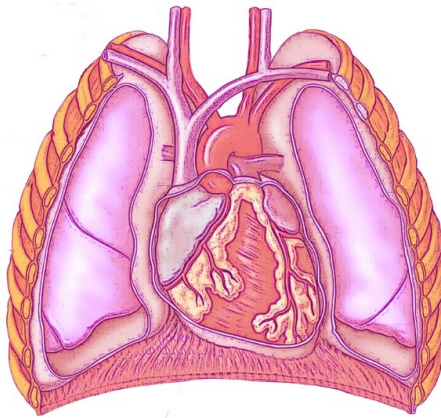




# Internal Medicine



Topic : ECG Basics  
Done by : Johainah Taha

# What is an ECG?

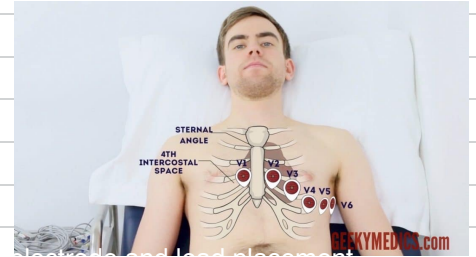
**ECG** is the abbreviated term for an **electrocardiogram**. It is used to record the **electrical activity** of the **heart** from different angles to both **identify and locate pathology**. **Electrodes** are placed on different parts of a patient's **limbs** and **chest** to **record the electrical activity**.

## Electrode placement

A **12-lead ECG** involves the use of **10 electrodes**, **six on the chest** and **four on the limbs**.

Apply the **six chest electrodes** in the following locations:

- **V1**: 4th intercostal space at the right sternal edge.
- **V2**: 4th intercostal space at the left sternal edge.
- **V3**: midway between the V2 and V4 electrodes.
- **V4**: 5th intercostal space in the midclavicular line.
- **V5**: left anterior axillary line at the same horizontal level as V4.
- **V6**: left mid-axillary line at the same horizontal level as V4 and V5.



Apply the **four limb electrodes** in the following locations:

- **Red (RA)**: right forearm, proximal to the wrist
- **Yellow (LA)**: left forearm, proximal to the wrist
- **Green (LL)**: left lower leg, proximal to the ankle
- **Black (RL)**: right lower leg, proximal to the ankle

Avoid areas with a large amount of adipose tissue, major muscle groups or bony prominences.

Some people find the mnemonic **"Ride Your Green Bike"** useful for remembering the placement of the limb leads, starting clockwise from the right wrist

## Parts of the ECG explained

### P waves

**P waves** represent **atrial depolarisation**. In healthy individuals, there should be a **P wave** preceding each **QRS complex**.

### PR interval

The **PR interval** begins at the **start of the P wave** and ends at the **beginning of the Q wave**. It represents the **time for electrical activity to move between the atria and the ventricles**.

### QRS complex

The **QRS complex** represents the **depolarisation of the ventricles**. It appears as three closely related waves on the ECG (the Q, R and S wave).

### ST segment

The **ST segment** starts at the **end of the S wave** and ends at the **beginning of the T wave**.

The **ST segment** is an isoelectric line representing the **time between depolarisation and repolarisation of the ventricles** (i.e. ventricular contraction).

### T wave

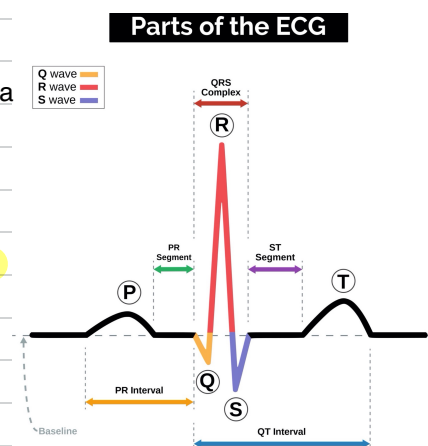
The **T wave** represents **ventricular repolarisation**. It appears as a small wave after the **QRS complex**.

### RR interval

The **RR interval** begins at the **peak of one R wave** and ends at the **peak of the next R wave**. It represents the **time between two QRS complexes**.

