

ElectroCardioGraphy

ECG made extra easy...

Overview

- Objectives for this tutorial
- What is an ECG?
- Overview of performing electrocardiography on a patient
- Simple physiology
- Interpreting the ECG

Objectives

By the end of this tutorial the student should be able to:

- State a definition of electrocardiogram
- Perform an ECG on a patient, including explaining to the patient what is involved
- Draw a diagram of the conduction pathway of the heart
- Draw a simple labelled diagram of an ECG tracing
- List the steps involved in interpreting an ECG tracing in an orderly way
- Recite the normal limits of the parameters of various parts of the ECG
- Interpret ECGs showing the following pathology:
 - MI, AF, 1st 2nd and 3rd degree heart block, p pulmonale, p mitrale, Wolff-Parkinson-White syndrome, LBBB, RBBB, Left and Right axis deviation, LVH, pericarditis, Hyper- and hypokalaemia, prolonged QT.

What is an ECG?

ECG = Electrocardiogram
Tracing of heart's electrical activity

Recording an ECG

Overview of procedure

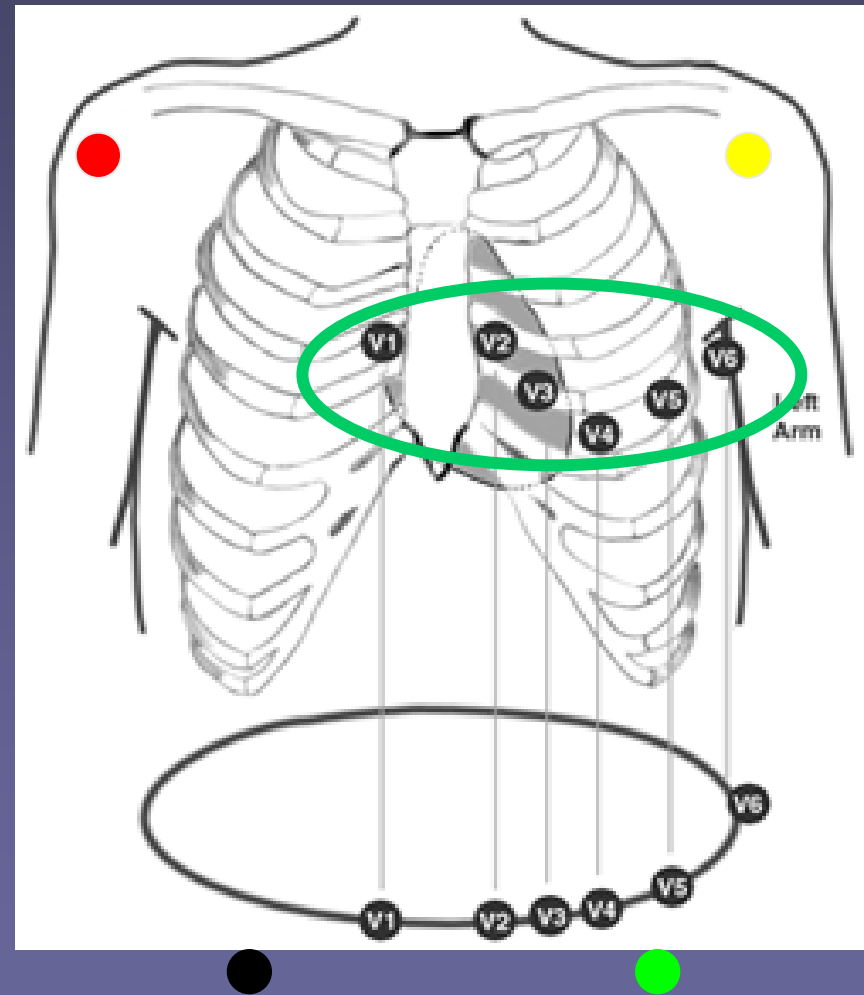
- GRIP
 - Greet, rapport, introduce, identify, privacy, explain procedure, permission
- Lay patient down
- Expose chest, wrists, ankles
- Clean electrode sites
 - May need to shave
- Apply electrodes
- Attach wires **correctly**
- Turn on machine
 - Calibrate to 10mm/mV
 - Rate at 25mm/s
- Record and print
- **Label** the tracing
 - Name, DoB, hospital number, date and time, reason for recording
- Disconnect if adequate and remove electrodes

Electrode placement

- 10 electrodes in total are placed on the patient
- Firstly self-adhesive 'dots' are attached to the patient. These have single electrical contacts on them
- The 10 leads on the ECG machine are then clipped onto the contacts of the 'dots'

Electrode placement in 12 lead ECG

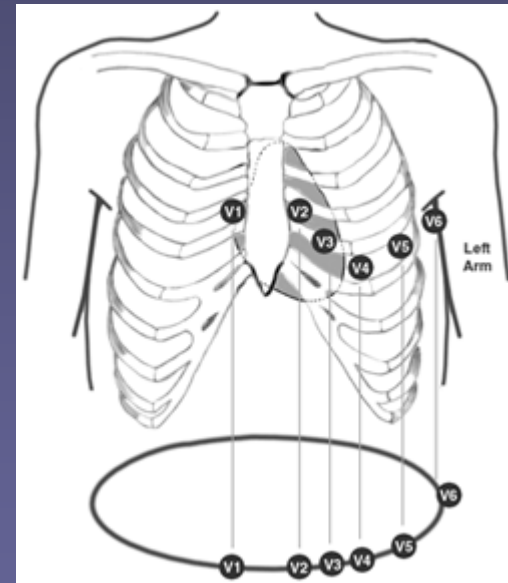
- 6 are chest electrodes
 - Called V1-6 or C1-6
- 4 are limb electrodes
 - **Right arm** **R**ide
 - **Left arm** **Y**our
 - **Left leg** **G**reen
 - **Right leg** **B**ike
- Remember
 - The right leg electrode is a neutral or “dummy”!



Electrode placement

For the chest electrodes

- V1 4th intercostal space right sternal edge
- V2 4th intercostal space left sternal edge
 - (to find the 4th space, palpate the manubriosternal angle (of Louis))
 - Directly adjacent is the 2nd rib, with the 2nd intercostal space directly below. Palpate inferiorly to find the 3rd and then 4th space
- V4 over the apex (5th ICS mid-clavicular line)
- V3 halfway between V2 and V4
- V5 at the same level as V4 but on the anterior axillary line
- V6 at the same level as V4 and V5 but on the mid-axillary line



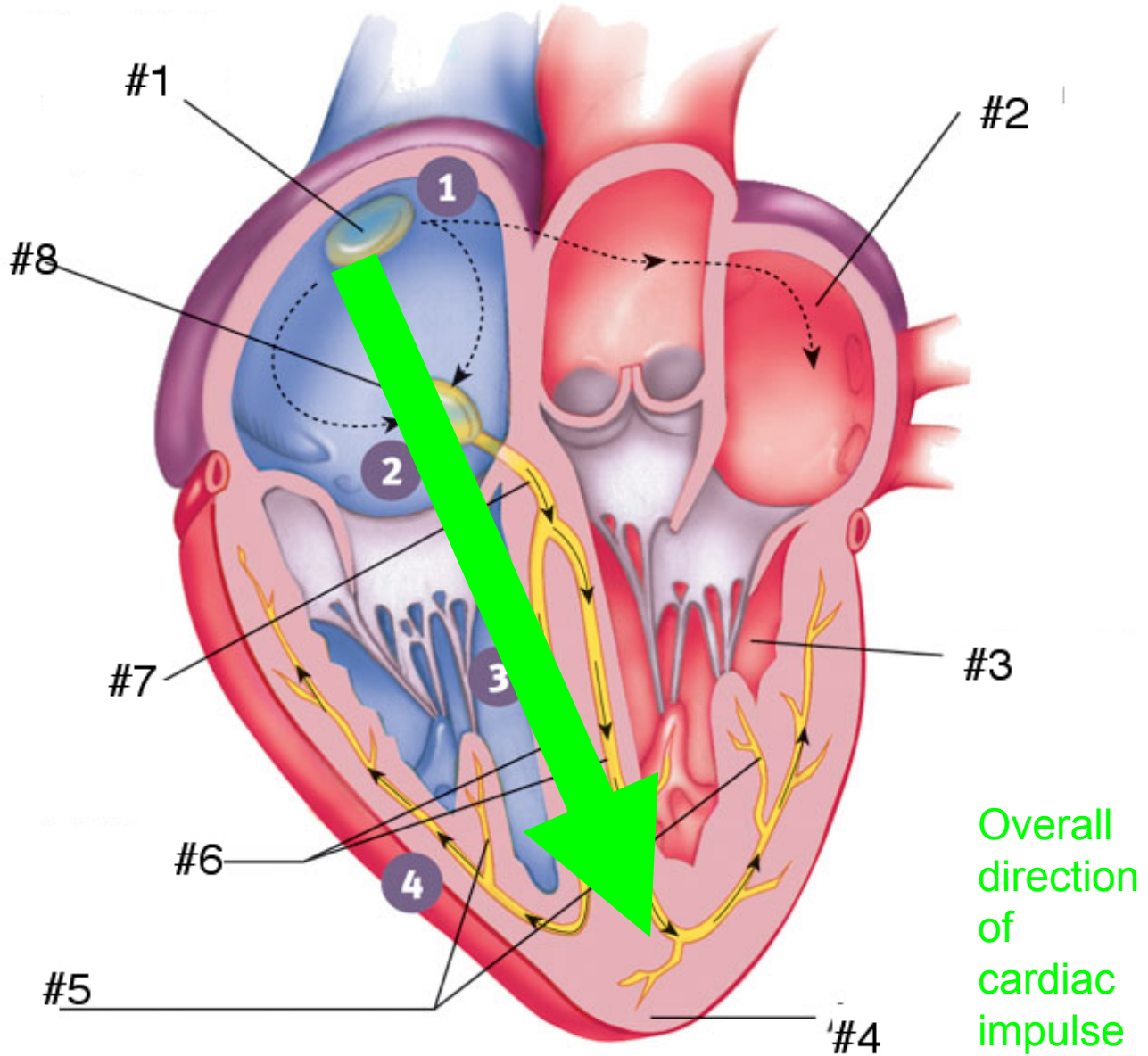
Recording the trace

- Different ECG machines have different buttons that you have to press.
- Ask one of the staff on the ward if it is a machine that you are unfamiliar with.
- Ask the patient to relax completely. Any skeletal muscle activity will be picked up as interference.
- If the trace obtained is no good, check that all the dots are stuck down properly – they have a tendency to fall off.

