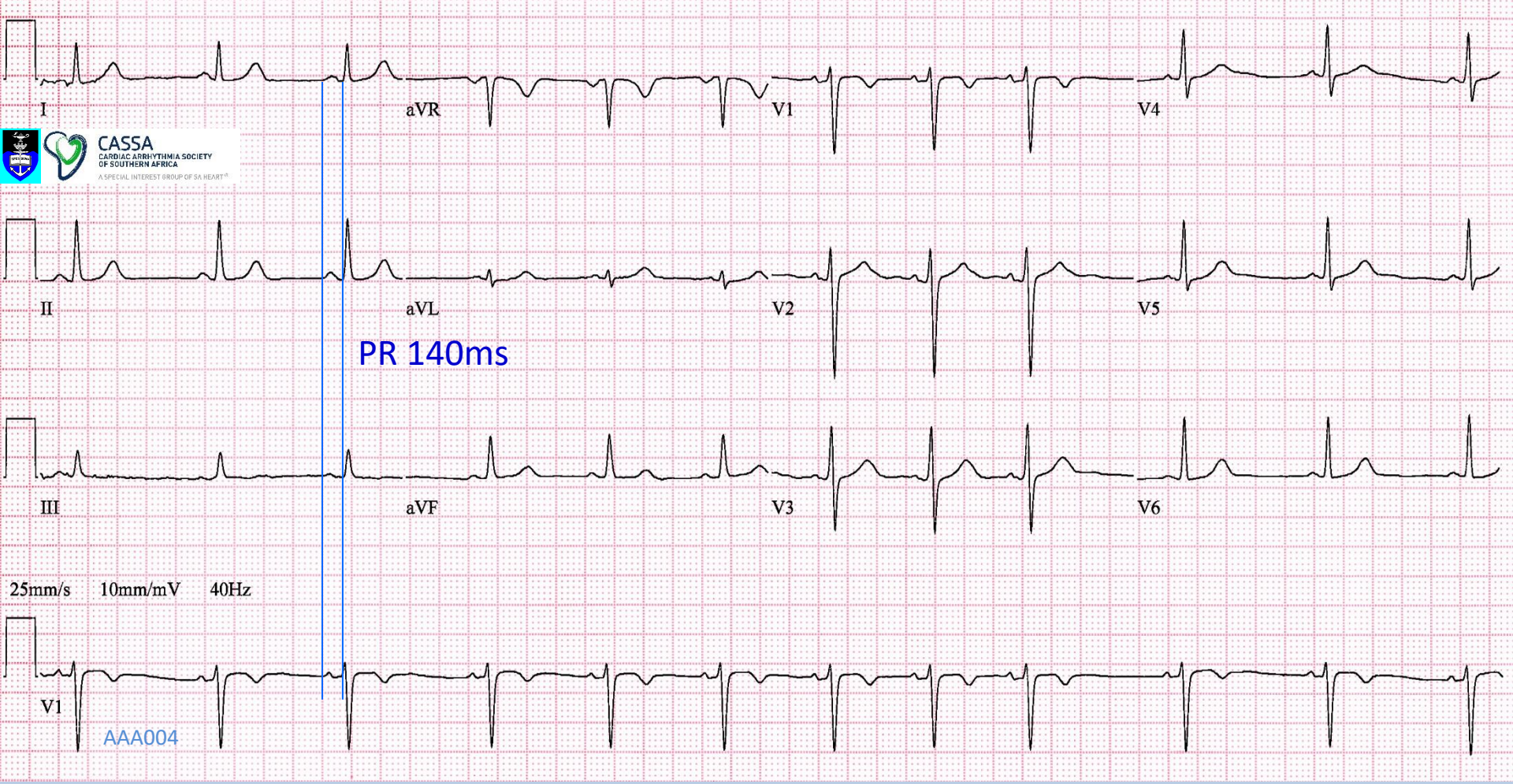
a) Normal?

b) Abnormal?

AAA004



Sinus arrhythmia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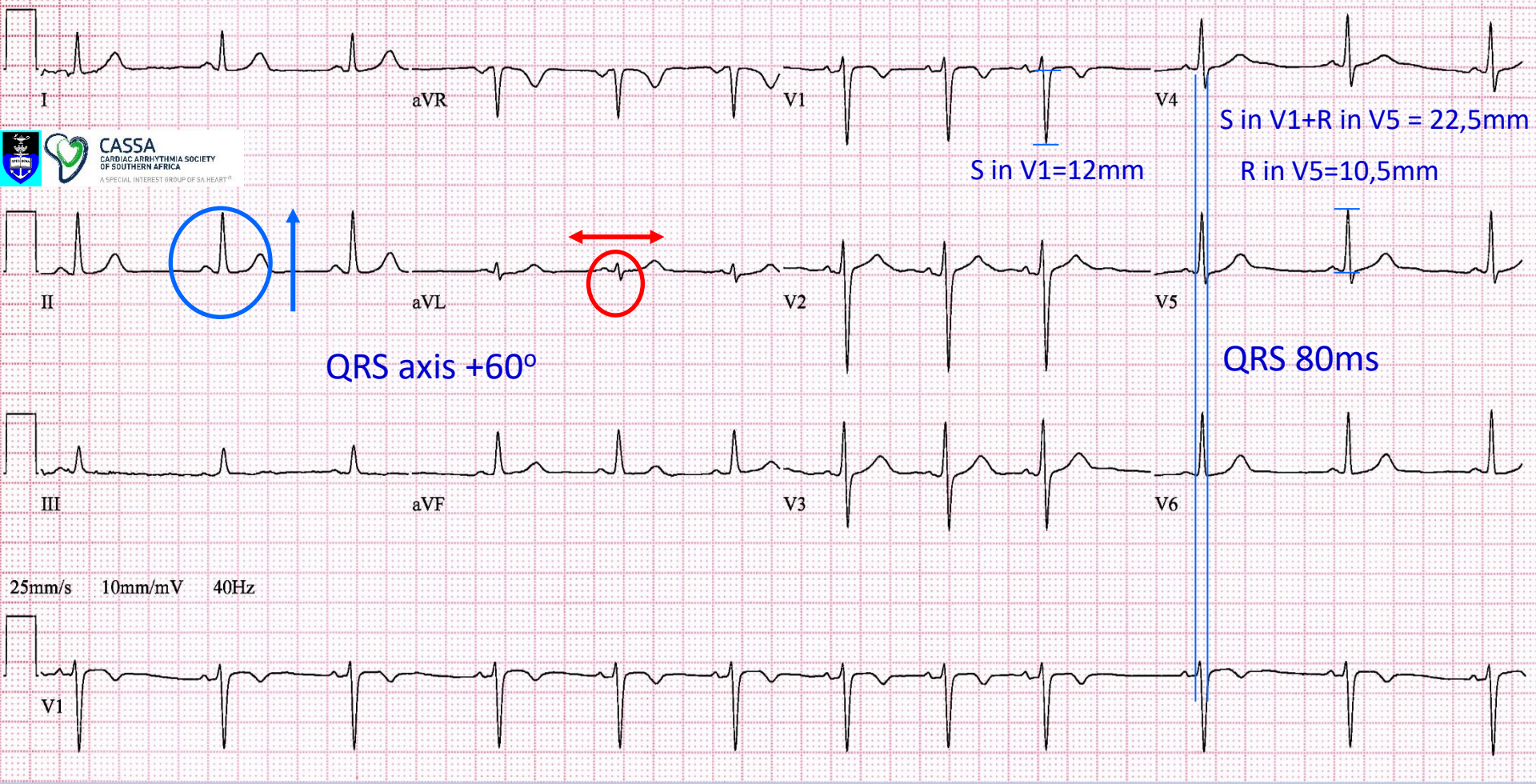
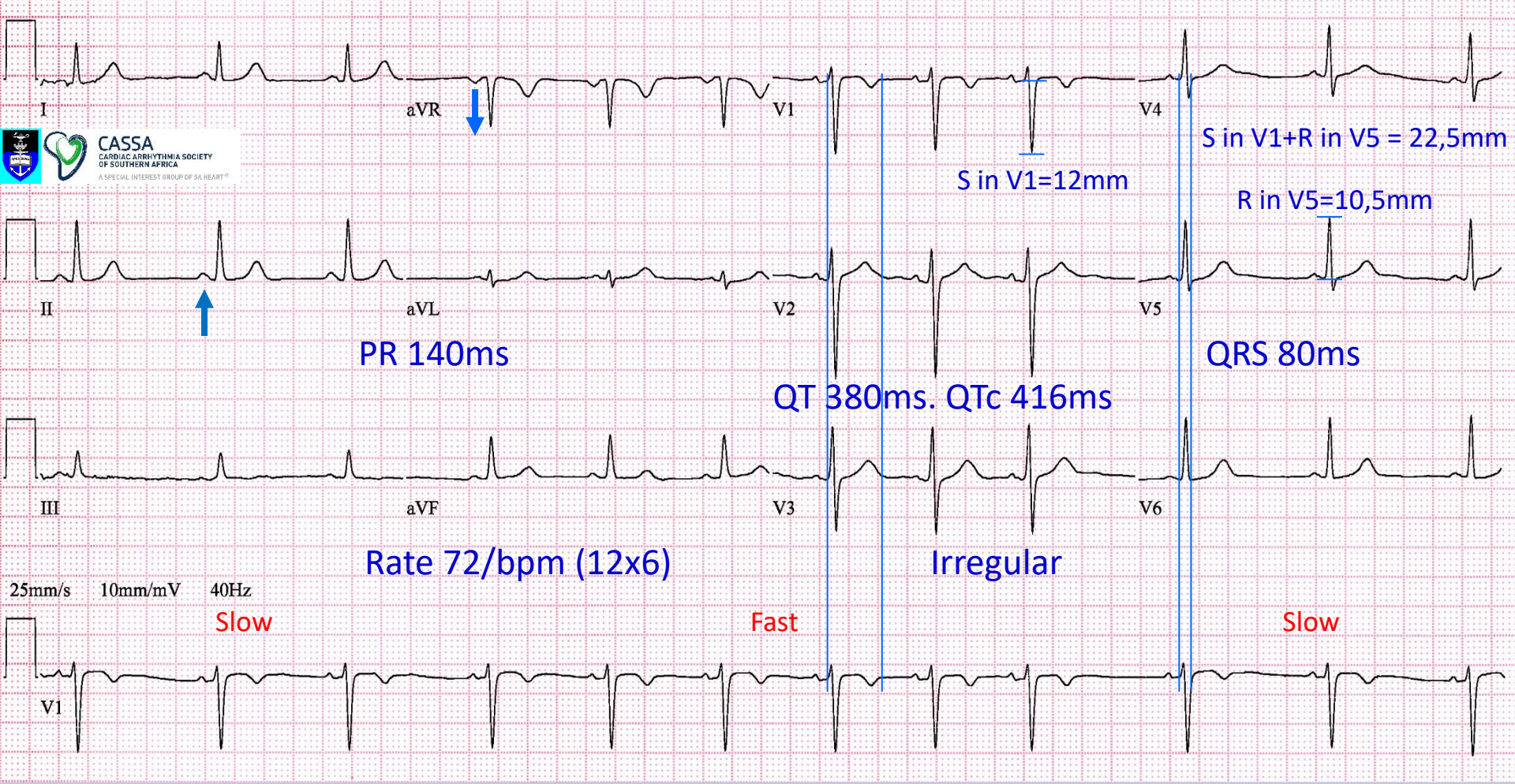
I
aVR
V1
V4
II
aVL
V2
V5
PR 140ms
III
aVF
V3
V6
25mm/s 10mm/mV 40Hz
V1
AAA004