### QT interval

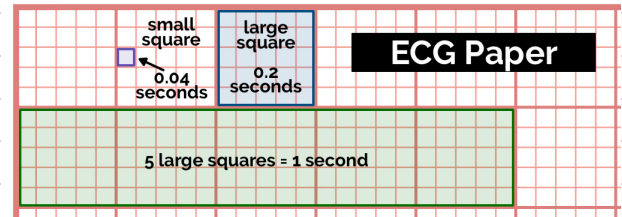
The **QT interval** begins at the start of the **QRS complex** and finishes at the end of the **T wave**. It represents the **time taken for the ventricles to depolarise and then repolarise**.



## How to read ECG paper

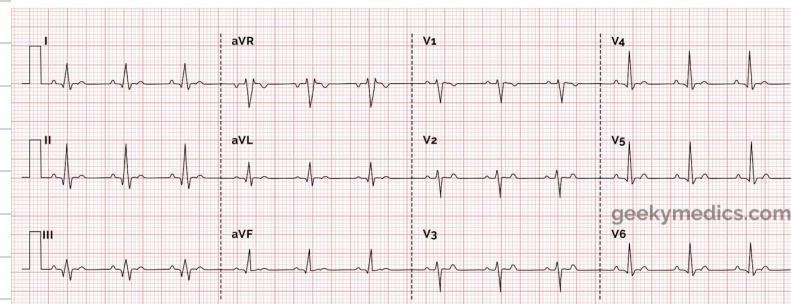
The paper used to record **ECGs** is **standardised** across most hospitals and has the following characteristics:

- Each **small square** represents **0.04 seconds**
- Each **large square** represents **0.2 seconds**
- **5 large squares = 1 second**
- **300 large squares = 1 minute**



This is an example of a **normal 12-lead ECG**, which can be used as a reference for each section of this guide

## Normal ECG



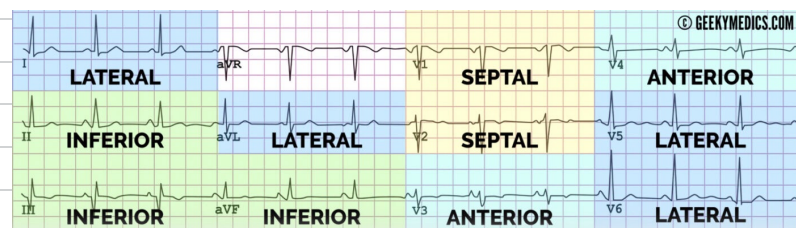
### Chest leads

**Table 3.** The chest leads.

| Electrode | View of the heart          |
|-----------|----------------------------|
| <b>V1</b> | Septal view of the heart   |
| <b>V2</b> | Septal view of the heart   |
| <b>V3</b> | Anterior view of the heart |
| <b>V4</b> | Anterior view of the heart |
| <b>V5</b> | Lateral view of the heart  |
| <b>V6</b> | Lateral view of the heart  |

**Table 4.** Other leads.

| Electrode       | View of the heart                                                                 |
|-----------------|-----------------------------------------------------------------------------------|
| <b>Lead I</b>   | Lateral view (calculated by analysing activity between the RA and LA electrodes)  |
| <b>Lead II</b>  | Inferior view (calculated by analysing activity between the RA and LL electrodes) |
| <b>Lead III</b> | Inferior view (calculated by analysing activity between the LA and LL electrodes) |
| <b>aVR</b>      | Lateral view (calculated by analysing activity between LA+LL -> RA)               |
| <b>aVL</b>      | Lateral view (calculated by analysing activity between RA+LL -> LA)               |
| <b>aVF</b>      | Inferior view (calculated by analysing activity between RA+LA -> LL)              |



| View of the heart | Leads          | Blood supply                                                                                                   |
|-------------------|----------------|----------------------------------------------------------------------------------------------------------------|
| Inferior          | II, III, aVF   | Right coronary artery (90%)<br>Left circumflex artery (10%)                                                    |
| Lateral           | I, aVL, V5, V6 | Left circumflex artery (lead I & aVL)<br>Distal LAD, left circumflex artery or right coronary artery (V5 & V6) |
| Anterior          | V3, V4         | Distal left anterior descending (LAD) artery                                                                   |
| Septal            | V1, V2         | Proximal left anterior descending (LAD) artery                                                                 |

# how to read an ECG

## 1 Heart rate

What is a normal adult heart rate?

- **Normal:** 60-100 bpm
- **Tachycardia:** > 100 bpm
- **Bradycardia:** < 60 bpm



### Regular heart rhythm

- number of **large squares** within 1 **R-R interval**.
- **Divide 300 by this number** to calculate **heart rate**.