Electrophysiology

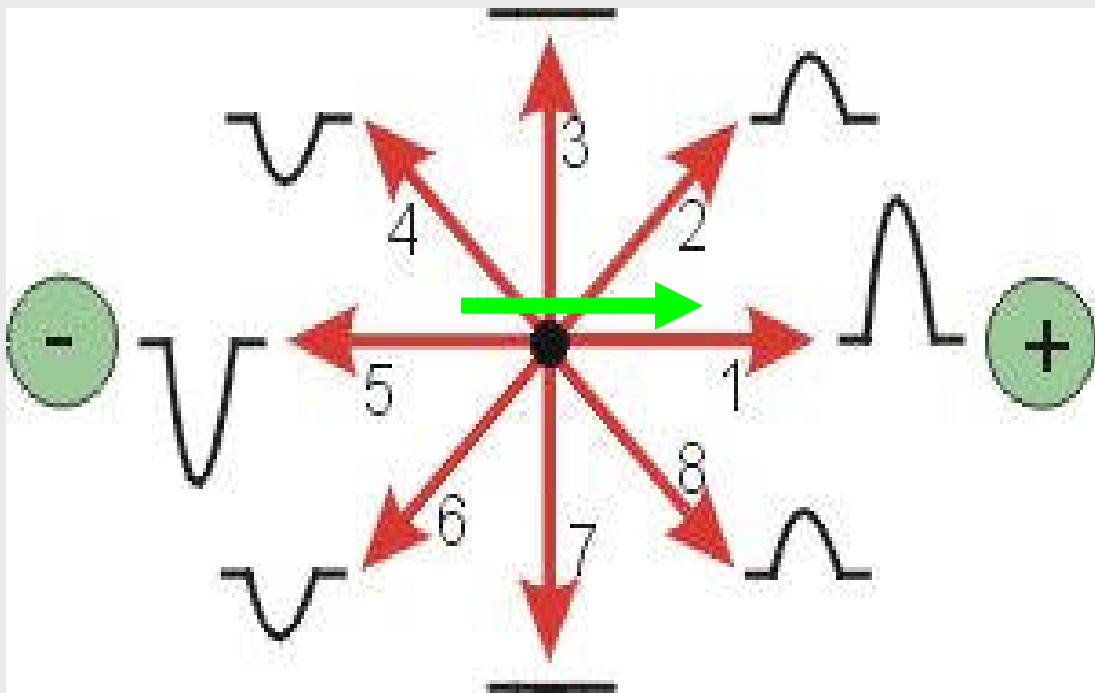
Electrophysiology

- Pacemaker = sinoatrial node
- Impulse travels across atria
- Reaches AV node
- Transmitted along interventricular septum in Bundle of His
- Bundle splits in two (right and left branches)
- Purkinje fibres



How does the ECG work?

- *Electrical impulse (wave of depolarisation) picked up by placing electrodes on patient*
- *The voltage change is sensed by measuring the current change across 2 electrodes – a positive electrode and a negative electrode*
- If the electrical impulse travels **towards** the positive electrode this results in a **positive** deflection
- If the impulse travels **away** from the positive electrode this results in a **negative** deflection



Away from the electrode
= negative deflection

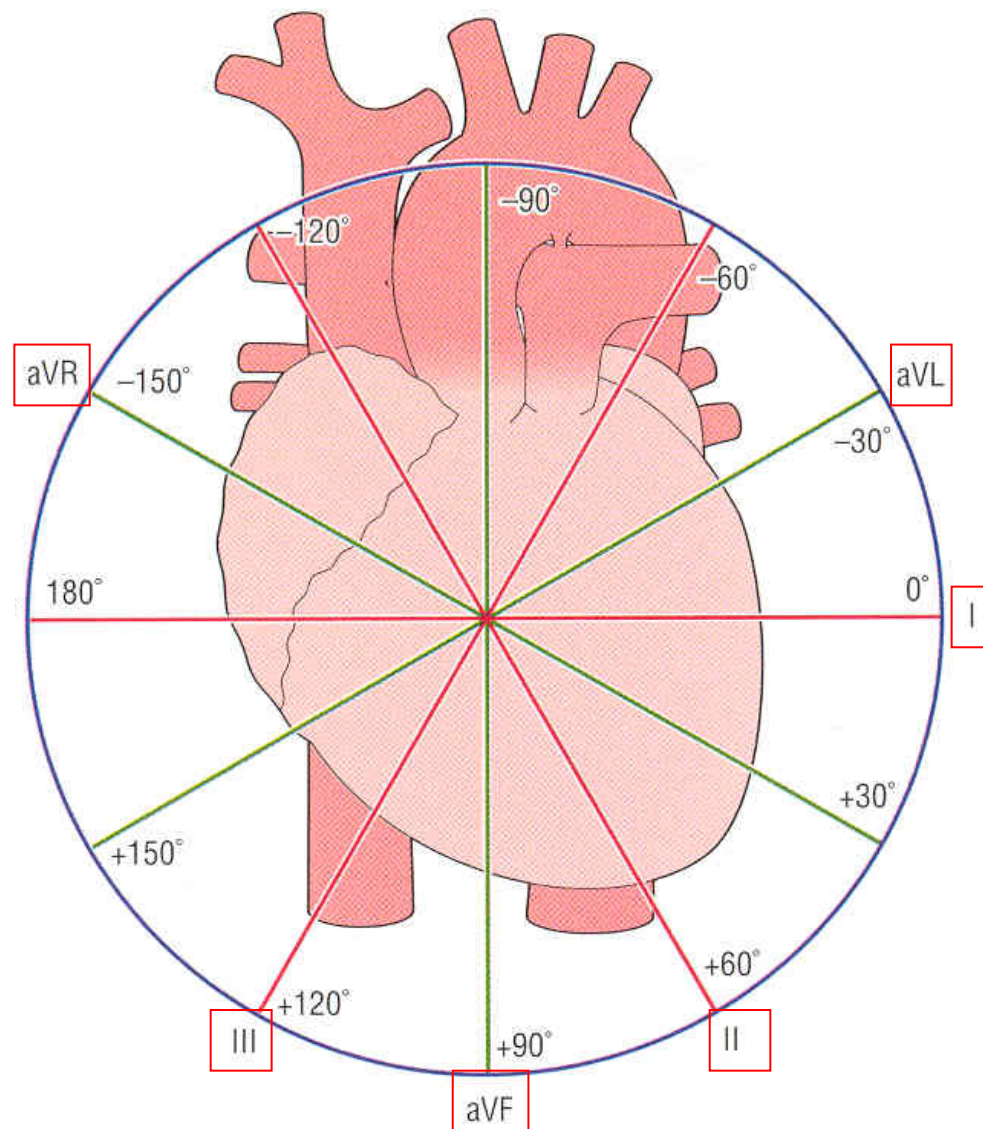
Towards the electrode
= positive deflection

Direction of impulse (axis)

Types of Leads

- Coronal plane (Limb Leads)
 1. Bipolar leads — I, II, III
 2. Unipolar leads — aVL, aVR, aVF
- Transverse plane
 - V₁ — V₆ (Chest Leads)

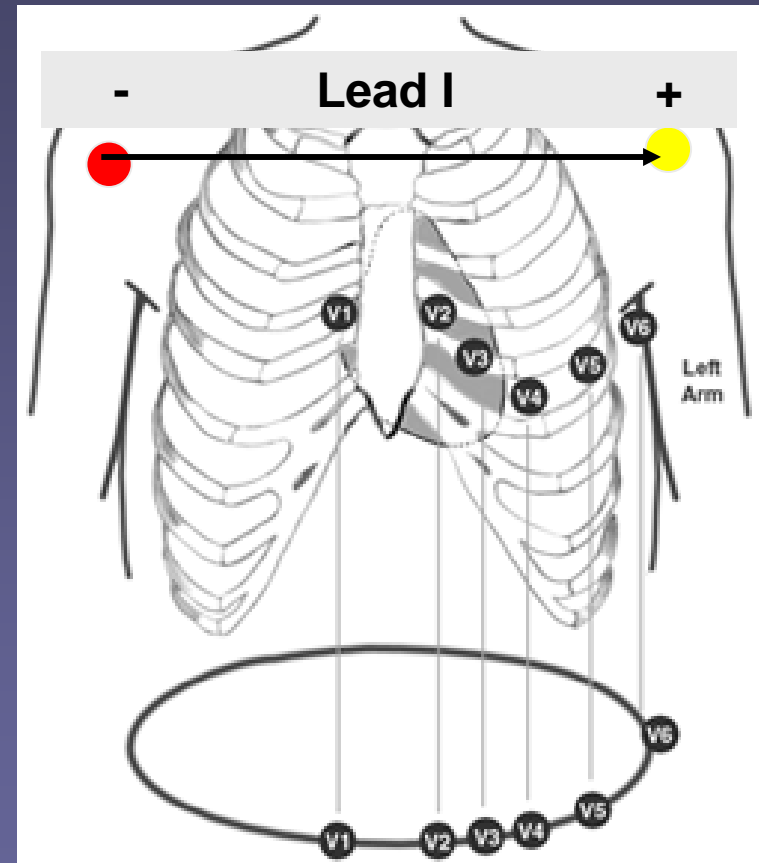
Electrodes around the heart



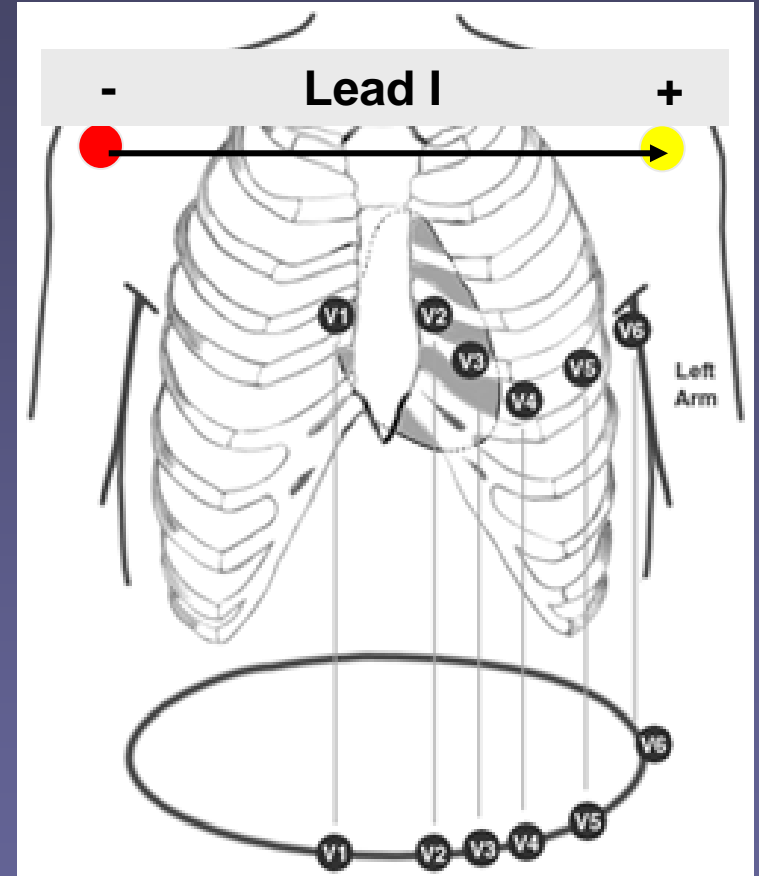
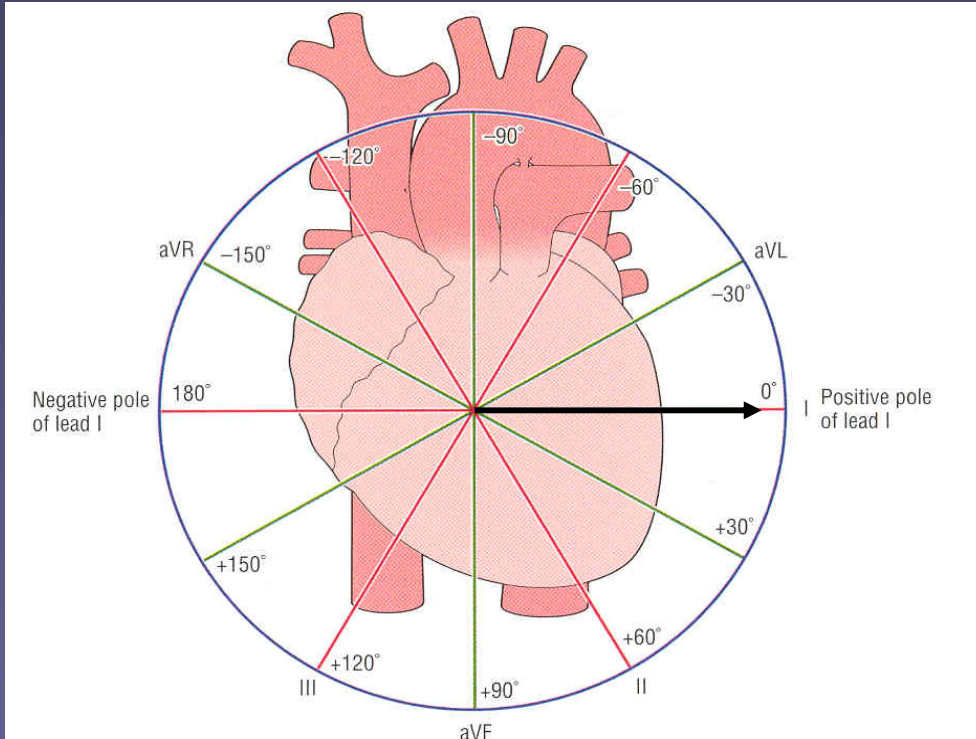
Leads

How are the 12 leads on the ECG (I, II, III, aVL, aVF, aVR, V1 – 6) formed using only 9 electrodes (and a neutral)?