I
aVR
V1
V4
S in V1=12mm
S in V1+R in V5 = 22,5mm
R in V5=10,5mm
II
aVL
V2
V5
QRS axis +60º
QRS 80ms
III
aVF
V3
V6
25mm/s 10mm/mV 40Hz
V1



Normal ECG – sinus arrhythmia

Normal Adult ECG values

- P wave
  - Axis: +30^{o} to +70^{o} (+ve II, -ve aVR)
  - Duration ≤ 110ms
- PR interval:
  - 120 to ≤ 200ms (3-5 small blocks)
- QRS
  - Duration: ≤ 100ms (≤ 2.5 small blocks)
  - Axis: +0^{o} to +90^{o} (0^{o} to -30^{o} grey zone)
  - Size: S in V1 + R in V5/V6 ≤ 3.5mV (35mm)
    - R in aVL ≤ 1.1mV (11mm)
- QTc
  - ≤ 440ms (males)
  - ≤ 460ms (females)

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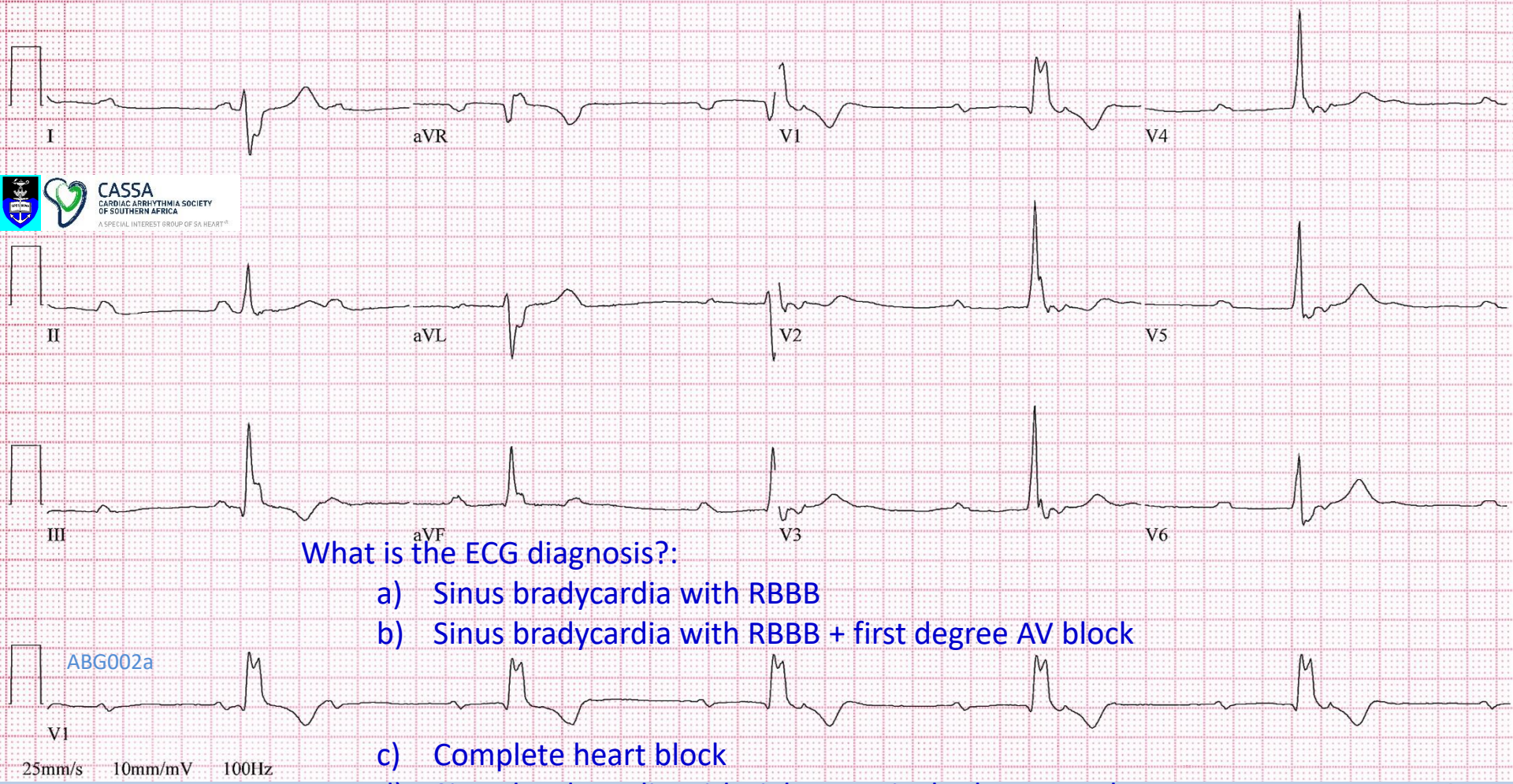
ECG 2



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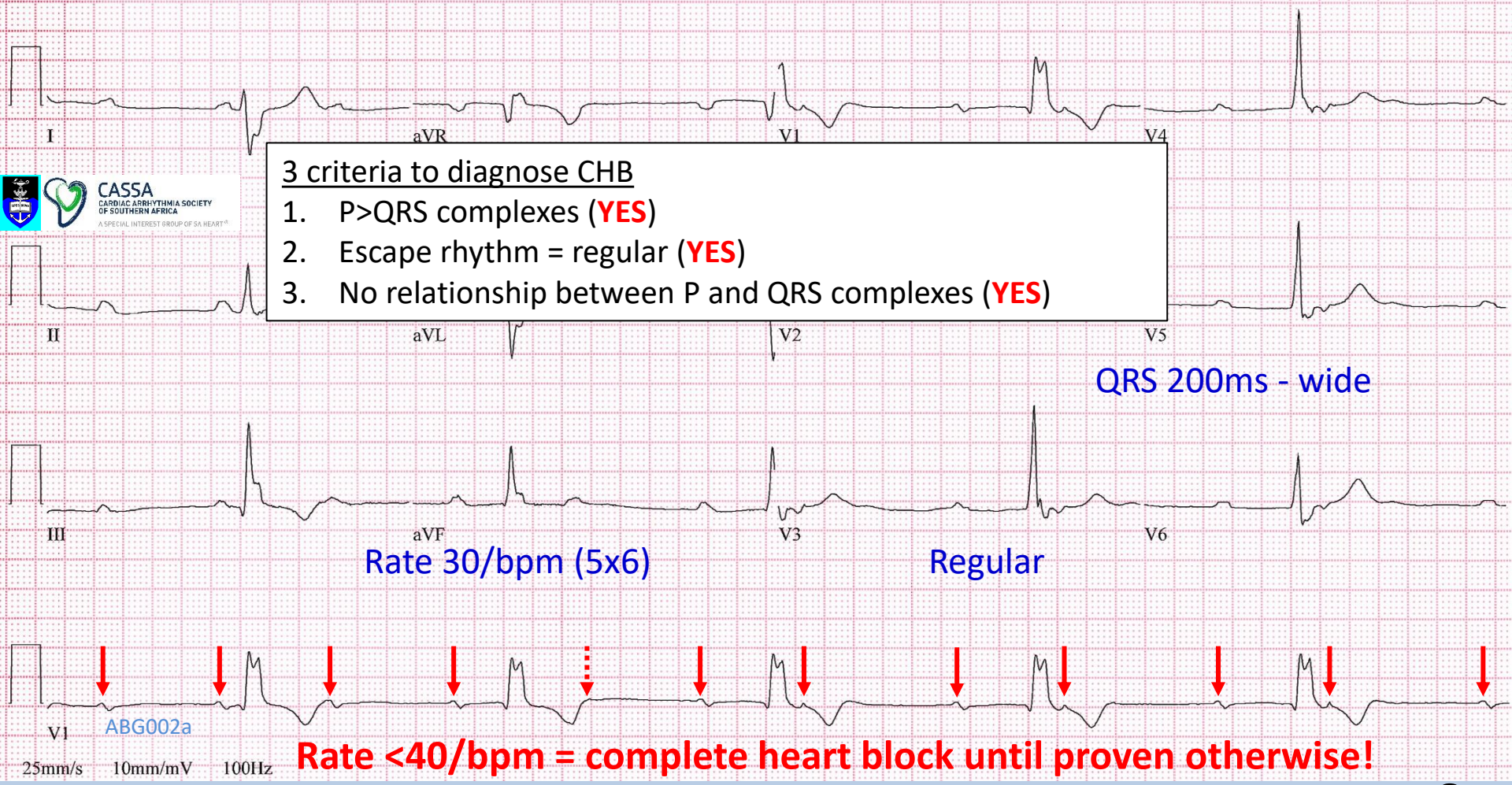
What is the ECG diagnosis?:

a) Sinus bradycardia with RBBB
b) Sinus bradycardia with RBBB + first degree AV block

ABG002a

c) Complete heart block
d) Sinus bradycardia with right ventricular hypertrophy



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3 criteria to diagnose CHB

1. P>QRS complexes (**YES**)
2. Escape rhythm = regular (**YES**)
3. No relationship between P and QRS complexes (**YES**)

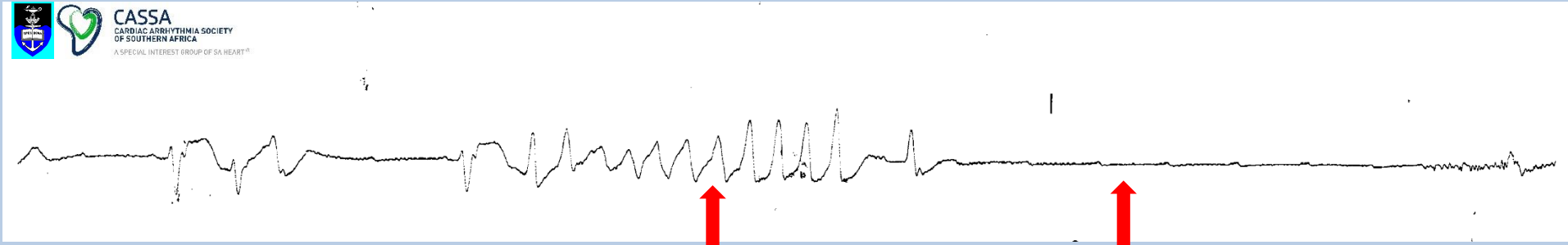
QRS 200ms - wide

Rate 30/bpm (5x6)

Regular

Rate <40/bpm = complete heart block until proven otherwise!