**Heart rate calculation example**

- 4 large squares in an R-R interval
- $300/4 = 75$  beats per minute

### Irregular heart rhythm

- Count the number of complexes on the rhythm strip each rhythm strip is typically 10 seconds long).
- Multiply the number of complexes by 6 (giving you the average number of complexes in 1 minute).

**Heart rate calculation example**

- 10 complexes on a rhythm strip
- $10 \times 6 = 60$  beats per minute

R

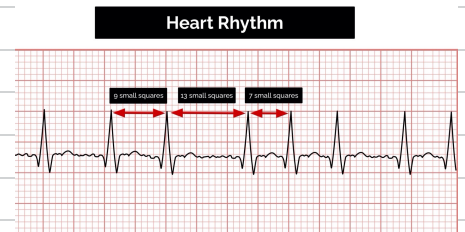
## 2 Heart rhythm

A patient's heart rhythm can be **regular** or **irregular**.

Irregular rhythms can be either:

- **Regularly irregular** (i.e. a recurrent pattern of irregularity)
- **Irregularly irregular** (i.e. completely disorganised)

Mark out several consecutive R-R intervals on a piece of paper, then move them along the rhythm strip to check if the subsequent intervals are similar.



### Hint

If you are suspicious of **atrioventricular block** (AV block), map out the **atrial rate** and the **ventricular rhythm** separately (i.e. mark the P waves and R waves). As you move along the rhythm strip, you can see if the **PR interval changes**, if **QRS complexes** are **missing** or if there is **complete dissociation** between the two.

## 3 Cardiac axis

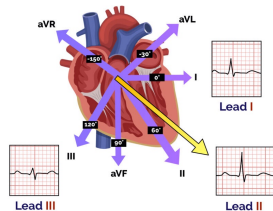
**Cardiac axis** describes the overall **direction of electrical spread** within the heart.

In a healthy individual, the axis should spread **from 11 o'clock to 5 o'clock**.

To determine the cardiac axis, you must look at **leads I, II and III**.

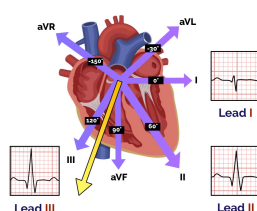


### Normal Cardiac Axis



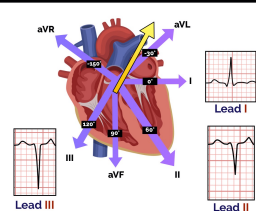
**Lead II** has the **most positive deflection** compared to leads I and III.

### Right Axis Deviation



**Lead III** has the **most positive deflection**, and **lead I** should be **negative**. associated with **right ventricular hypertrophy**.

### Left Axis Deviation

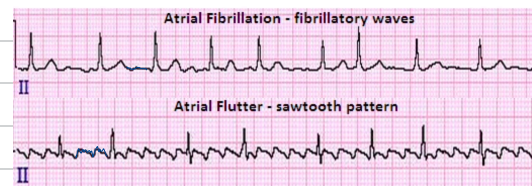


**Lead I** has the **most positive deflection**. **Leads II and III** are **negative**. associated with **heart conduction abnormalities**.

## 4 P waves

The next step is to **look at the P waves** and answer the following questions:

1. Are P waves **present**?
2. If so, is each P wave **followed by a QRS complex**?
3. Do the P waves look normal? – check **duration, direction and shape**
4. If P waves are absent, is there any atrial activity?
  - **Sawtooth baseline** → flutter waves
  - **Chaotic baseline** → fibrillation waves
  - **Flat line** → no atrial activity at all



### Hint

If P waves are **absent** and there is an **irregular rhythm**, it may suggest a diagnosis of **atrial fibrillation**.

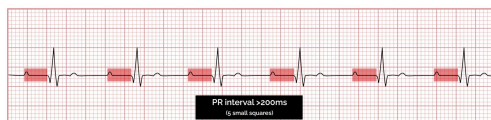
## 5 PR interval

The **PR interval** should be between **120-200 ms** (3-5 small squares).

A prolonged PR interval suggests the presence of **atrioventricular delay (AV block)**.



### First Degree Heart Block



**fixed prolonged PR interval (>200 ms).**

Occurs between the SA node and the AV node (i.e. within the atrium).