- Lead I is formed using the **right arm electrode (red)** as the negative electrode and the **left arm (yellow)** electrode as the positive

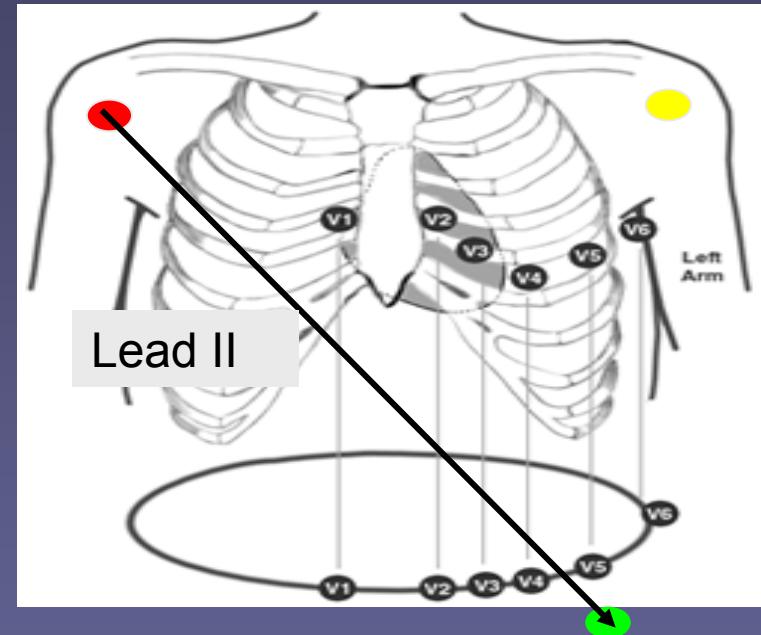


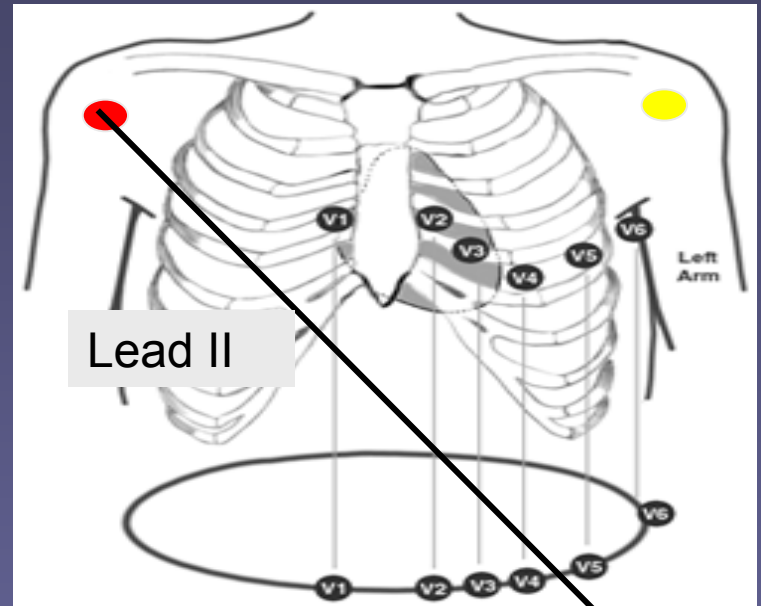
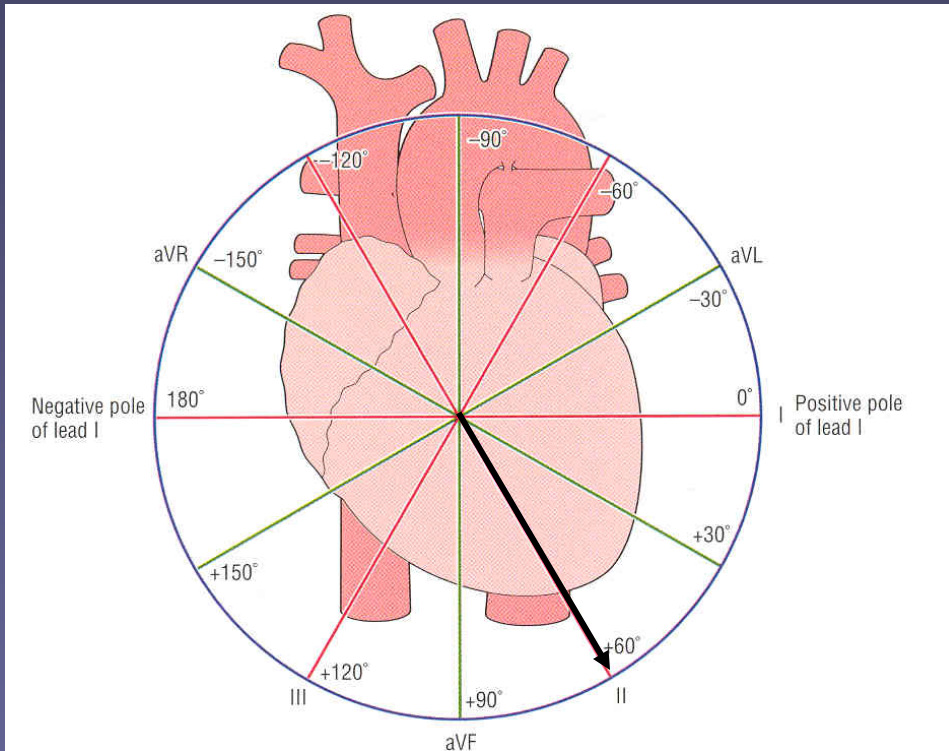
Leads



Leads

- Lead II is formed using the **right arm electrode (red)** as the negative electrode and the **left leg electrode** as the positive





Leads

- Lead III is formed using the **left arm electrode** as the negative electrode and the **left leg electrode** as the positive
- aVL, aVF, and aVR are *composite leads*, computed using the information from the other leads

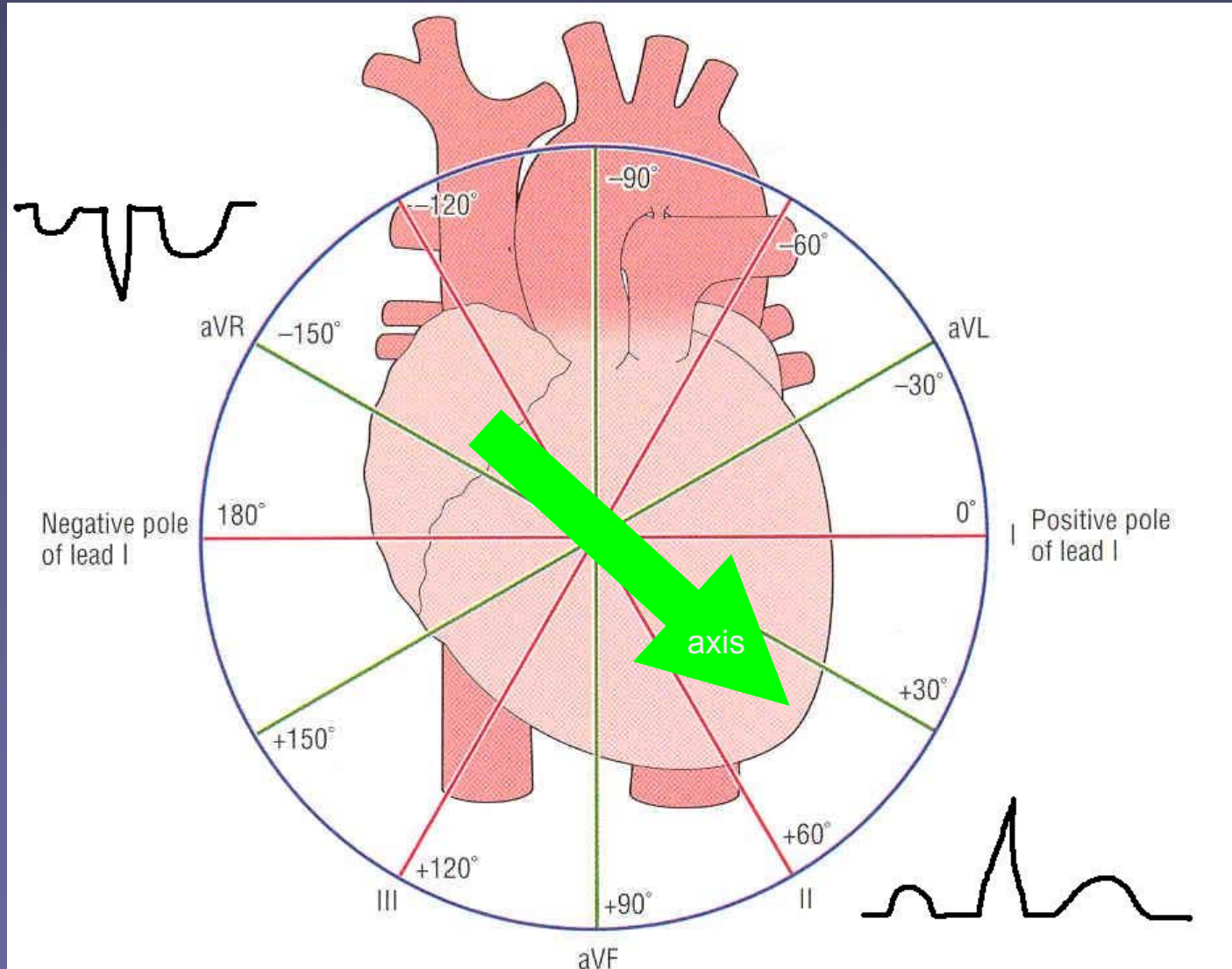
Leads and what they tell you

Limb leads

Limb leads look at the heart in the coronal plane

- aVL, I and II = lateral
- II, III and aVF = inferior
- aVR = right side of the heart