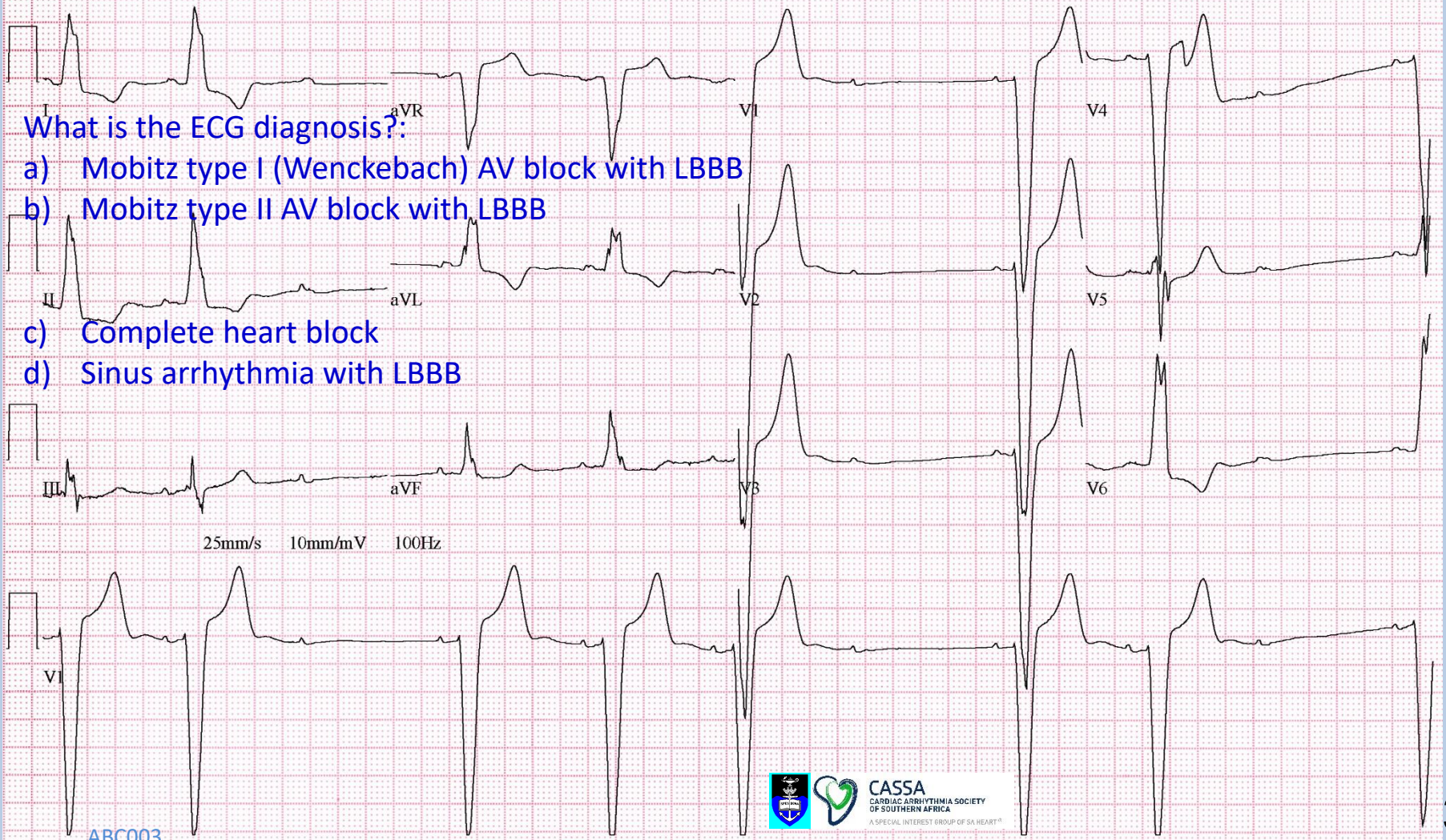
Complete heart block is a medical emergency and patients should be referred for urgent pacing



Mechanisms of death with CHB:

1. Pause-dependent Torsades de Pointes
2. Asystole (ventricular escape rhythm fails)

ECG 3



What is the ECG diagnosis?:

a) Mobitz type I (Wenckebach) AV block with LBBB
b) Mobitz type II AV block with LBBB
c) Complete heart block
d) Sinus arrhythmia with LBBB

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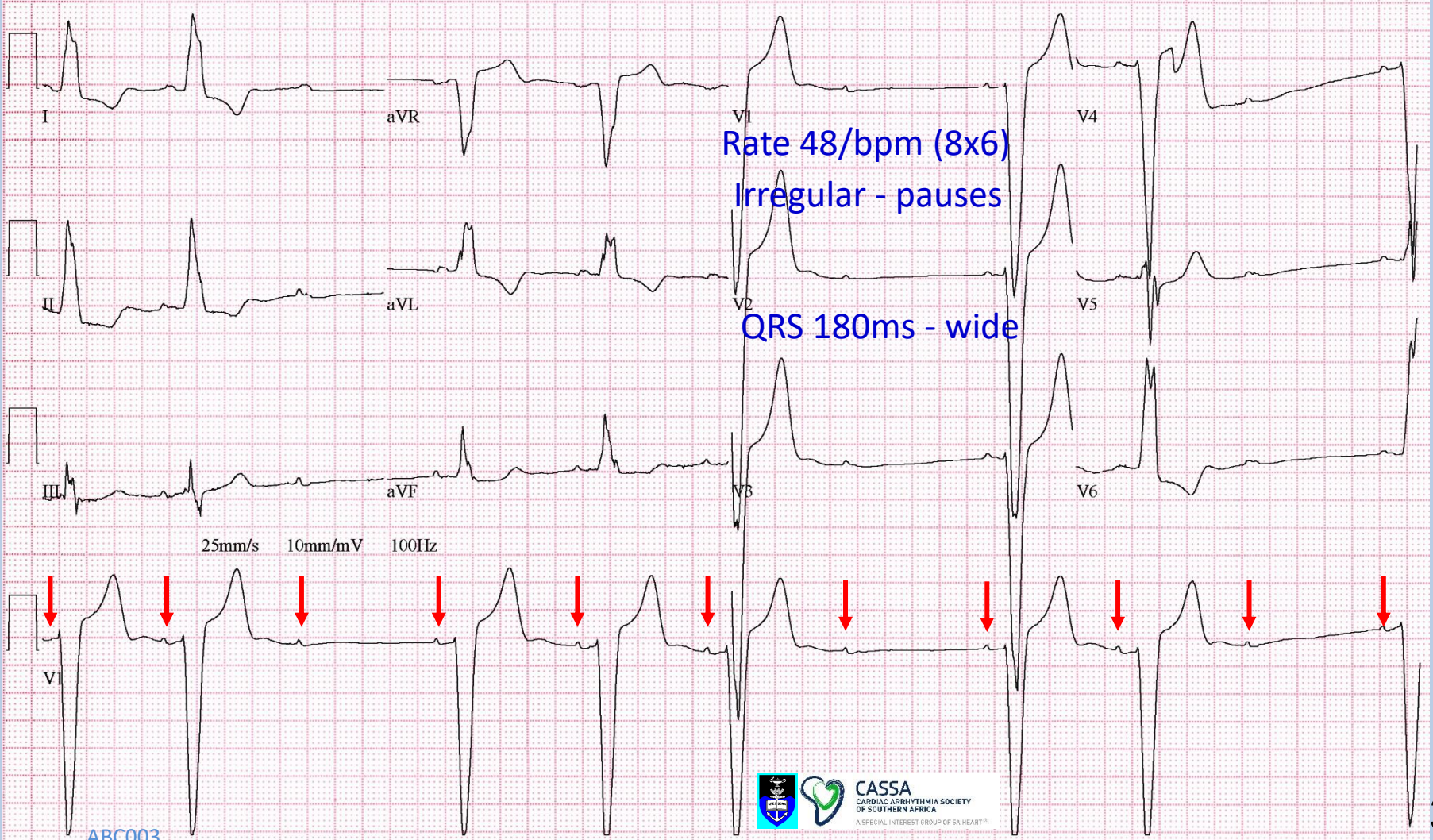
ABC003



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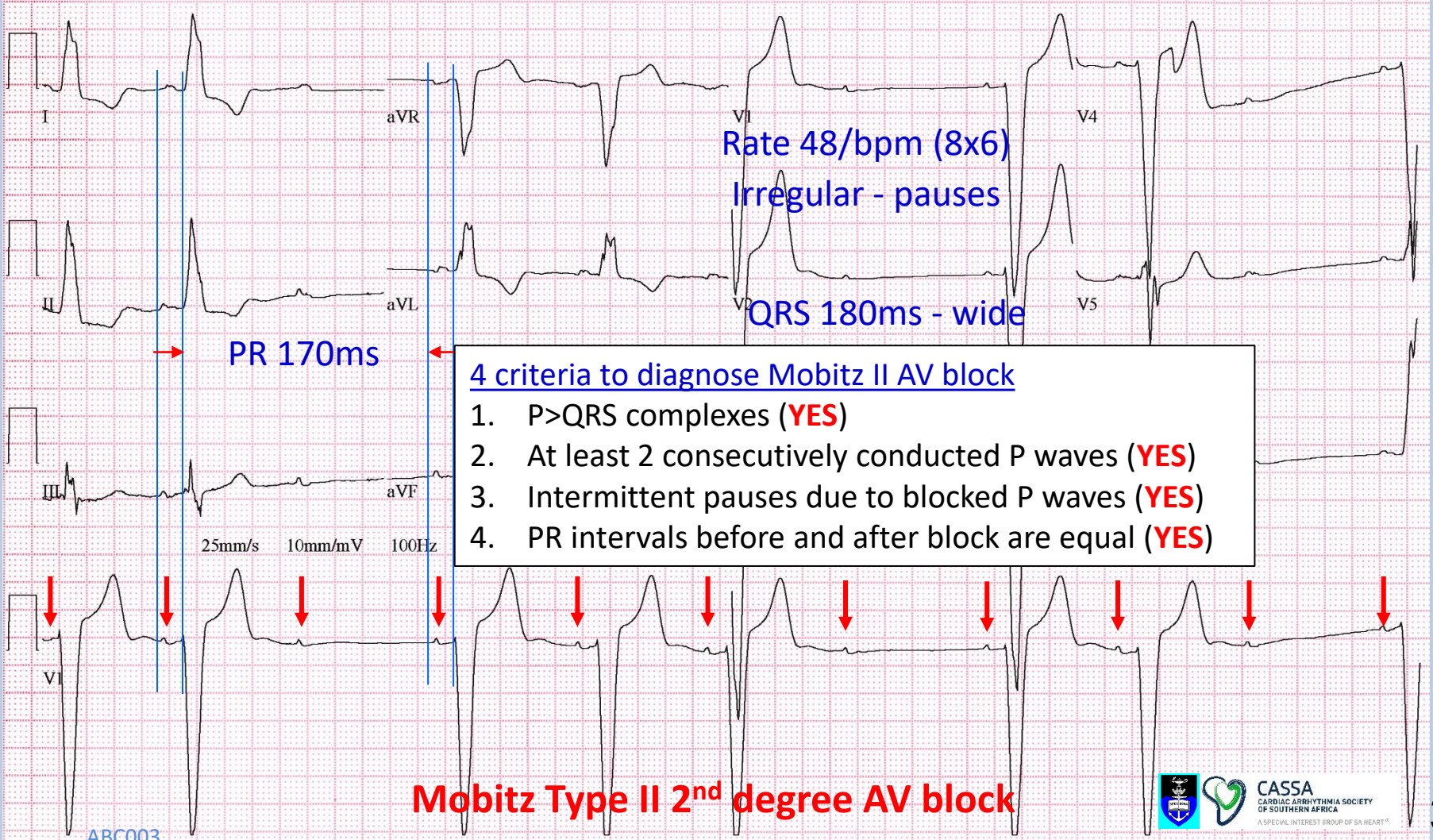
ABC003



4 criteria to diagnose Mobitz II AV block

1. P>QRS complexes (**YES**)
2. At least 2 consecutively conducted P waves (**YES**)
3. Intermittent pauses due to blocked P waves (**YES**)
4. PR intervals before and after block are equal (**YES**)