### Second Degree Heart Block

Mobitz type 1 (Wenckebach)



**progressive prolongation of the PR interval** until eventually the atrial impulse is not conducted and the **QRS complex is dropped**. AV nodal conduction **resumes** with the next beat, and the sequence of progressive PR interval prolongation and the eventual dropping of a QRS complex **repeats** itself.

Mobitz I AV block (Wenckebach) occurs **IN** the AV node (this is the only piece of conductive tissue in the heart which exhibits the ability to conduct at different speeds).

### Third Degree Heart Block

Complete Heart Block



**no electrical communication between the atria and ventricles** due to a complete failure of conduction.

Occurs at or after the AV node resulting in a complete blockade of distal conduction.

### Second Degree Heart Block

Mobitz type 2

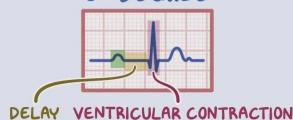


**consistent PR interval duration with intermittently dropped QRS complexes** due to a failure of conduction. The intermittent dropping of the QRS complexes typically follows a **repeating cycle** of every 3rd (3:1 block) or 4th (4:1 block) P wave.

Mobitz II AV block occurs **AFTER** the AV node in the bundle of His or Purkinje fibres.

## AV BLOCKS

### 1<sup>ST</sup> DEGREE

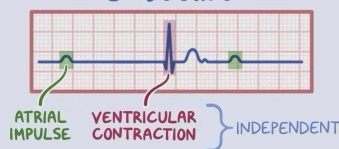


### 2<sup>ND</sup> DEGREE

MOBITZ TYPE I



### 3<sup>RD</sup> DEGREE



### MOBITZ TYPE II



## QRS complex

When assessing a QRS complex, you need to pay attention to the following **characteristics**:

1-Width.

2-Height.

3-Morphology

### Width

The width can be described as **NARROW** ( $< 0.12$  seconds) or **BROAD** ( $> 0.12$  seconds):

- A **narrow QRS complex** occurs when the impulse is conducted down the bundle of His and the Purkinje fibre to the ventricles. This results in well organised synchronised ventricular depolarisation.
- A **broad QRS complex** occurs if there is an abnormal depolarisation sequence – for example, a ventricular ectopic where the impulse spreads slowly across the myocardium from the focus in the ventricle. In contrast, an atrial ectopic would result in a narrow QRS complex because it would conduct down the heart's normal conduction system. Similarly, a **bundle branch block** results in a broad QRS complex because the impulse gets to one ventricle rapidly down the intrinsic conduction system and then spreads slowly across the myocardium to the other ventricle.

### Bundle branch block

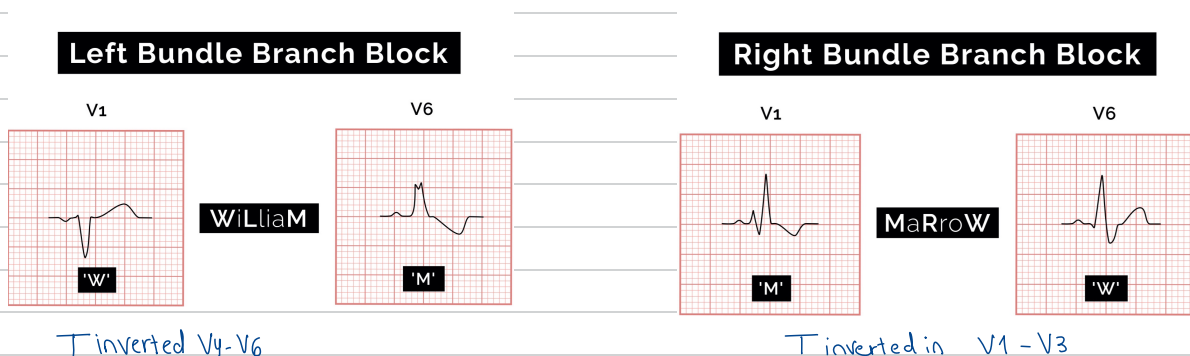
Broad QRS complexes are a hallmark feature of **bundle branch block**, which includes **left bundle branch block** (LBBB) and **right bundle branch block** (RBBB).

The **WILLIAM MaRRoW** mnemonic can be used to quickly recognise left and right bundle branch blocks by looking at **V1** and **V6**.

The **middle letters** of the names help you remember which bundle branch block each name is referring to (two Ls in **WILLIAM** = **left bundle branch block**, two Rs in **MaRRoW** = **right bundle branch block**).