Leads look at the heart from different directions



Leads and what they tell you

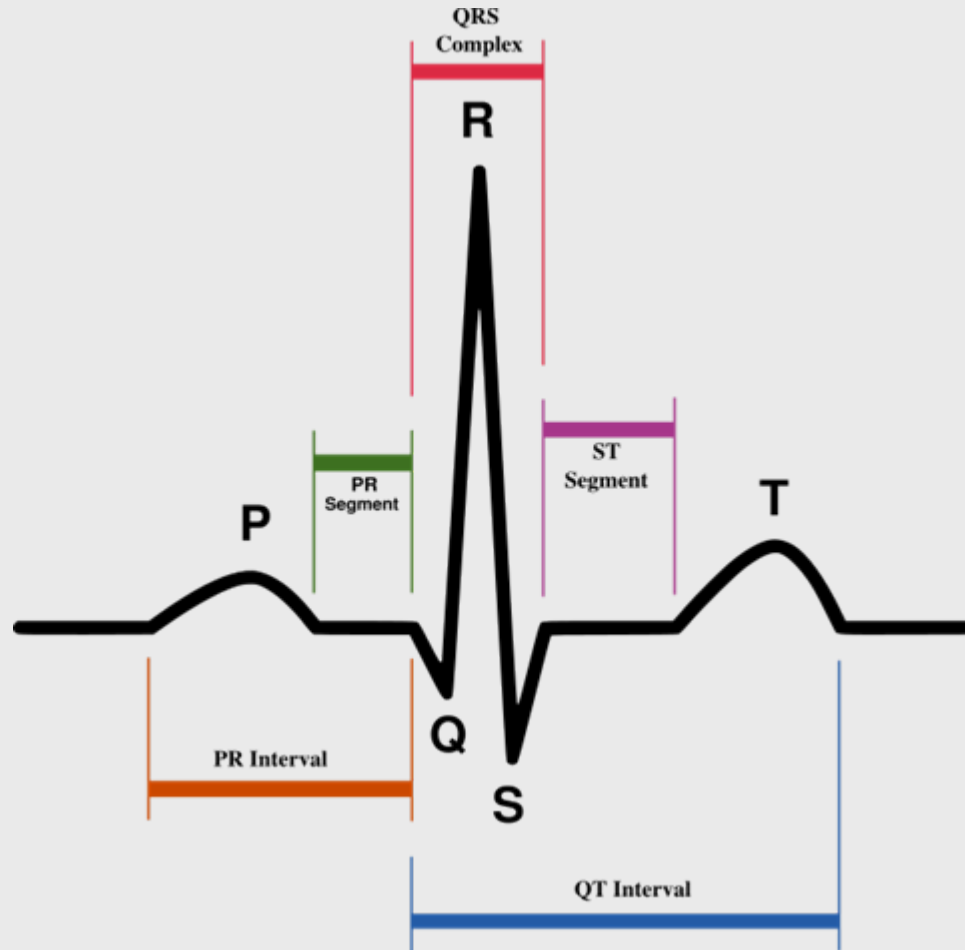
Each lead can be thought of as 'looking at' an area of myocardium

Chest leads

V₁ to V₆ 'look' at the heart on the transverse plane

- V₁ and V₂ look at the anterior of the heart and R ventricle
- V₃ and V₄ = anterior and septal
- V₅ and V₆ = lateral and left ventricle

Elements of the trace



What do the components represent?

- P wave = atrial depolarisation
- QRS = ventricular depolarisation
- T = repolarisation of the ventricles

Interpreting the ECG

Interpreting the ECG

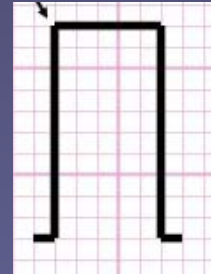
- Check
 - Name
 - DoB
 - Time and date
 - Indication e.g. “chest pain” or “routine pre-op”
 - Any previous or subsequent ECGs
 - Is it part of a serial ECG sequence? In which case it may be numbered
- Calibration
- Rate
- Rhythm
- Axis
- Elements of the tracing in each lead

Calibration

Check that your ECG is calibrated correctly

Height

- 10mm = 1mV
- Look for a reference pulse which should be the rectangular looking wave somewhere near the left of the paper. It should be 10mm (10 small squares) tall



Paper speed

- 25mm/s
- 25 mm (25 small squares / 5 large squares) equals one second

Rate

- If the heart rate is **regular**
 - Count the number of large squares between R waves
 - i.e. the RR interval in large squares
 - Rate = $\frac{300}{RR}$

e.g. RR = 4 large squares

$300/4 = 75$ beats per minute

Rate

If the rhythm is **irregular** (see next slide on rhythm to check whether your rhythm is regular or not) it may be better to estimate the rate using the rhythm strip at the bottom of the ECG (usually lead II)

The rhythm strip is usually 25cm long (250mm i.e. 10 seconds)

If you count the number of R waves on that strip and multiple by 6 you will get the rate

Rhythm

Is the rhythm regular?

- The easiest way to tell is to take a sheet of paper and line up one edge with the tips of the R waves on the rhythm strip.
- Mark off on the paper the positions of 3 or 4 R wave tips
- Move the paper along the rhythm strip so that your first mark lines up with another R wave tip
- See if the subsequent R wave tips line up with the subsequent marks on your paper
- If they do line up, the rhythm is regular. If not, the rhythm is irregular

Rhythm

Sinus Rhythm

- Definition Cardiac impulse originates from the sinus node. Every QRS must be preceded by a P wave.
- (This does not mean that every P wave must be followed by a QRS – such as in 2nd degree heart block where some P waves are not followed by a QRS, however every QRS is preceded by a P wave and the rhythm originates in the sinus node, hence it is a sinus rhythm. It could be said that it is not a *normal* sinus rhythm)

Rhythm

Sinus arrhythmia

- There is a change in heart rate depending on the phase of respiration
- Q. If a person with sinus arrhythmia inspires, what happens to their heart rate?
- A. The heart rate speeds up. This is because on inspiration there is a **decrease** in intrathoracic pressure, this leads to an increased venous return to the right atrium. Increased stretching of the right atrium sets off a brainstem reflex (Bainbridge's reflex) that leads to sympathetic activation of the heart, hence it speeds up)
- This physiological phenomenon is more apparent in children and young adults

Rhythm

Sinus bradycardia

- Rhythm originates in the sinus node
- Rate of less than 60 beats per minute

Sinus tachycardia

- Rhythm originates in the sinus node
- Rate of greater than 100 beats per minute

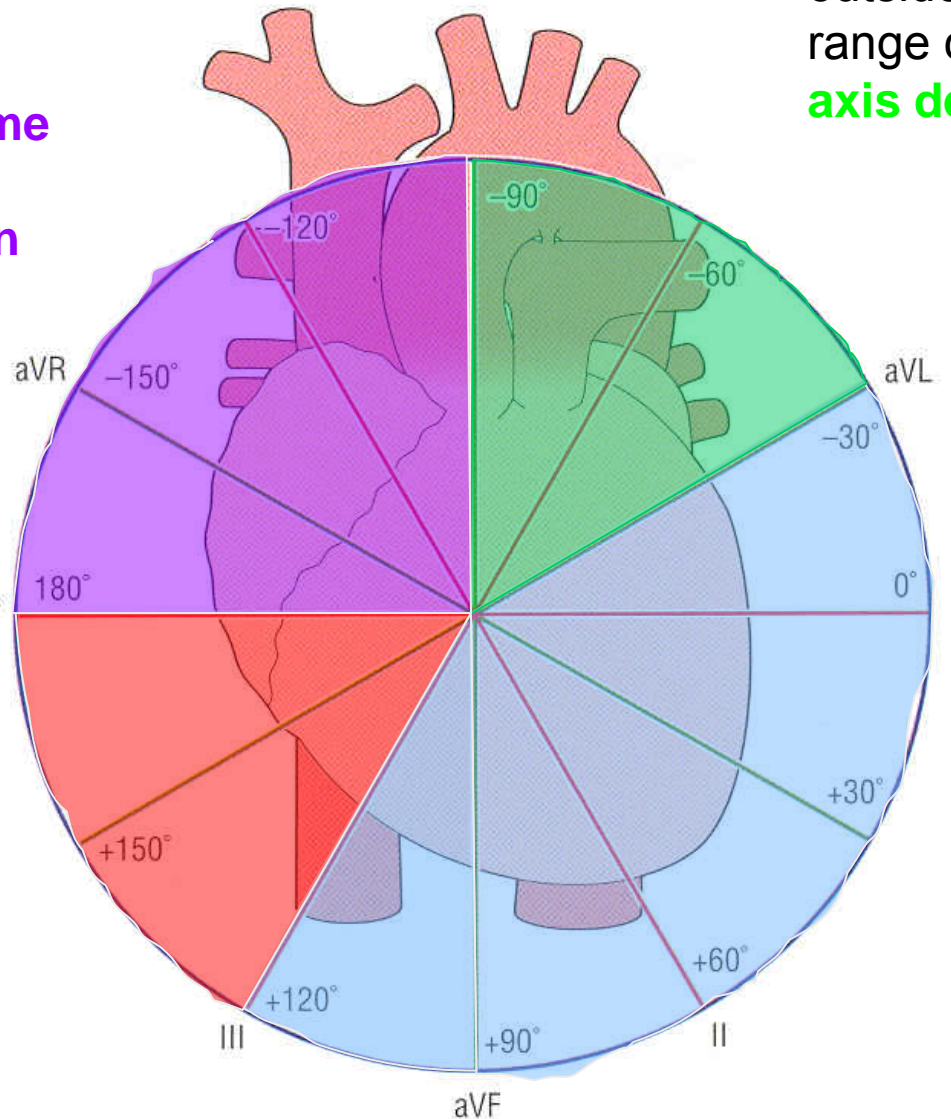
Axis

- The axis can be thought of as the overall direction of the cardiac impulse or wave of depolarisation of the heart
- An abnormal axis (axis deviation) can give a clue to possible pathology

Axis

An axis falling outside the normal range can be **left axis deviation**

or **extreme axis deviation**



right axis deviation

A **normal axis** can lie anywhere between -30 and $+90$ degrees or $+120$ degrees according to some

Axis deviation - Causes

- Wolff-Parkinson-White syndrome can cause both Left and Right axis deviation

A useful mnemonic:

- “**RAD RALPH** the **LAD** from **VILLA**”

- **Right Axis Deviation**

- Right ventricular hypertrophy
- Anterolateral MI
- Left **P**osterior **H**emiblock

- **Left Axis Deviation**

- Ventricular tachycardia
- Inferior MI
- Left ventricular hypertrophy
- Left **A**nterior hemiblock

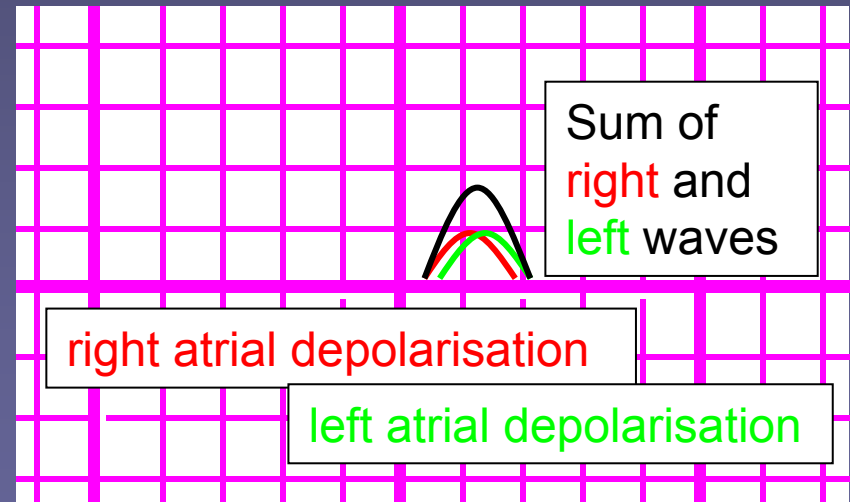
The P wave

The P wave represents atrial depolarisation

It can be thought of as being made up of two separate waves due to **right** atrial depolarisation and **left** atrial depolarisation.

Which occurs first?