Mobitz Type II 2nd degree AV block

ABC003

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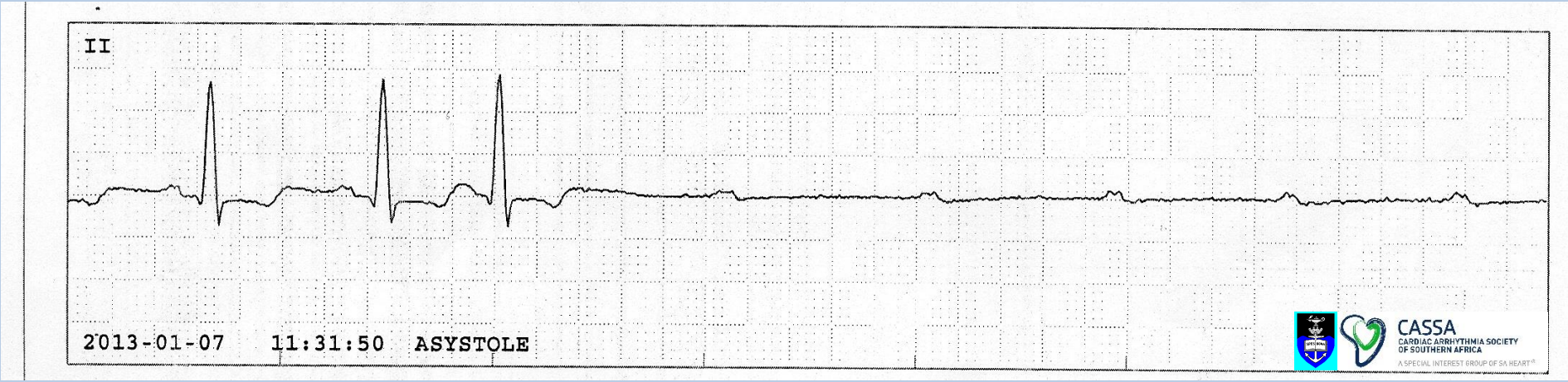
Second degree heart block is a medical emergency and patients should be referred for urgent pacing



3a

ECG 4

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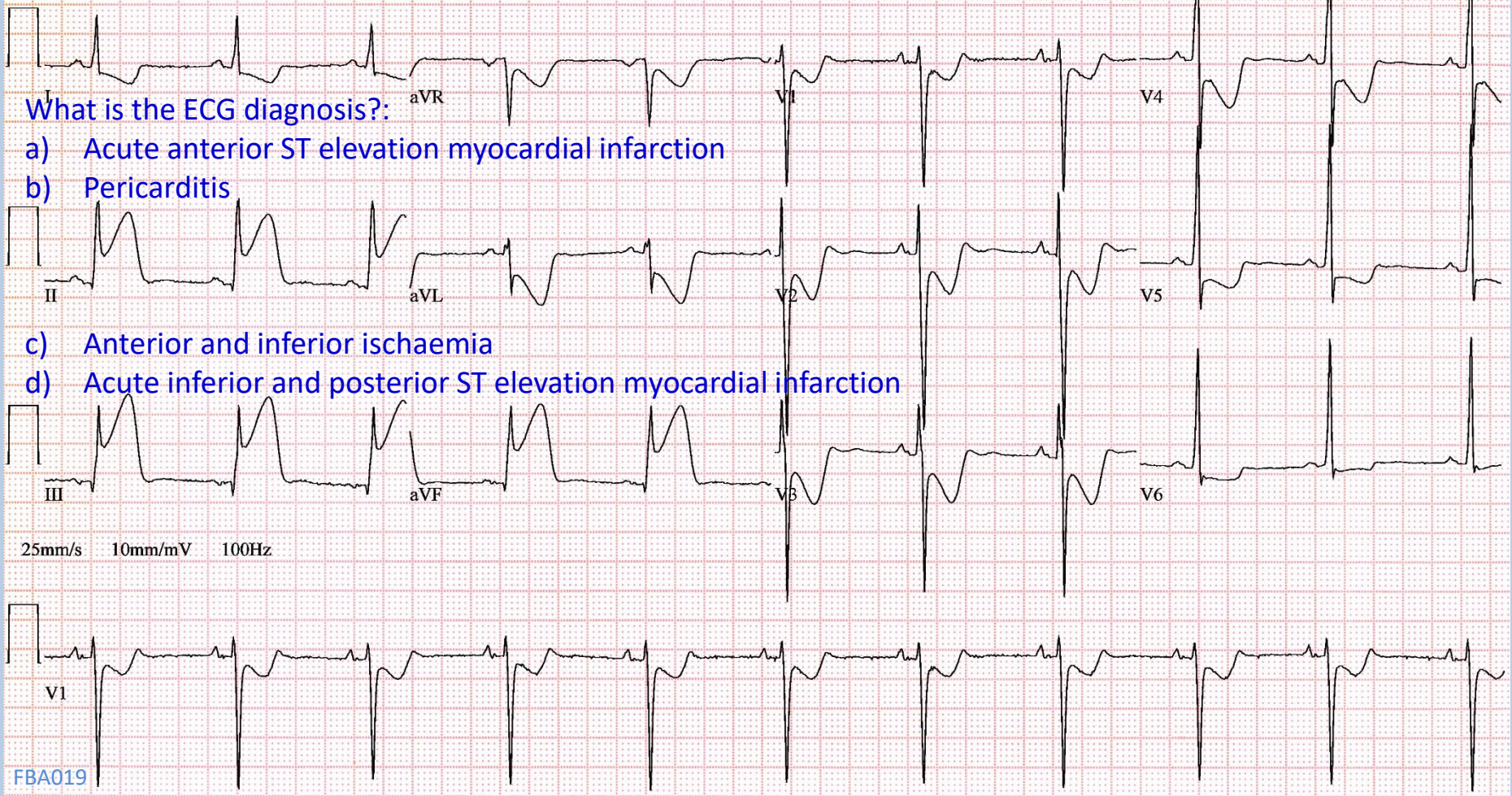


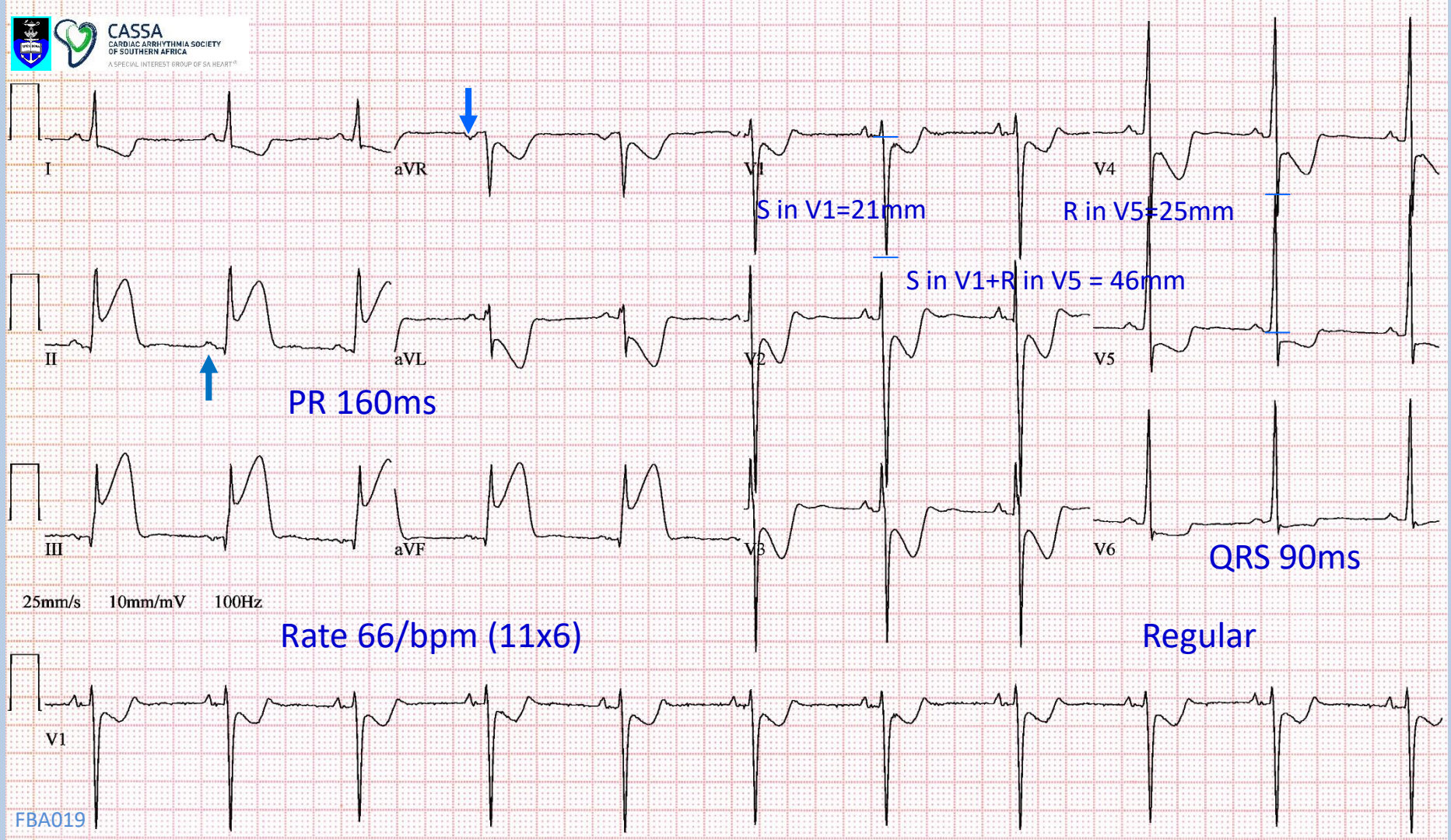
What is the ECG diagnosis?:

a) Acute anterior ST elevation myocardial infarction

b) Pericarditis

c) Anterior and inferior ischaemia

d) Acute inferior and posterior ST elevation myocardial infarction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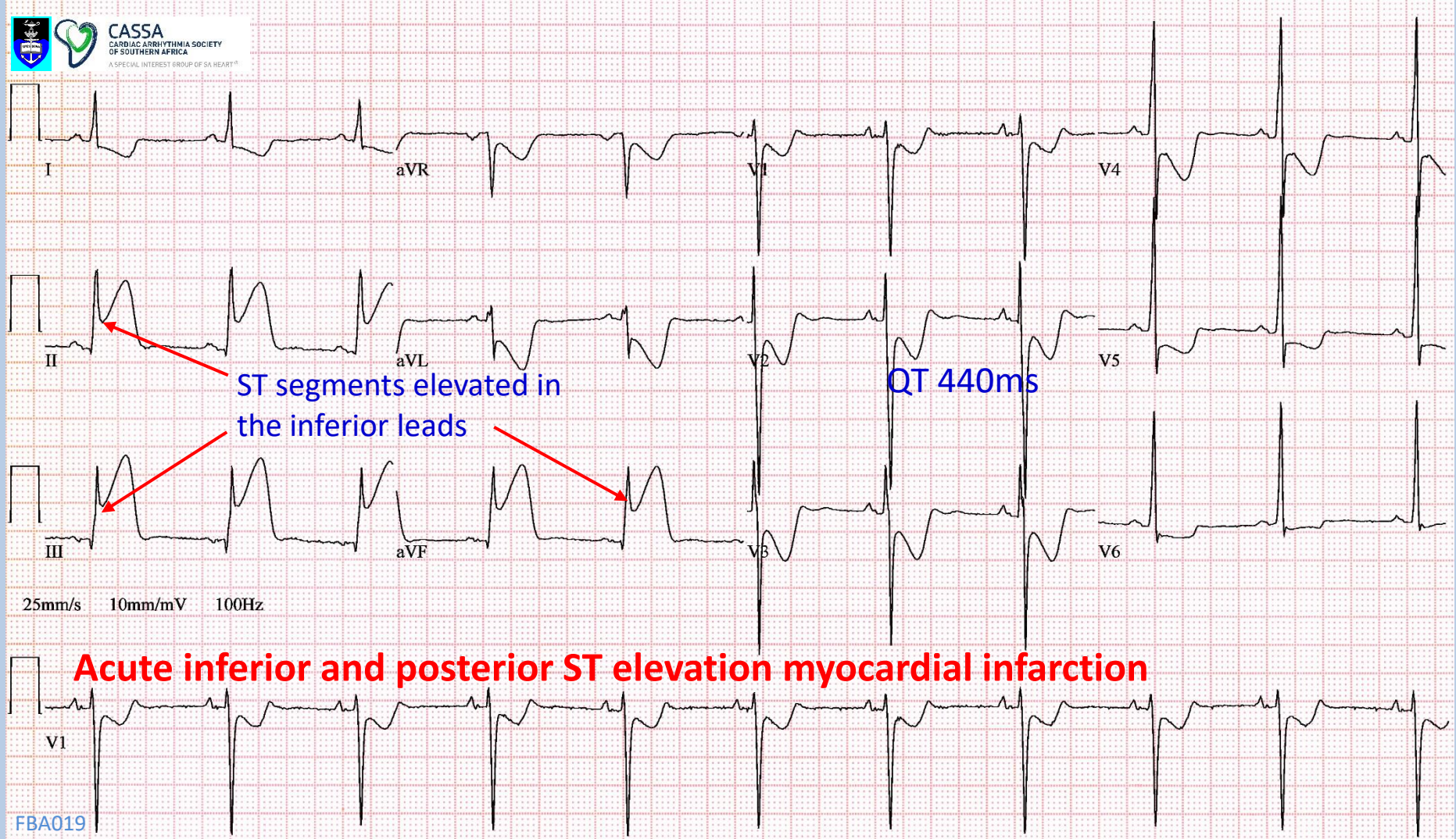
I
aVR
V1
V4
S in V1=21mm
R in V5=25mm
S in V1+R in V5 = 46mm
II
aVL
V2
V5
PR 160ms
III
aVF
V3
V6
QRS 90ms
25mm/s 10mm/mV 100Hz
Rate 66/bpm (11x6)
Regular
V1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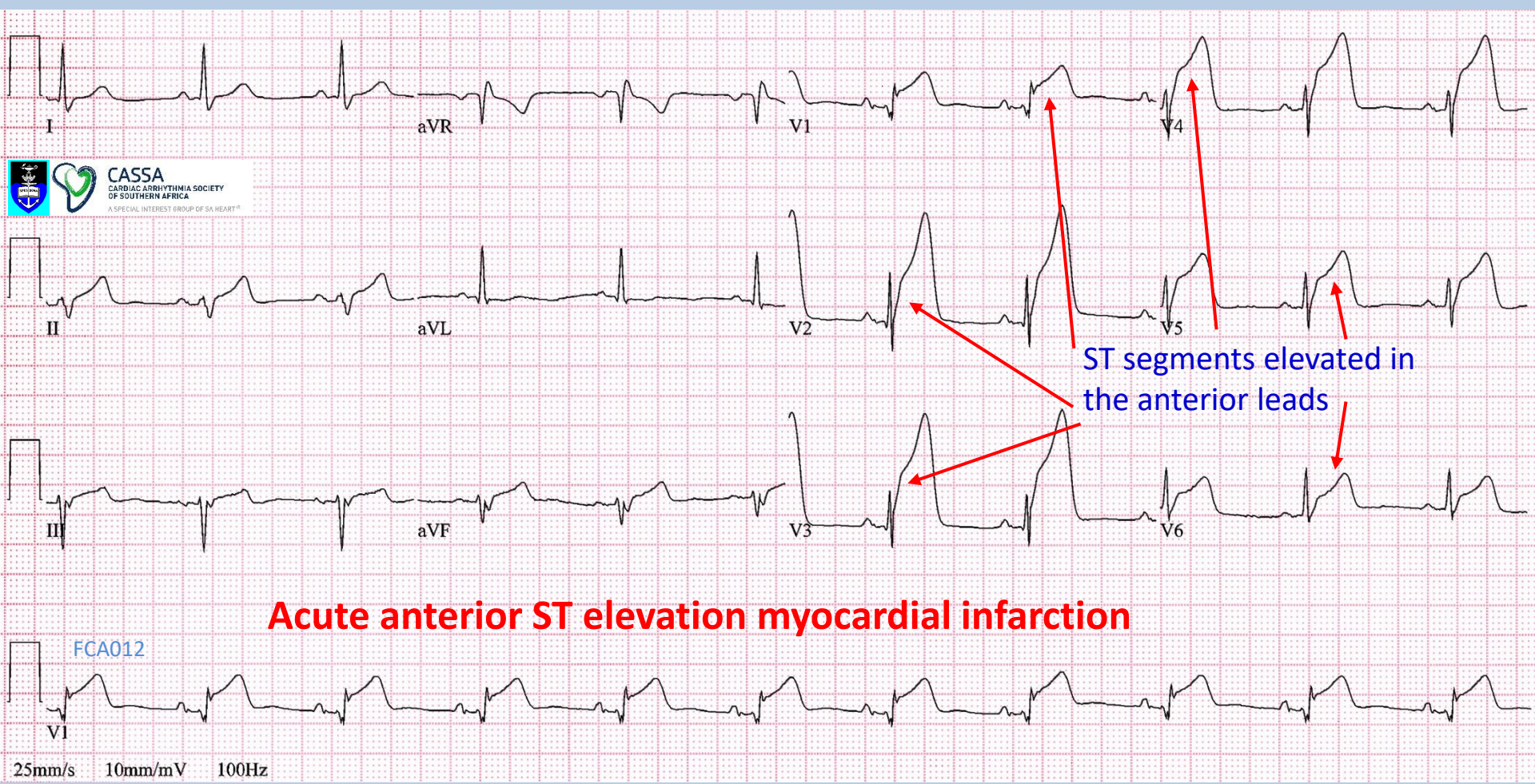
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
25mm/s 10mm/mV 100Hz
V1
ST segments elevated in the inferior leads
QT 440ms
Acute inferior and posterior ST elevation myocardial infarction


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
25mm/s
10mm/mV
100Hz
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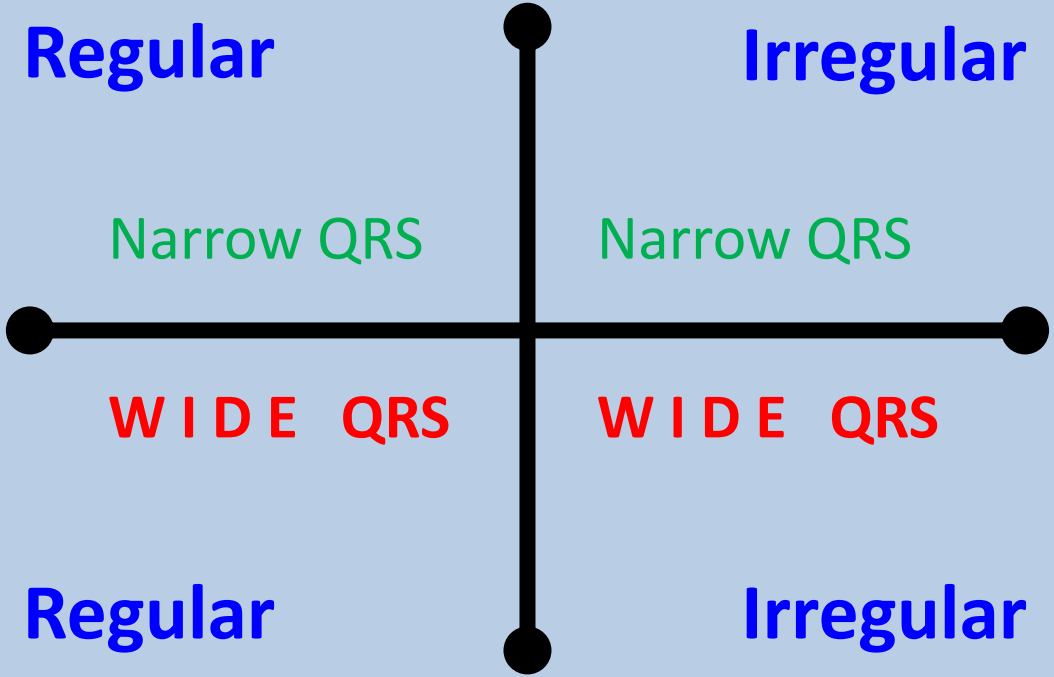
ST segments elevated in the anterior leads
Acute anterior ST elevation myocardial infarction
FCA012

TACHYARRHYTHMIAS



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TACHYARRHYTHMIAS

Regular

Narrow QRS

Sinus tachycardia
Atrial flutter
AVJRT (AVNRT, AVRT)
Atrial tachycardia
Junctional ectopic tachycardia

Irregular

Narrow QRS

Atrial Fibrillation
Atrial flutter/tachy + variable AVB
Multifocal atrial tachycardia

W I D E QRS

Regular

Ventricular tachycardia

SVT with BBB
SVT with IVCD
Paced rhythm
Antidromic AVRT
Pre-excited SVT

W I D E QRS

Irregular

AF with BBB
A flutter/tachy + variable AVB + BBB
Preexcited AF
Polymorphic VT

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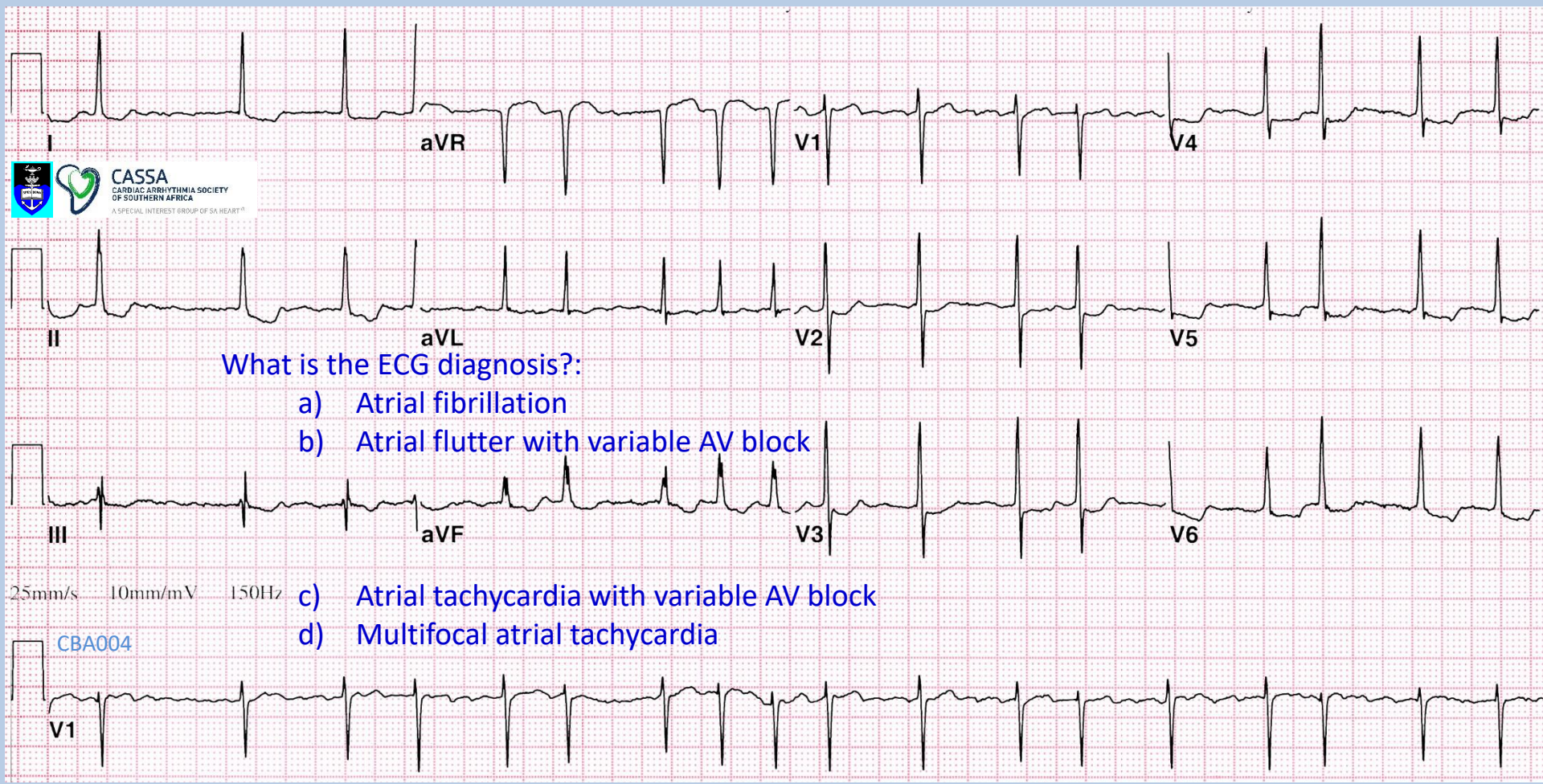
ECG 5