Each name's **first** and **last letter** helps you recognise the ECG features of the associated bundle branch block.

- **LBBB**: deep S wave in V1 which may be notched ("W") and broad "M" shaped R wave in V6
- **RBBB**: RSR' pattern in V1 ("M") and broad S wave in V6 ("W")



### Height

Height can be described as either **SMALL** or **TALL**:

- **Small complexes** are defined as  $< 5\text{mm}$  in the limb leads or  $< 10\text{mm}$  in the chest leads.
- **Tall complexes** imply **ventricular hypertrophy** (although can be due to body habitus e.g. tall slim people).

There are numerous algorithms for measuring LVH, such as the **Sokolow-Lyon** index or the **Cornell index**

## Morphology

### Delta wave

the ventricles are being activated earlier than normal from a point distant from the AV node. The early activation then spreads slowly across the myocardium, causing the QRS complex's **slurred upstroke**.

The presence of a delta wave **does NOT diagnose**

**Wolff-Parkinson-White syndrome**. This requires evidence of tachyarrhythmias AND a delta wave

#### Delta Wave

Associated with Wolff-Parkinson-White Syndrome



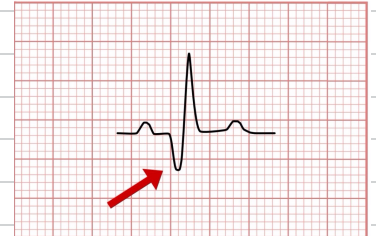
### Q-waves

**Isolated Q waves** can be normal.

A **pathological Q wave** is **> 25% the size of the R wave that follows it** or **> 2mm in height and > 40ms in width**.

A single Q wave is not a cause for concern – look for Q waves in an entire territory (e.g. anterior/inferior) for **evidence of previous myocardial infarction**.

#### Pathological Q Wave



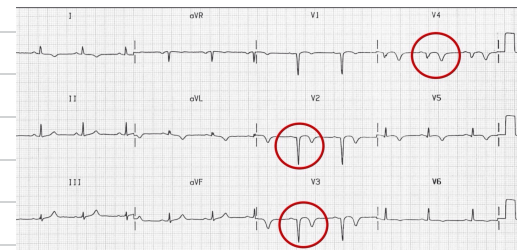
### R and S waves

-Assess the R wave progression across the chest leads (from small in V1 to large in V6).

-The transition from S > R wave to R > S wave should occur in **V3 or V4**.

-Poor progression (i.e. S > R through to leads V5 and V6) can be a sign of previous MI but can also occur in very large people due to poor lead position.

#### Poor R Wave Progression



### J point segment

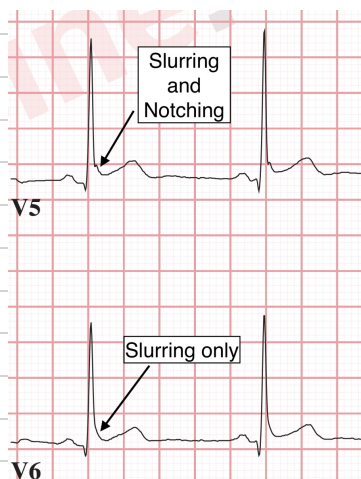
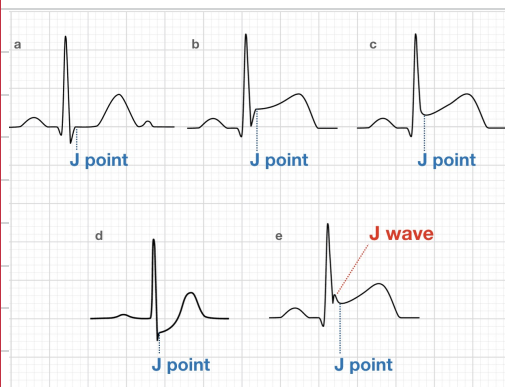
The **J point** is where the **S wave joins the ST segment**.

This point can be elevated, resulting in the ST segment that follows it being raised (this is known as “high take-off”).

High take-off (or **benign early repolarisation**) is a normal variant that causes a lot of angst and confusion as it **LOOKS** like ST elevation.

**Key points** for assessing the J point segment:

- Benign early repolarisation occurs mostly under the age of 50 (over the age of 50, ischaemia is more common and should be suspected first).
- Typically, the J point is raised with widespread ST elevation in multiple territories making ischaemia less likely.
- The T waves are also raised (in contrast to a STEMI, where the T wave remains the same size and the ST segment is raised).
- The ECG abnormalities do not change! During a STEMI, the changes will evolve – in benign early repolarisation, they will remain the same.