Right atrial depolarisation



The P wave

Dimensions

- No hard and fast rules

Height

- a P wave over 2.5mm should arouse suspicion

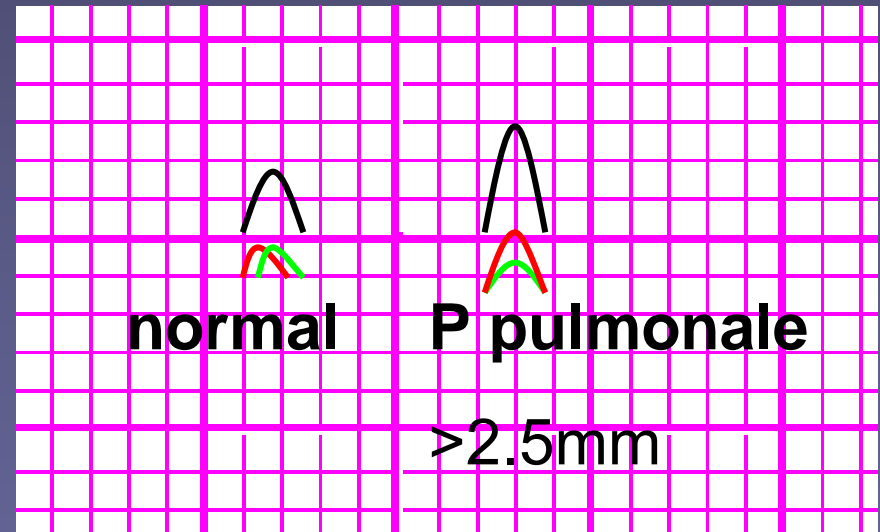
Length

- a P wave longer than 0.08s (2 small squares) should arouse suspicion

The P wave

Height

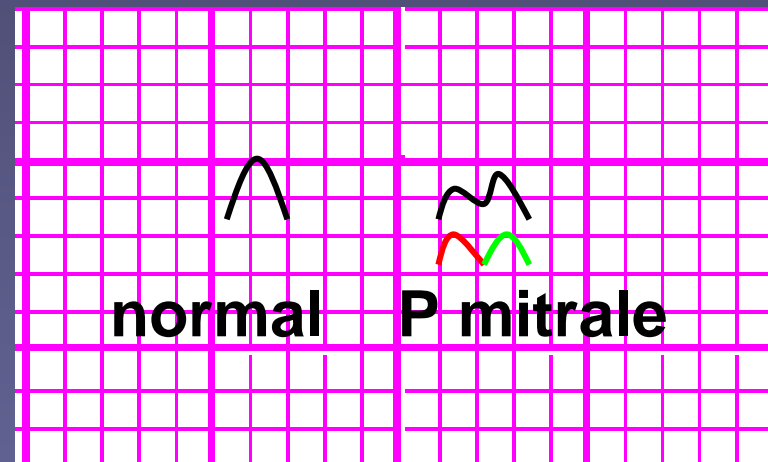
- A tall P wave (over 2.5mm) can be called *P pulmonale*
- Occurs due to **R atrial hypertrophy**
- Causes include:
 - pulmonary hypertension,
 - pulmonary stenosis
 - tricuspid stenosis



The P wave

Length

- A P wave with a length >0.08 seconds (2 small squares) and a bifid shape is called *P mitrale*
- It is caused by left atrial hypertrophy and delayed **left atrial depolarisation**
- Causes include:
 - Mitral valve disease
 - LVH



The PR interval

- The PR interval is measured between the start of the P wave to the start of the QRS complex
- (therefore if there is a Q wave before the R wave the PR interval is measured from the start of the P wave to the start of the Q wave, not the start of the R wave)

The PR interval

- The PR interval corresponds to the time period between depolarisation of the atria and ventricular depolarisation.
- A normal PR interval is between 0.12 and 0.2 seconds (3-5 small squares)

The PR interval

- If the PR interval is short (less than 3 small squares) it may signify that there is an accessory electrical pathway between the atria and the ventricles, hence the ventricles depolarise early giving a short PR interval.
- One example of this is Wolff-Parkinson-White syndrome where the accessory pathway is called the bundle of Kent. See next slide for an animation to explain this

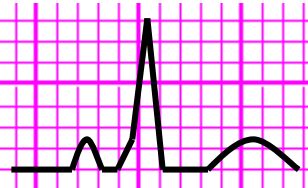
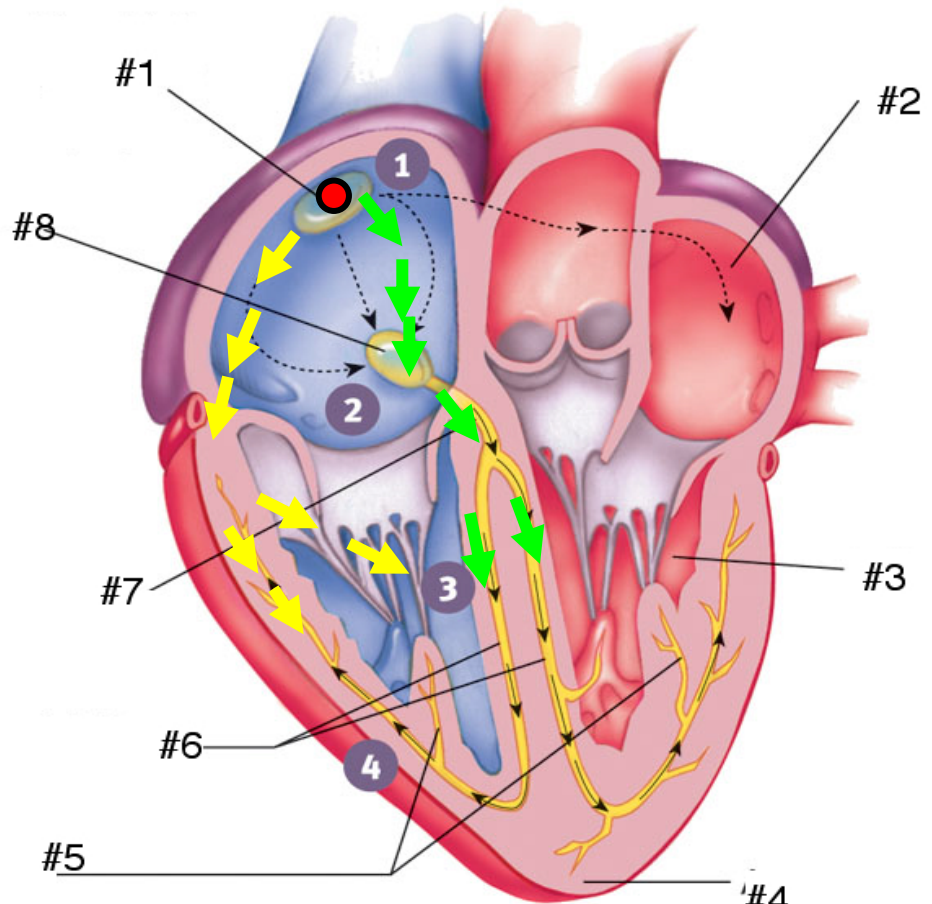
Depolarisation begins at the **SA node**

The wave of depolarisation spreads across the atria

It reaches the AV node and the accessory bundle

Conduction is delayed as usual by the in-built delay in the AV node

However, the accessory bundle has no such delay and depolarisation begins early in the part of the ventricle served by the bundle



As the depolarisation in this part of the ventricle does not travel in the high speed conduction pathway, the spread of depolarisation across the ventricle is slow, causing a slow rising delta wave

Until rapid depolarisation resumes via the normal pathway and a more normal complex follows

The PR interval

- If the PR interval is long (>5 small squares or 0.2s):
 - If there is a constant long PR interval 1st degree heart block is present
- First degree heart block is a longer than normal delay in conduction at the AV node

The PR interval

- If the PR interval looks as though it is **widening** every beat and then a QRS complex is missing, there is **2nd degree heart block, Mobitz type I**. The lengthening of the PR interval in subsequent beats is known as the Wenckebach phenomenon
- (remember (**w**)one, **W**enckebach, **w**idens)
- If the PR interval is **constant** but then there is a missed QRS complex then there is **2nd degree heart block, Mobitz type II**

The PR interval

- If there is **no discernable relationship** between the P waves and the QRS complexes, then **3rd degree heart block** is present

Heart block (AV node block)

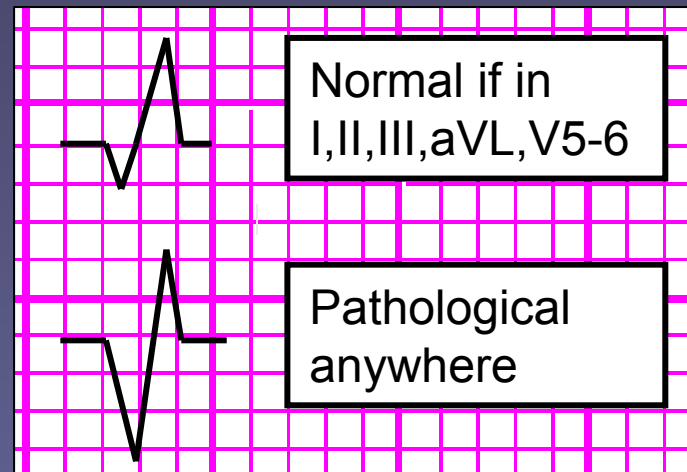
Summary

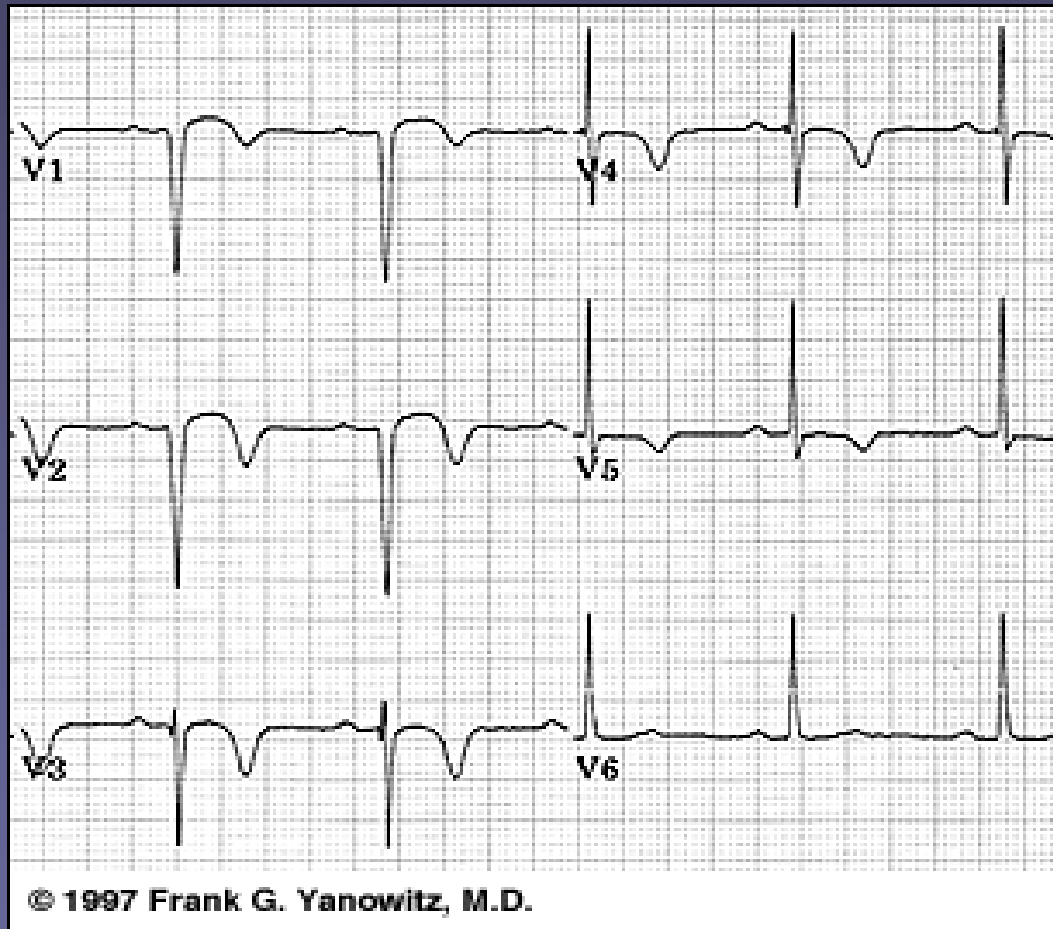
- 1st degree
 - constant PR, >0.2 seconds
- 2nd degree type 1 (Wenckebach)
 - PR widens over subsequent beats then a QRS is dropped
- 2nd degree type 2
 - PR is constant then a QRS is dropped
- 3rd degree
 - No discernable relationship between p waves and QRS complexes

The Q wave

Are there any pathological Q waves?