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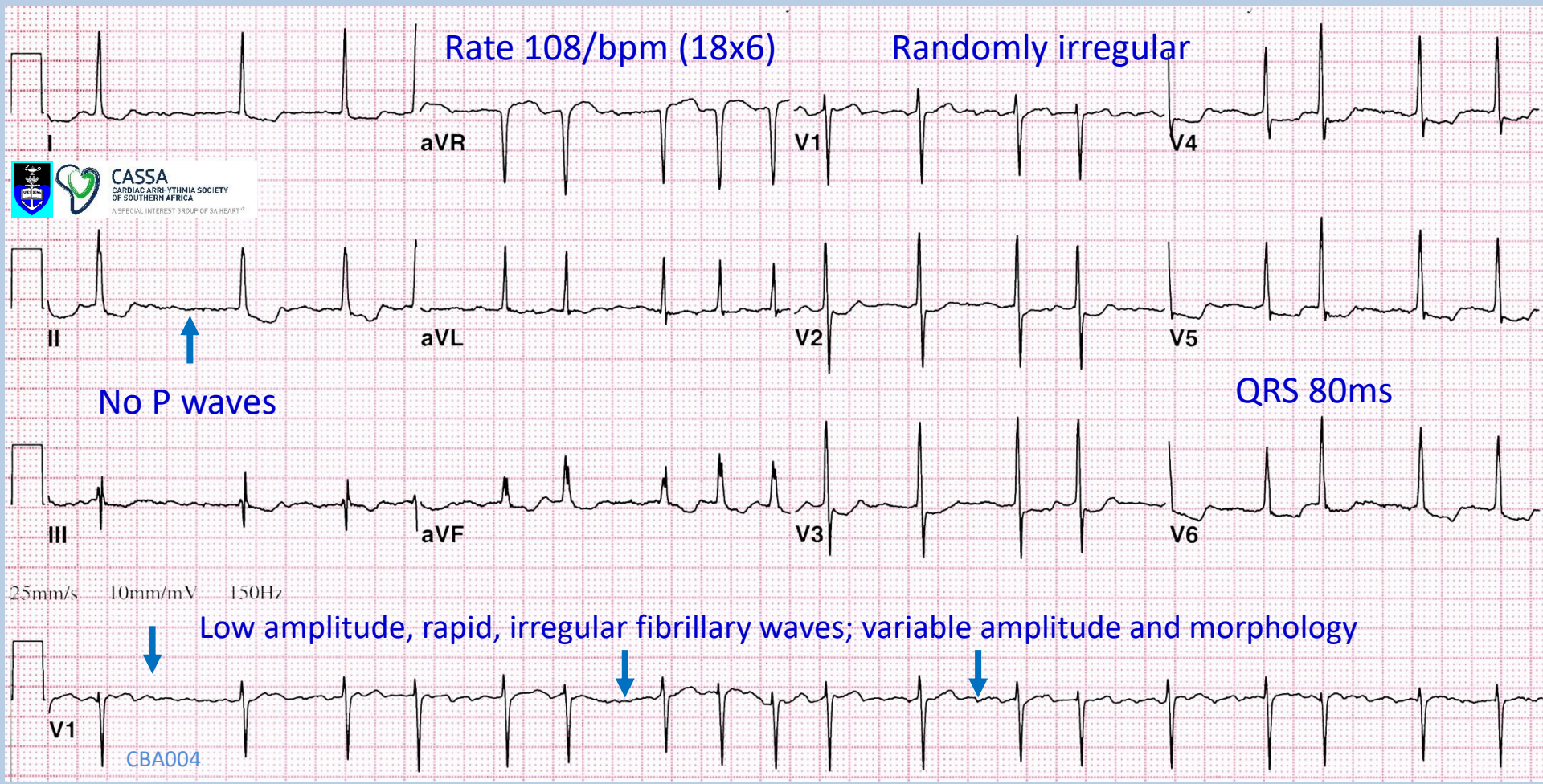
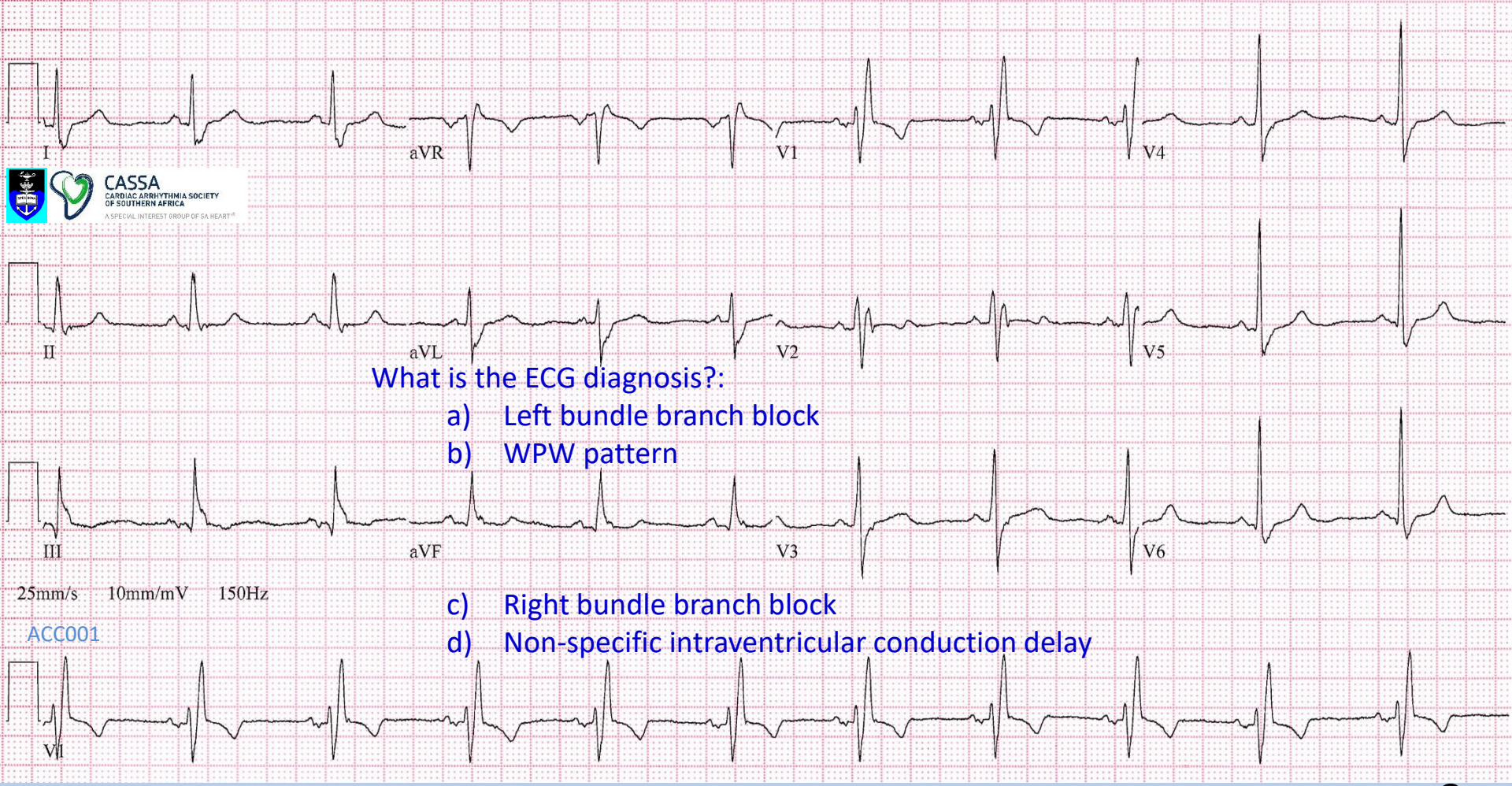
What is the ECG diagnosis?:

a) Atrial fibrillation
b) Atrial flutter with variable AV block
c) Atrial tachycardia with variable AV block
d) Multifocal atrial tachycardia



Randomly irregular, narrow QRS tachycardia: Default diagnosis = atrial fibrillation