## 7 ST segment

The **ST segment** is the part of the ECG **between the end of the S wave and the start of the T wave**.

In a healthy individual, it should be an isoelectric line (neither elevated nor depressed).

Abnormalities of the ST segment should be investigated to rule out pathology.



### ST-elevation

significant when it is **greater than 1 mm** (1 small square) in 2

**or more contiguous limb leads or >2mm in 2 or more chest leads.**

It is most commonly caused by **acute full-thickness myocardial infarction**

### ST depression

**ST depression  $\geq 0.5$  mm in  $\geq 2$  contiguous leads**

indicates **myocardial ischaemia**.

## 8 T waves

**T waves** represent the **repolarisation of the ventricles**.

### Tall T waves

T waves are considered **tall** if they are:

- **> 5mm in the limb leads AND > 10mm in the chest leads**

Tall T waves can be associated with:

- **Hyperkalaemia** ("tall tented T waves")
- **Hyperacute STEMI**

Tall T Waves  
Hyperkalaemia



### Inverted T waves

T waves are **normally** inverted in **V1**, and inversion in **lead III** is a normal variant.

Inverted T waves in other leads are a nonspecific sign of a wide variety of conditions:

- **Ischaemia**
- **Bundle branch blocks** (V4-6 in LBBB and V1-V3 in RBBB)
- **Pulmonary embolism**
- **Left ventricular hypertrophy** (in the lateral leads)
- **Hypertrophic cardiomyopathy** (widespread)
- General illness

T Wave Inversion



Around 50% of patients admitted to ITU have some evidence of T wave inversion during their stay.

Observe the distribution of the T wave inversion (e.g. anterior/lateral/posterior leads). You must take this ECG finding and apply it in the clinical context of your patient.

### Biphasic T waves

have **two peaks** and can indicate **ischaemia** and **hypokalaemia**.

### Flattened T waves

**Flattened T waves** are a non-specific sign that may represent **ischaemia** or **electrolyte imbalance**.



## U waves

U waves are **not** a **common** finding.

The U wave is a **> 0.5mm deflection after the T wave** best seen in **V2 or V3**.

These become larger the slower the bradycardia – classically U waves are seen in various **electrolyte imbalances**, **hypothermia** and secondary to **antiarrhythmic therapy** (such as **digoxin**, procainamide or amiodarone).

### U Wave



## Documenting the ECG results in the notes

1. Document the time and date.
2. Write the indication for the ECG (e.g. chest pain, tachycardia).
3. Document your interpretation of the ECG:
  - Rate
  - Rhythm
  - Axis
  - P waves
  - PR interval
  - QRS complex
  - QT interval
  - ST-segment
  - T waves
4. Document your overall impression (e.g. ST-elevation -> MI).
5. Document your plan based on the ECG findings

HOSPITAL: GM Infirmary  
WARD: 23  
CONSULTANT: Dr Smith

PATIENT NAME: Sarah Green  
DATE OF BIRTH: 11/5/1984  
HOSPITAL NUMBER: X748493

| DATE / TIME      | DOCUMENTATION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 18/2/17<br>15:47 | <p>Dr Raymond Elliott - F2</p> <p>ECG performed on 18/2/17 at 15:30</p> <p>Indication for ECG - Tachycardia</p> <p>Interpretation of ECG</p> <ul style="list-style-type: none"><li>- Rate 110bpm</li><li>- Rhythm irregular</li><li>- Axis - normal</li><li>- PR interval - 140ms</li><li>- QRS complex - 90ms</li><li>- QT interval - 370ms</li><li>- ST segment - No pathological ST segment changes</li><li>- T waves - No pathological T wave changes</li></ul> <p>Impression</p> <p>Narrow complex tachycardia - atrial fibrillation</p> <p>Plan</p> <ol style="list-style-type: none"><li>1) Clinical review - history / examination</li><li>2) Monitor vital signs</li><li>3) Bloods - FBC / U&amp;E / Bone profile / TFTs / CRP</li><li>4) Discuss with senior to decide on further management</li></ol> <p>Dr Raymond Elliott<br/>F2<br/>RElliott<br/>Bleep 542742<br/>GMC number 37588</p> |