- A Q wave can be pathological if it is:
 - Deeper than 2 small squares (0.2mV)and/or
 - Wider than 1 small square (0.04s)and/or
 - In a lead other than III or one of the leads that look at the heart from the left (I, II, aVL, V5 and V6) where small Qs (i.e. not meeting the criteria above) can be normal





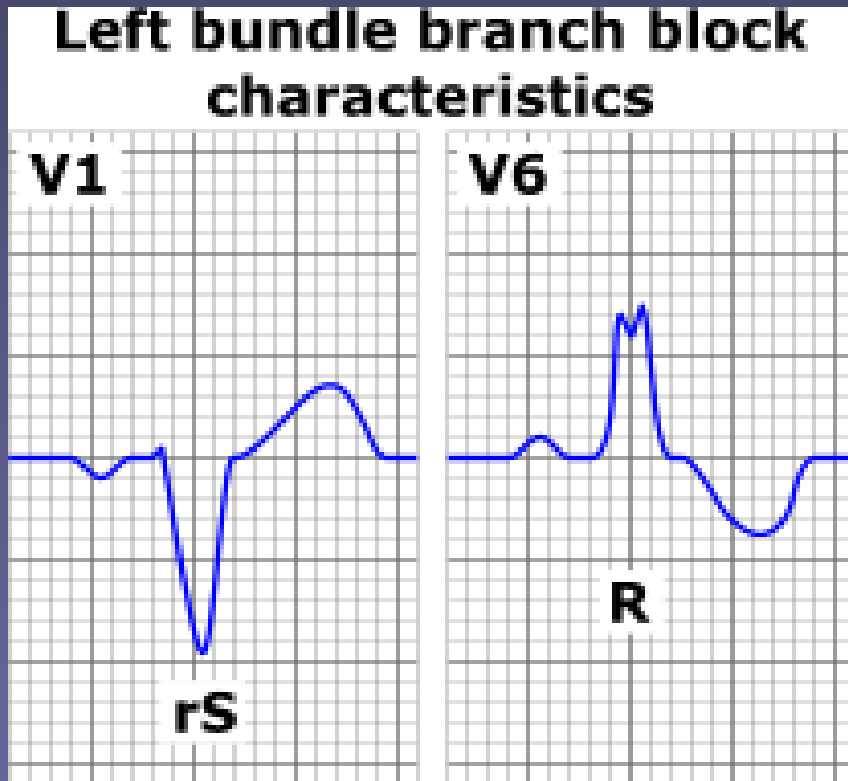
The QRS height

- If the complexes in the chest leads look very tall, consider left ventricular hypertrophy (LVH)
- If the depth of the S wave in V_1 added to the height of the R wave in V_6 comes to more than 35mm, LVH is present

QRS width

- The width of the QRS complex should be less than 0.12 seconds (3 small squares)
- Some texts say less than 0.10 seconds (2.5 small squares)
- If the QRS is wider than this, it suggests a ventricular conduction problem – usually right or left bundle branch block (RBBB or LBBB)

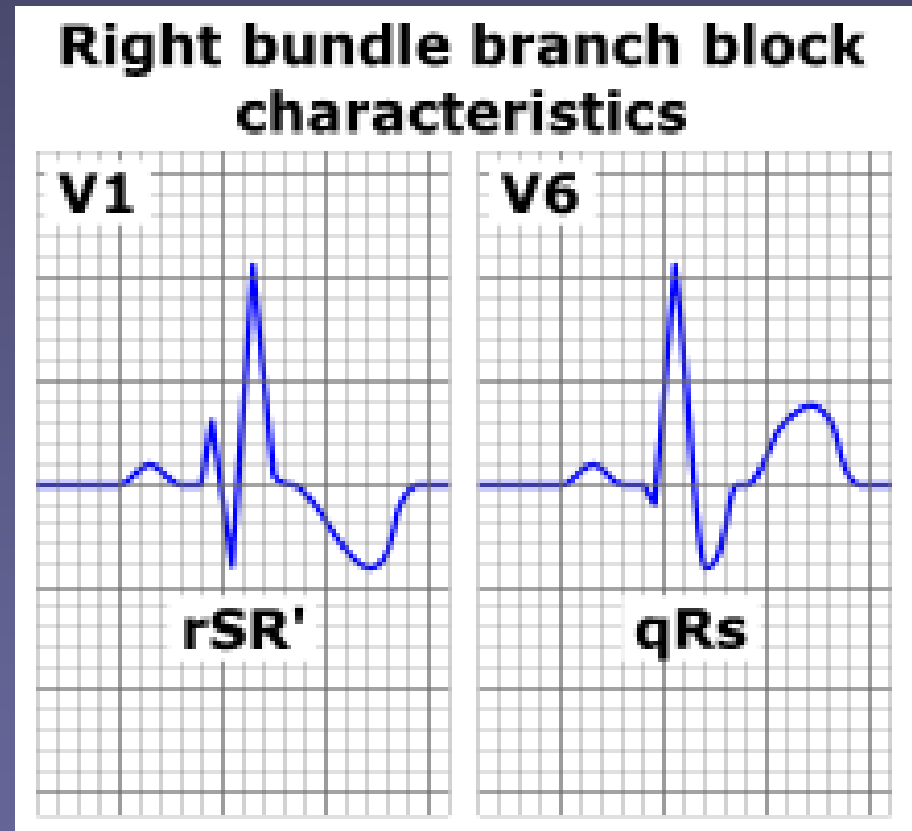
LBBB



- If **left** bundle branch block is present, the QRS complex may look like a 'W' in V_1 and/or an 'M' shape in V_6 .
- New onset LBBB with chest pain consider Myocardial infarction
- Not possible to interpret the ST segment.

RBBB

- It is also called RSR pattern
- If **right** bundle branch block is present, there may be an 'M' in V1 and/or a 'W' in V6.
- Can occur in healthy people with normal QRS width – partial RBBB



QRS width

It is useful to look at leads V_1 and V_6

- LBBB and RBBB can be remembered by the mnemonic:
- **WiLLiaM MaRRoW**
- Bundle branch block is caused either by infarction or fibrosis (related to the ageing process)

The ST segment

- The ST segment should sit on the isoelectric line
- It is abnormal if there is planar (i.e. flat) elevation or depression of the ST segment
- Planar ST elevation can represent an MI or Prinzmetal's (vasospastic) angina
- Planar ST depression can represent ischaemia

Myocardial infarction

- Within hours:
 - T wave may become peaked
 - ST segment may begin to rise
- Within 24 hours:
 - T wave inverts (may or may not persist)
 - ST elevation begins to resolve
 - If a left ventricular aneurysm forms, ST elevation may persist
- Within a few days:
 - pathological Q waves can form and usually persist

Myocardial infarction

- The leads affected determine the site of the infarct
- Inferior II, III, aVF
- Anteroseptal V1-V4
- Anterolateral V4-V6, I, aVL
- Posterior Tall wide R and ST↓ in V1 and V2