ECG 6



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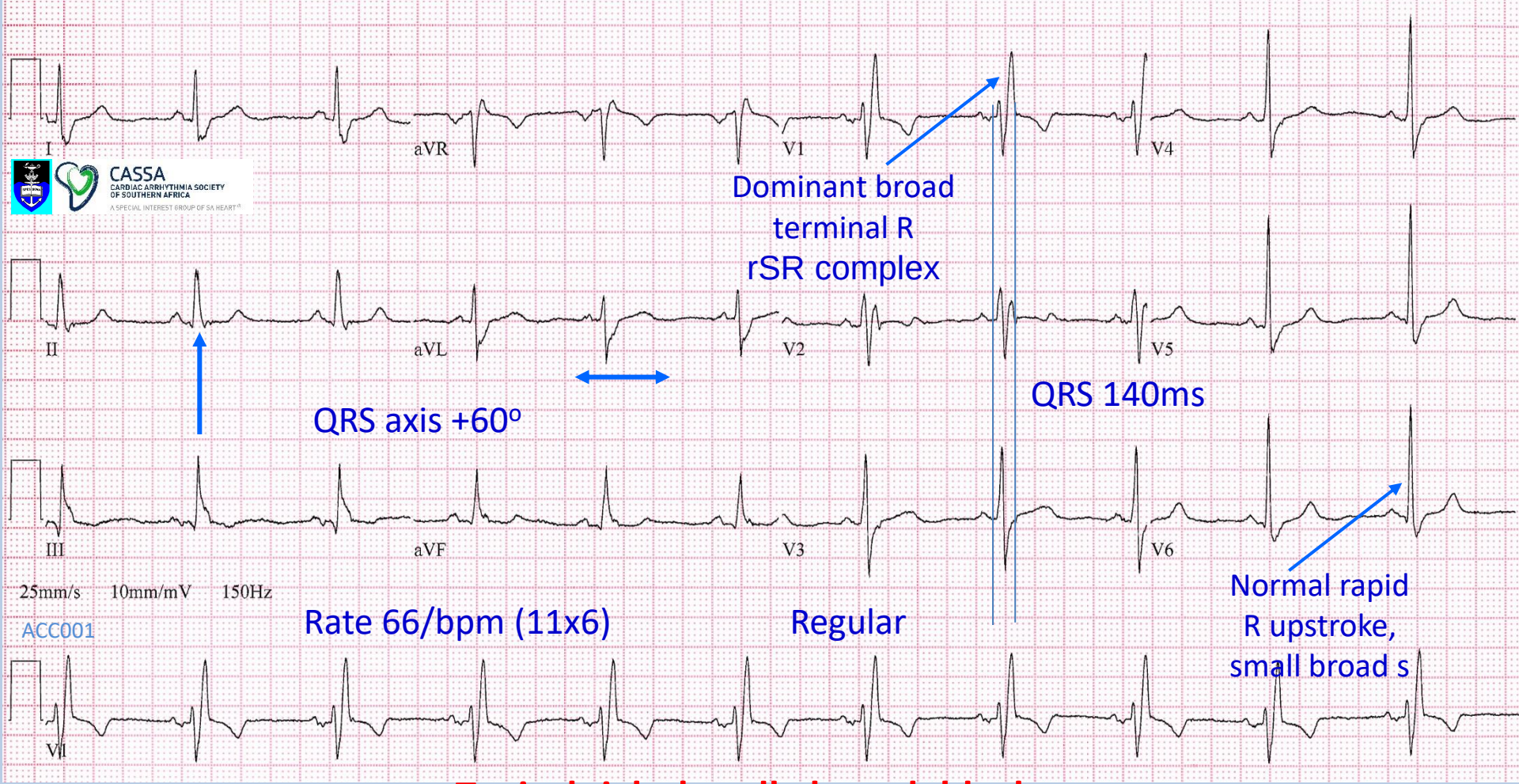
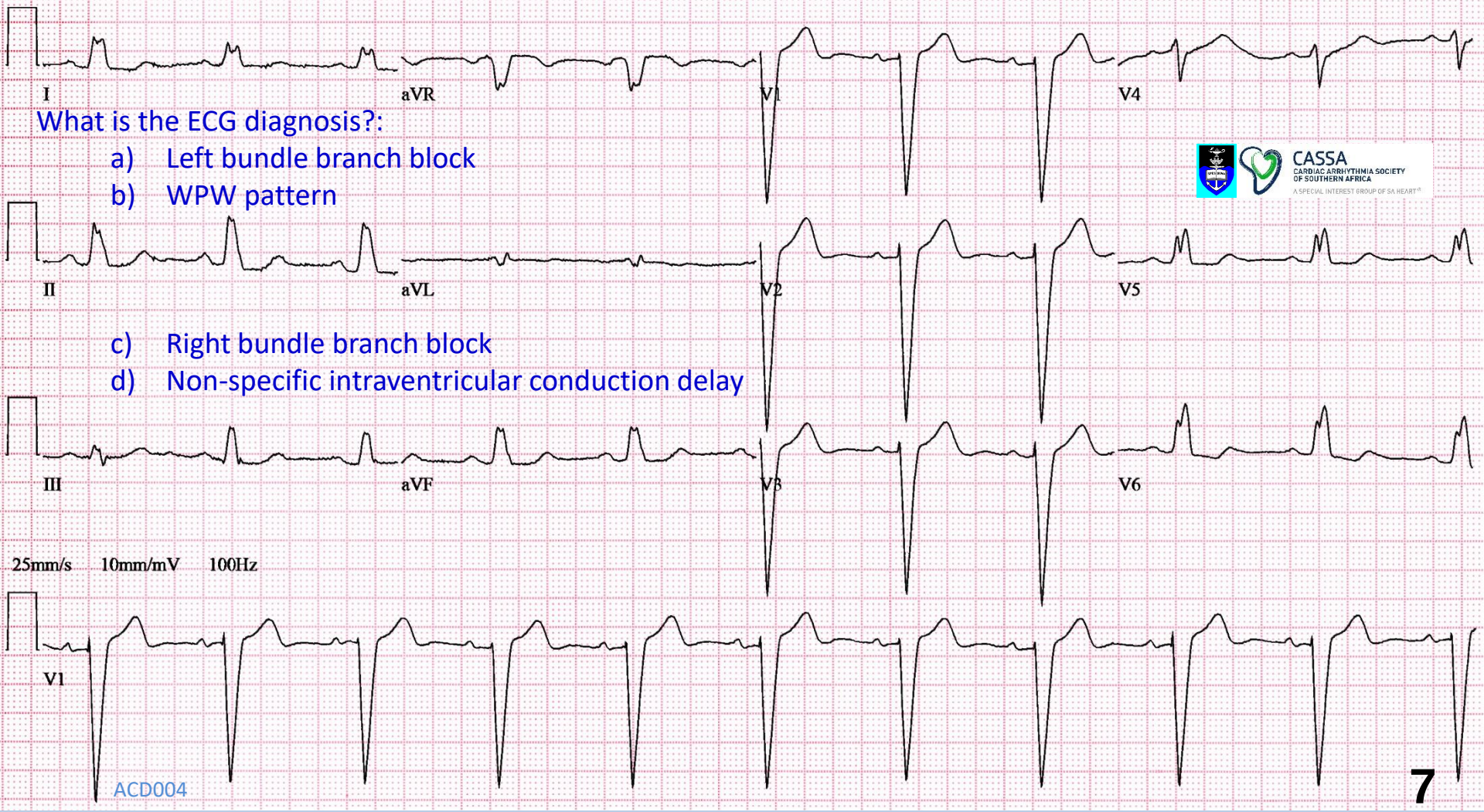
What is the ECG diagnosis?:

a) Left bundle branch block
b) WPW pattern
c) Right bundle branch block
d) Non-specific intraventricular conduction delay



Typical right bundle branch block

ECG 7



What is the ECG diagnosis?:

a) Left bundle branch block
b) WPW pattern
c) Right bundle branch block
d) Non-specific intraventricular conduction delay

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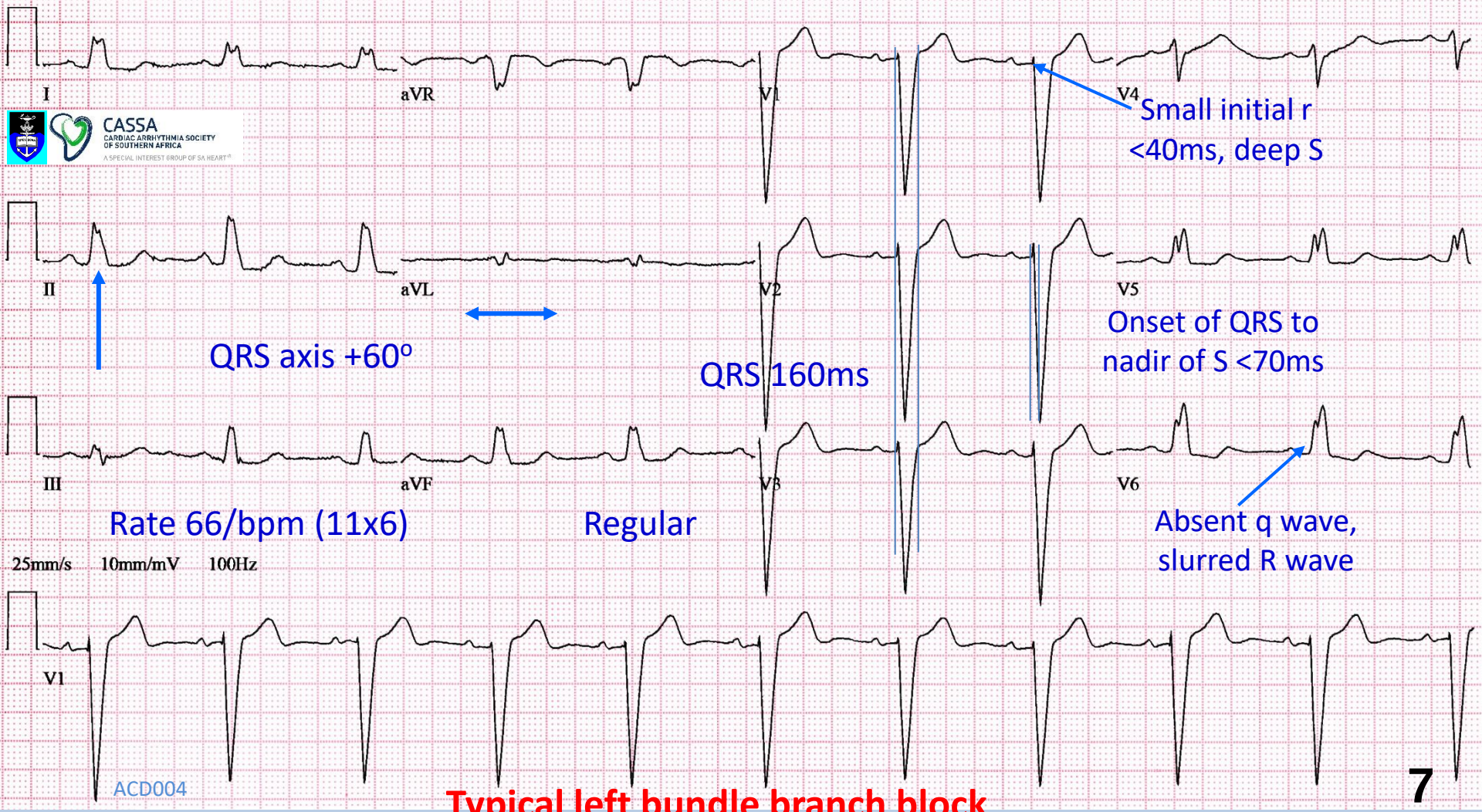

Typical left bundle branch block

Summary

- Approach to ECG analysis
  - Overview
  - Rate, rhythm (regular or irregular), QRS width
  - Systematic analysis
- Examples of essential ECGs
  1. Normal
  2. Complete heart block
  3. Mobitz II 2nd degree AV block
  4. Inferior and anterior ST elevation myocardial infarction
  5. Atrial fibrillation
  6. Right bundle branch block
  7. Left bundle branch block
- Next module: 7 more ECGs

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- Free download
- You will find answers to a lot of your questions in this app
- The app has been redesigned and updated
- The new version includes searchable terms and clinical correlations