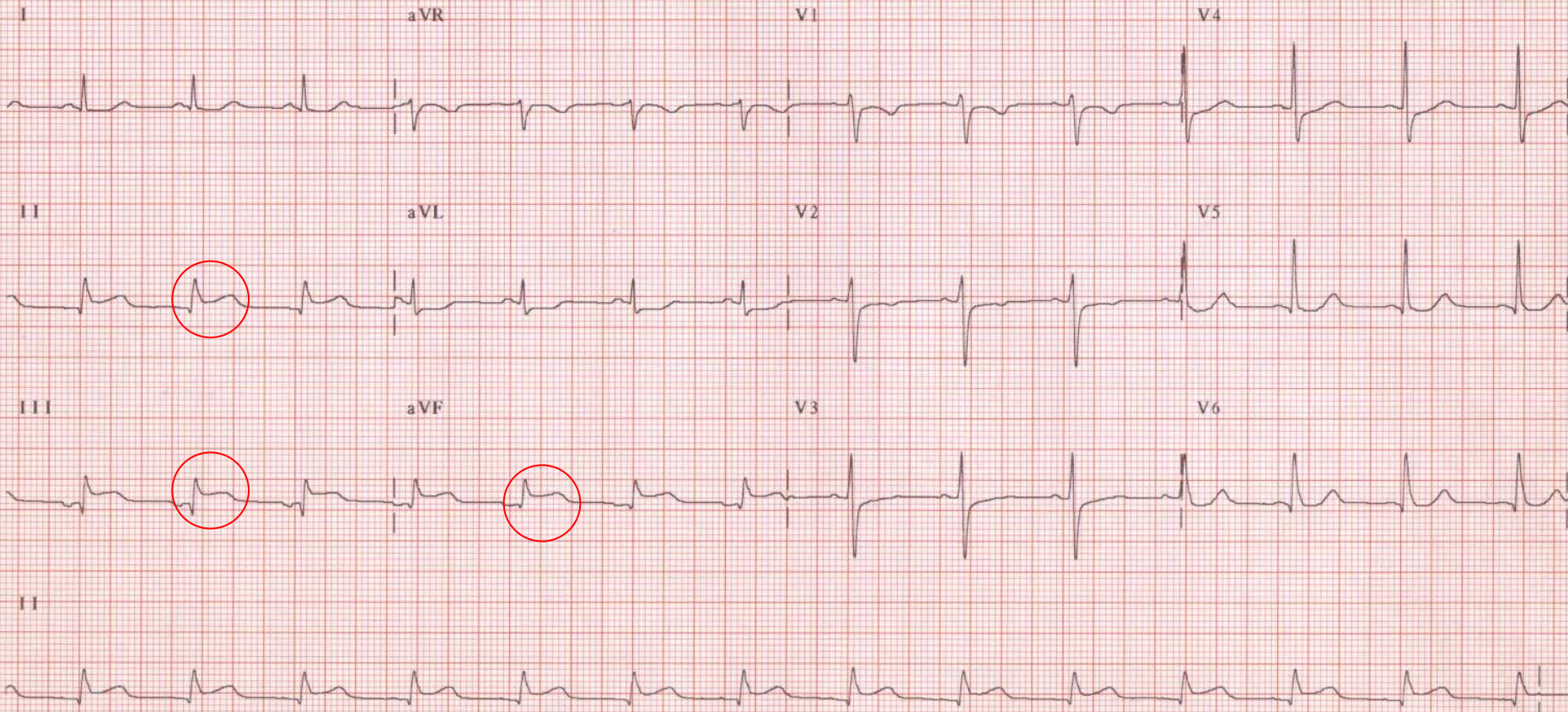
Acute Anterior MI



ST elevation

Inferior MI

T 73



ST elevation

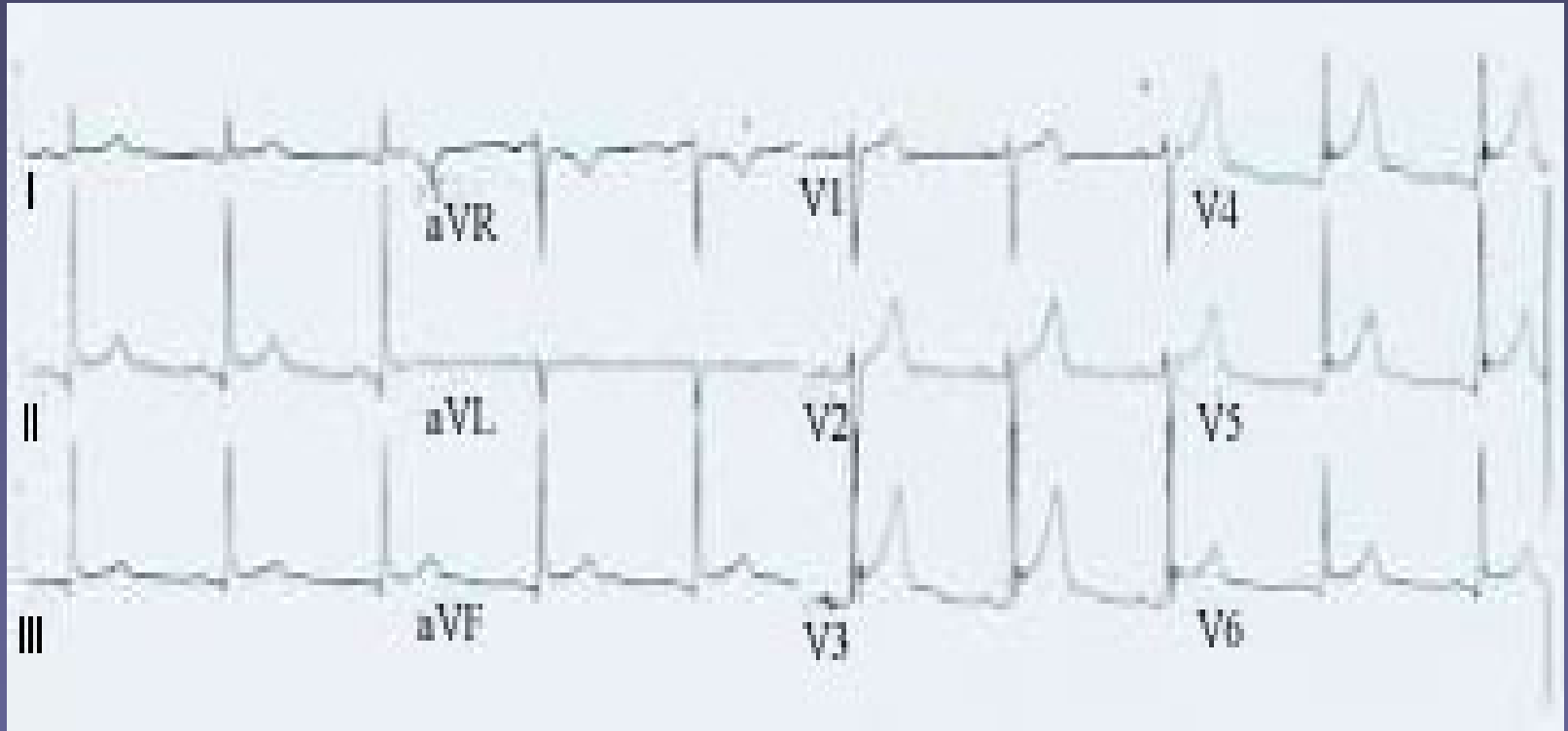
LOC 00000-0000 Speed: 25 mm/sec Limb: 10 mm/mV Chest: 10 mm/mV

F 60 μ 0.5-100 Hz W HP7 0038

The ST segment

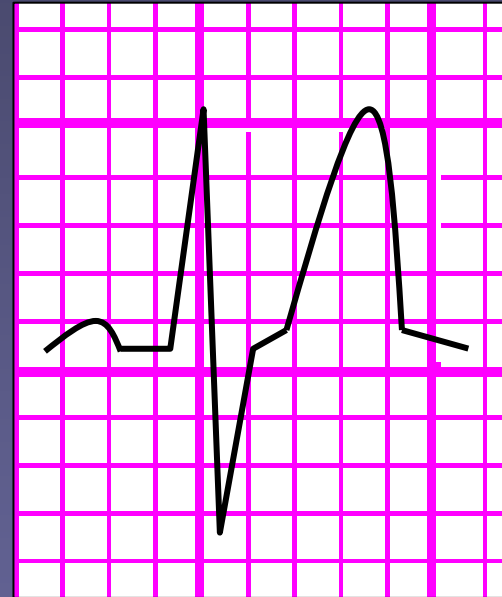
- If the ST segment is elevated but slanted, it may not be significant
- If there are raised ST segments in most of the leads, it may indicate pericarditis – especially if the ST segments are saddle shaped. There can also be PR segment depression

Pericarditis



The T wave

- Are the T waves too tall?
 - No definite rule for height
 - T wave generally shouldn't be taller than half the size of the preceding QRS
- Causes:
 - Hyperkalaemia
 - Acute myocardial infarction



The T wave

- If the T wave is flat, it may indicate hypokalaemia
- If the T wave is inverted it may indicate ischaemia

The QT interval

- The QT interval is measured from the *start* of the QRS complex to the *end* of the T wave.
- The QT interval varies with heart rate
- As the heart rate gets faster, the QT interval gets shorter
- It is possible to correct the QT interval with respect to rate by using the following formula:
 - $QT_c = QT/\sqrt{RR}$ (QT_c = corrected QT)

The QT interval

- The normal range for QTc is 0.38-0.42
- A short QTc may indicate hypercalcaemia
- A long QTc has many causes
- Long QTc increases the risk of developing an arrhythmia

The U wave

- U waves occur after the T wave and are often difficult to see
- They are thought to be due to repolarisation of the atrial septum
- Prominent U waves can be a sign of hypokalaemia, hyperthyroidism

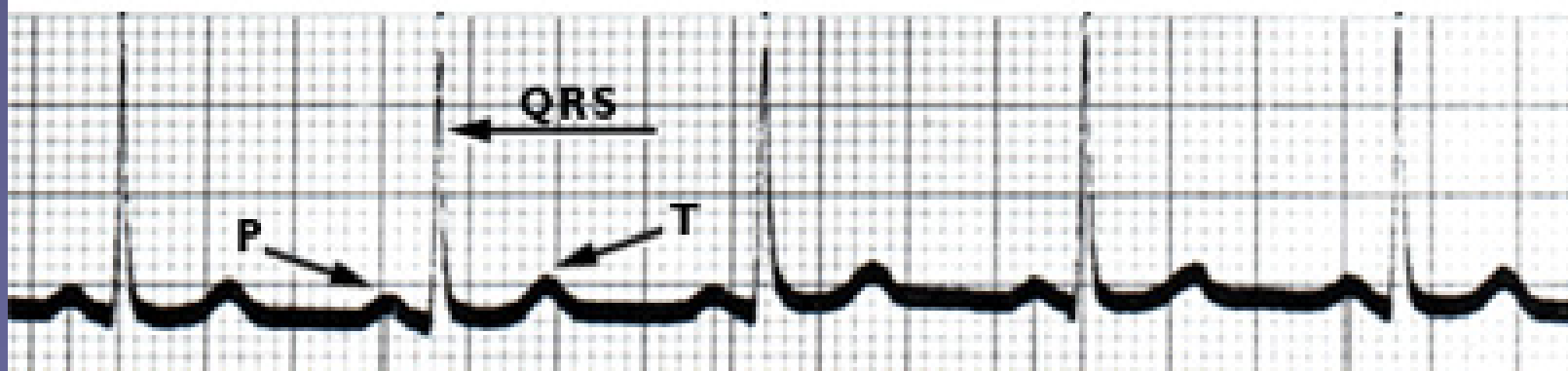
Supraventricular tachycardias

- These are tachycardias where the impulse is initiated in the atria (sinoatrial node, atrial wall or atrioventricular node)
- If there is a normal conduction pathway when the impulse reaches the ventricles, a narrow QRS complex is formed, hence they are narrow complex tachycardias
- However if there is a conduction problem in the ventricles such as LBBB, then a broad QRS complex is formed. This would result in a form of broad complex tachycardia

ECG: Paroxysmal Atrial Tachycardia



ECG: Normal Heartbeat

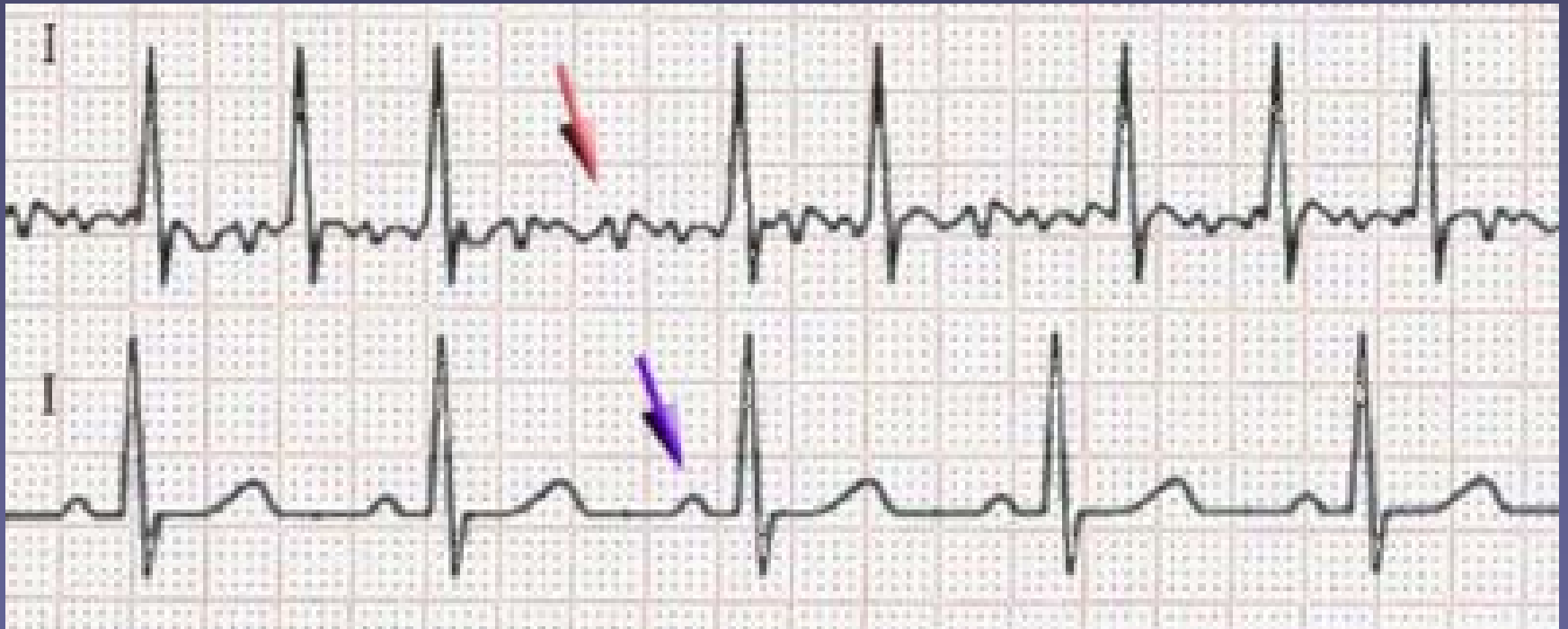


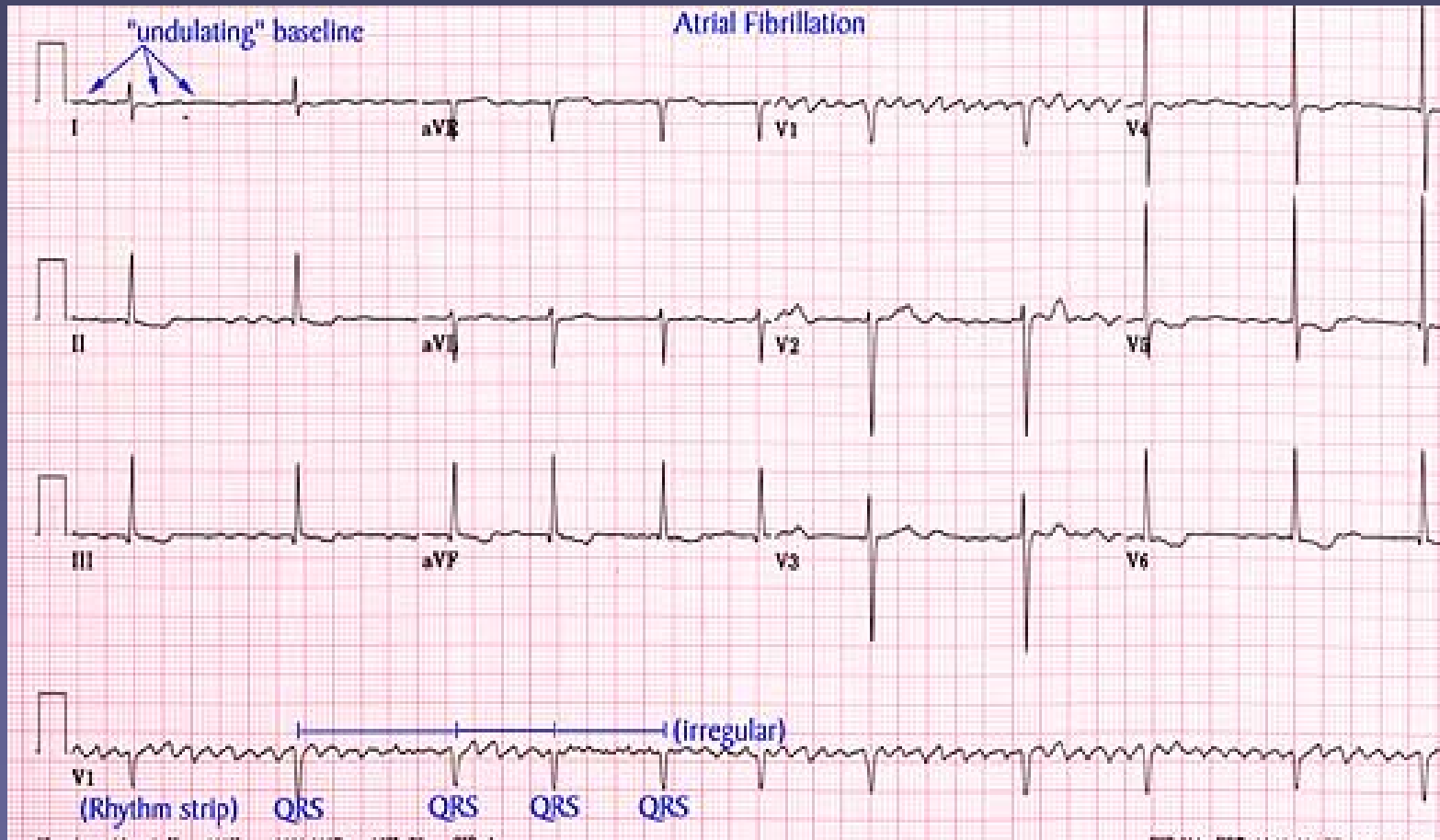
Atrial Fibrillation

Features:

- There maybe tachycardia
- The rhythm is usually irregularly irregular
- No P waves are discernible – instead there is a shaky baseline
 - This is because there is no order to atrial depolarisation, different areas of atrium depolarise at will

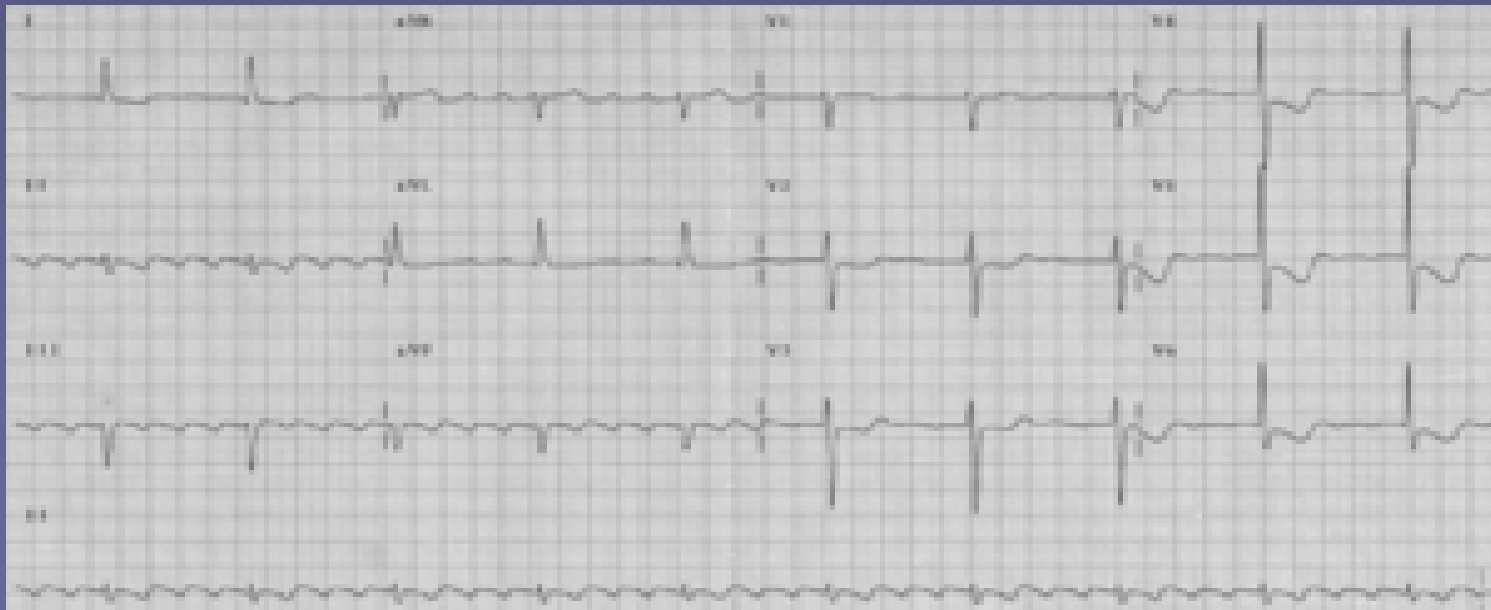
Atrial Fibrillation



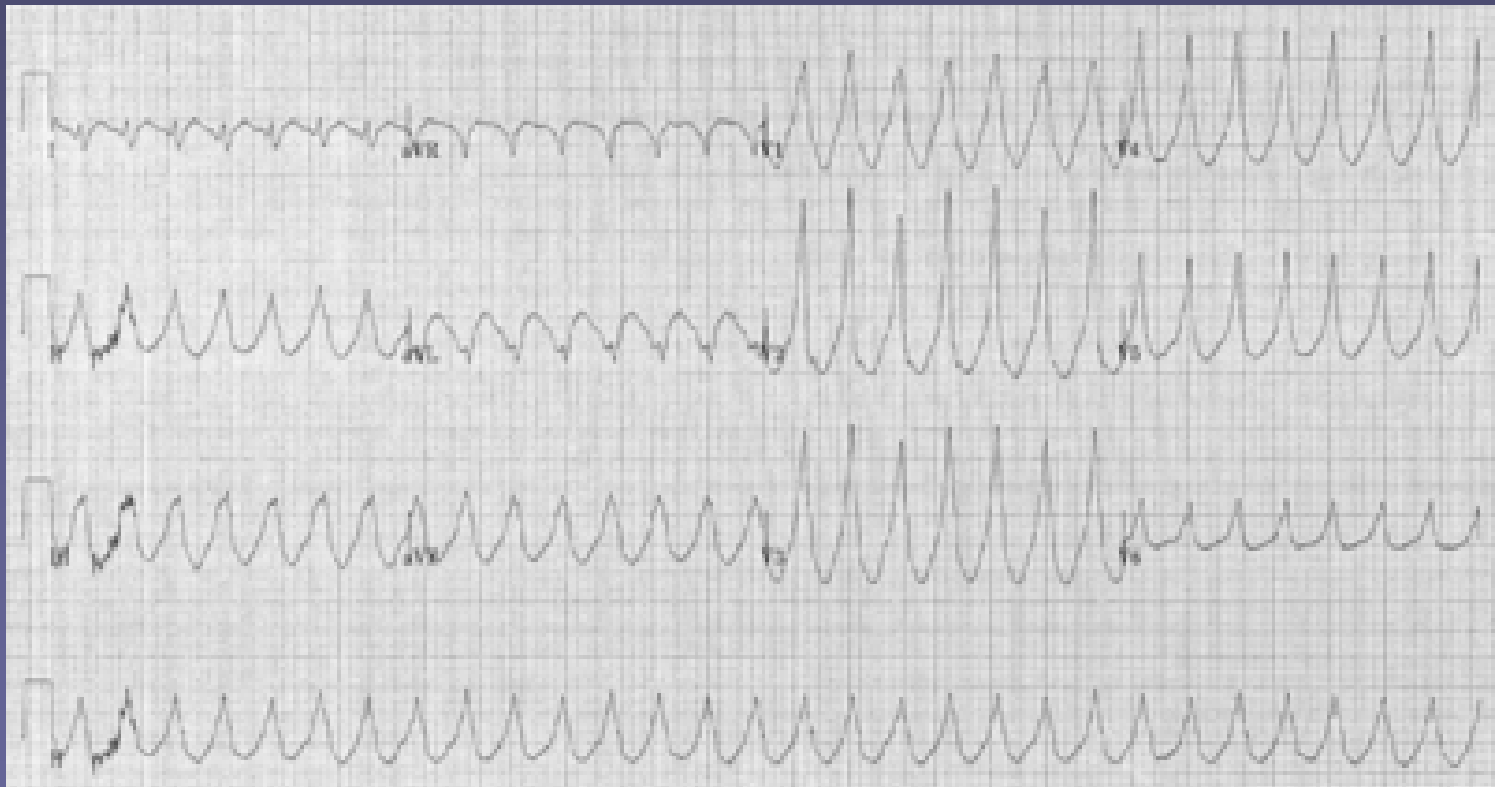


Atrial flutter

- There is a saw-tooth baseline which rises above and dips below the isoelectric line.
- Atrial rate 250/min
- This is created by circular circuits of depolarisation set up in the atria



Ventricular Tachycardia



Ventricular Tachycardia

- QRS complexes are wide and irregular in shape
- Usually secondary to infarction
- Circuits of depolarisation are set up in damaged myocardium
- This leads to recurrent early repolarisation of the ventricle leading to tachycardia
- As the rhythm originates in the ventricles, there is a broad QRS complex
- Hence it is one of the causes of a broad complex tachycardia
- Need to differentiate with supraventricular tachycardia with aberrant conduction

Ventricular Fibrillation



Ventricular fibrillation

- Completely disordered ventricular depolarisation
- Not compatible with a cardiac output
- Results in a completely irregular trace consisting of broad QRS complexes of varying widths, heights and rates

Elements of the tracing

P wave

- Magnitude and shape,
- e.g. P pulmonale, P mitrale

PR interval (start of P to start of QRS)

- Normal 3-5 small squares, 0.12-0.2s

Pathological Q waves?

QRS complex

- Magnitude, duration and shape
- ≤ 3 small squares or 0.12s duration

ST segment

- Should be isoelectric

T wave

- Magnitude and direction

QT interval (Start QRS to end of T)

- Normally < 2 big squares or 0.4s at 60bpm
- Corrected to 60bpm
- $(QT_c) = QT / \sqrt{RR\text{interval}}$

Further work

- Check out the various quizzes / games available on the Imperial Intranet
- Get doctors on the wards to run through a patient's ECG with you