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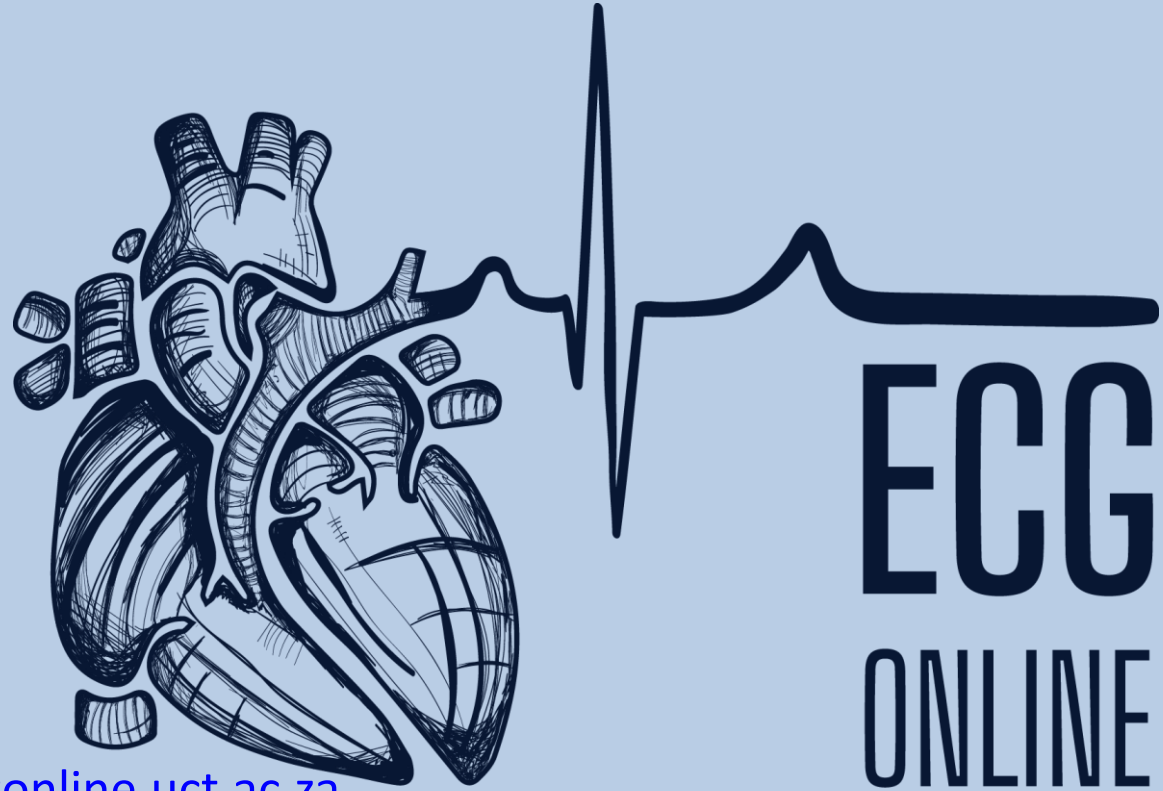

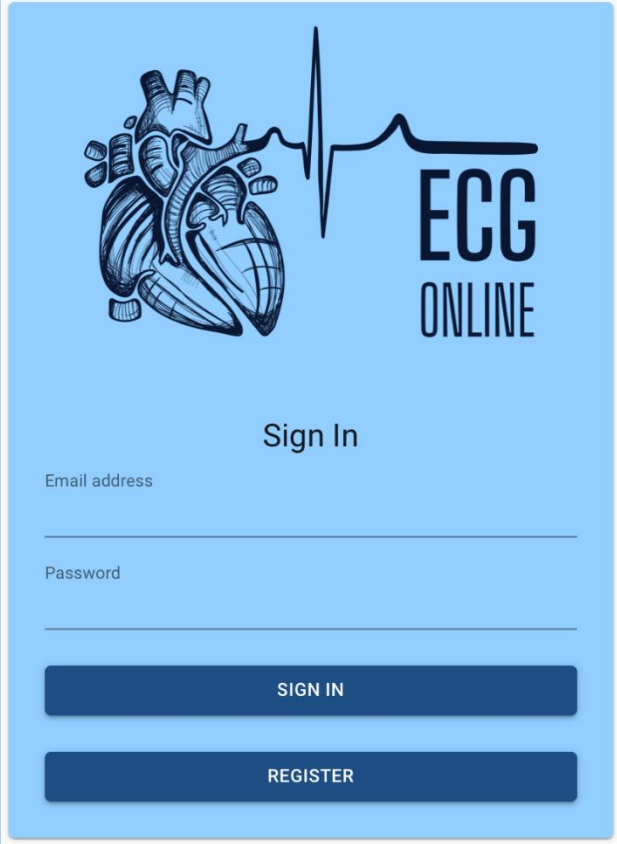

ecgonline.uct.ac.za

This free web-based resource was developed for students to allow self-directed learning of ECGs. It consists at present of 5 modules, each of 5-6 ECGs. The ECGs must be analysed systematically before coming to a conclusion. The correct answer is then provided with backup text to explain the reasons. The user can move forward, or redo the same ECG as desired.

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ECG Online | ECG Online

ECG Online

ENLARGE ECG | SAVE | SUBMIT YOUR ANSWER | ×

Step 1
Rhythm analysis

Step 2
Waveform analysis

P wave

PR interval

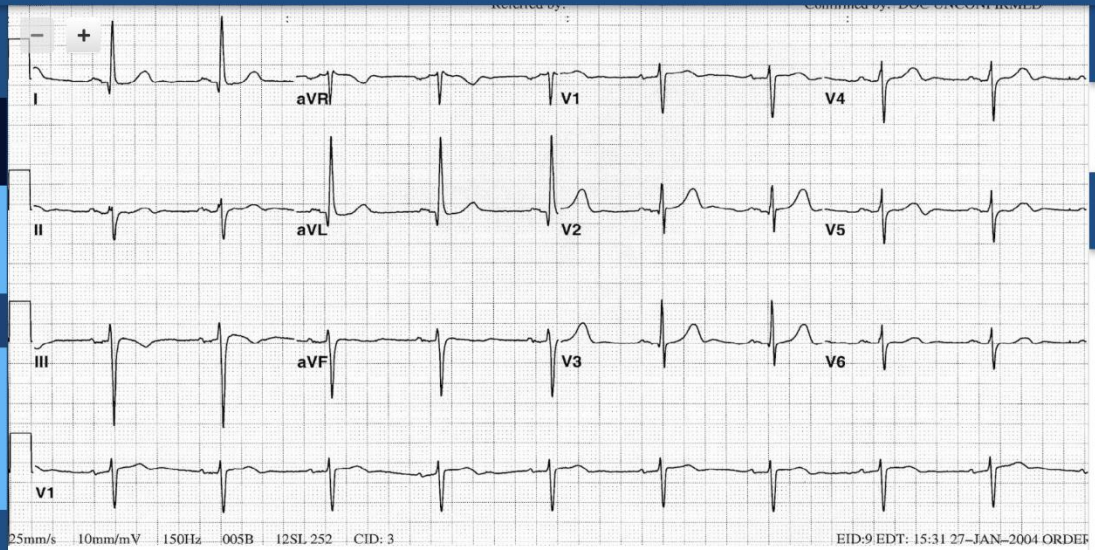
QRS complex

ST segment

T wave

QT interval

Step 3
Conclusion



QRS width
80 ms

QRS axis
-45 degrees

- [x] Normal morphology
- [ ] Complete RBBB
- [ ] Incomplete RBBB
- [ ] Complete LBBB
- [ ] Incomplete LBBB
- [ ] Atypical / bizarre wide QRS
- [ ] Delta waves
- [ ] J waves
- [ ] Epsilon waves
- [ ] Variable QRS morphology

- ( ) Normal axis
- ( ) Right axis deviation
- (•) Left axis deviation
- ( ) Extreme axis deviation

- [ ] Normal R wave progression
- [x] Poor R wave progression
- [ ] Dominant R in V1
- [ ] Increased left ventricular voltage
- [ ] Low QRS amplitude

- [ ] Pathological Q in inferior leads
- [ ] Pathological Q in anterior leads
- [ ] QS complexes in lateral leads
- [ ] Premature narrow complex
- [ ] Premature wide complex
- [ ] Narrow escape beat / rhythm
- [ ] Wide escape beat / rhythm
- [ ] Capture beat
- [ ] Fusion beat
- [ ] Electrical alternans

Clinical scenario

A 74 year old woman is admitted for elective knee replacement. Prior to the surgery an ECG is done and the Anaesthetist asks your opinion.

Summary of analysis

Regular
Narrow complex
Bradycardia with a ventricular rate of 54

P wave upright in II / inverted in aVR
P wave before every QRS complex
QRS complex after every P wave
Normal P wave morphology

Constant PR interval measuring 160 ms
The PR interval is normal

QRS width 80 ms
Normal QRS morphology
QRS axis -45 degrees
Left axis deviation
Poor R wave progression

Sample ECG

The ECG Atlas of Cardiac Rhythms

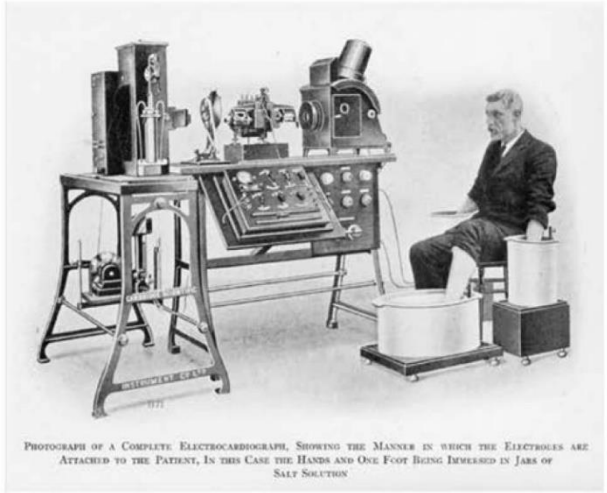
This book contains around 95 full size 12 lead ECGs which are analysed in detail. It covers all the rhythms you are likely to see in practice grouped into:

- **Bradycardias and conduction disturbances**
- **Abnormal rhythms at normal rates (including paced)**
- **Narrow QRS tachycardias**
- **Wide QRS tachycardias**

Rob Scott Millar

To get the book, go to: http://www.ecgrhythmsatlas.com/

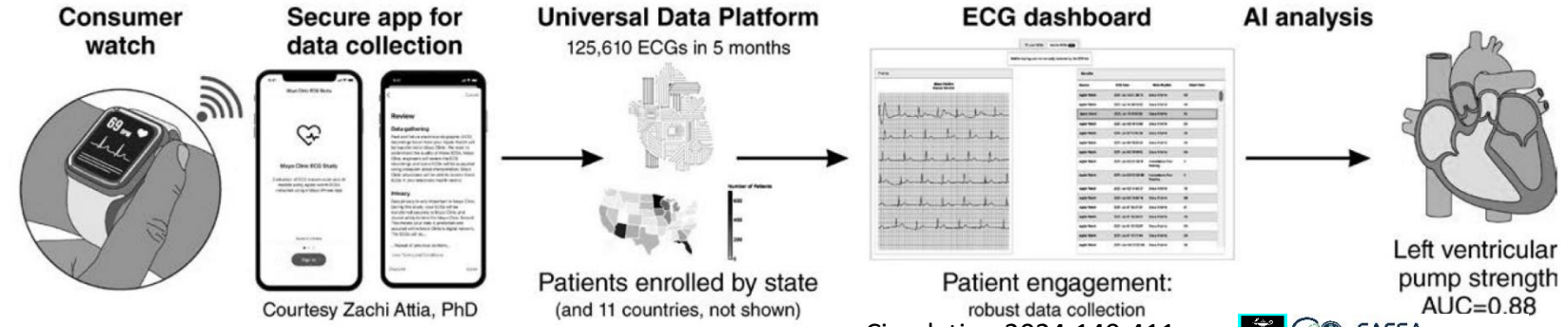
A



PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

1903 – Willem Einthoven

B



Circulation 2024;149:411

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Figure. The evolution of the ECG.

AI indicates artificial intelligence; App, application; and AUC, area under the curve. **A** is in the public domain (PD-US).