How to Read an ECG

geekymedics.com/how-to-read-an-ecg

Dr Matthew Jackson 28 February 2011

This guide demonstrates **how to read an ECG** using a systematic approach. If you want to put your ECG interpretation knowledge to the test, check out our **ECG quiz** on the Geeky Medics quiz platform.

You may also be interested in our **ECG flashcard deck** which can be purchased as part of our collection of **1000+ OSCE flashcards**.

Confirm details

Before beginning ECG interpretation, you should check the following details:

- Confirm the **name** and **date of birth** of the patient matches the details on the ECG.
- Check the **date** and **time** that the ECG was performed.
- Check the calibration of the ECG (usually 25mm/s and 10mm/1mV).

You might also be interested in our **OSCE Flashcard Collection** which contains **over 2000 flashcards** that cover **clinical examination**, **procedures**, **communication skills** and **data interpretation**.

Heart rate

What's a normal adult heart rate?

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

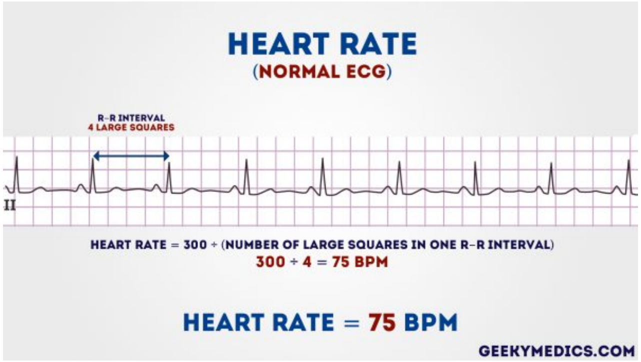
Regular heart rhythm

If a patient has a **regular heart rhythm** their heart rate can be calculated using the following method:

- **Count** the number of **large squares** present within one **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



How to calculate a heart rate on a normal ECG

Irregular heart rhythm

If a patient's heart rhythm is **irregular** the first method of heart rate calculation doesn't work (as the R-R interval differs significantly throughout the ECG). As a result, you need to apply a different method:

- 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 x 6 = 60 beats per minute

Heart rhythm

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

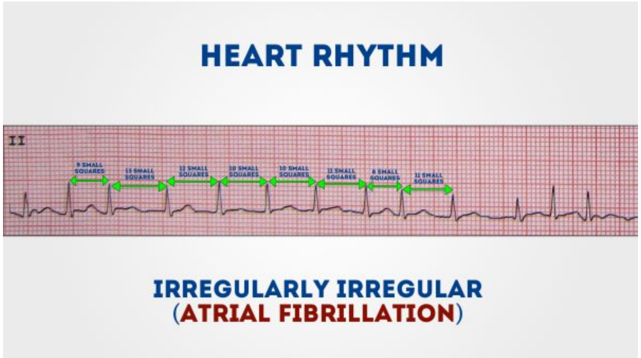
Irregular rhythms can be either:

- **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 that there is some **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 then see if the **PR interval changes**, if **QRS complexes** are **missing** or if there is **complete dissociation** between the two.



Measure the R-R intervals to assess if the rhythm is regular or irregular [1]

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**.

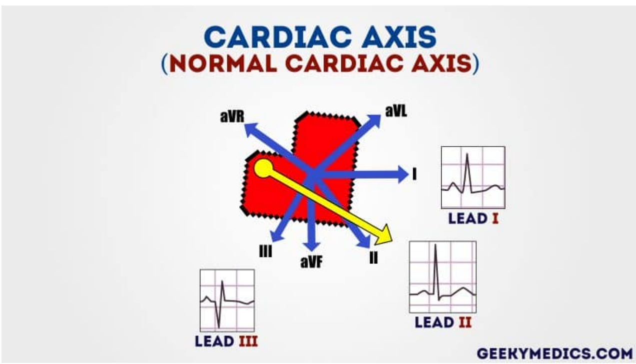
To determine the cardiac axis you need to look at **leads I, II and III**.

Read our cardiac axis guide to learn more.

Normal cardiac axis

Typical ECG findings for **normal cardiac axis**:

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

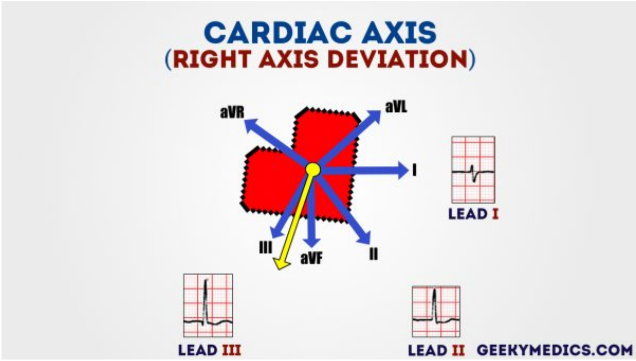


Normal cardiac axis

Right axis deviation

Typical ECG findings for **right axis deviation**:

- **Lead III** has the **most positive deflection** and **lead I** should be **negative**.
- Right axis deviation is associated with right ventricular hypertrophy.

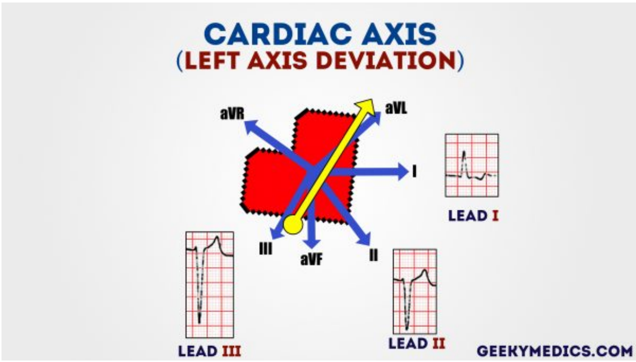


Right axis deviation [2]

Left axis deviation

Typical ECG findings for **left axis deviation**:

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



Left axis deviation [2]

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?

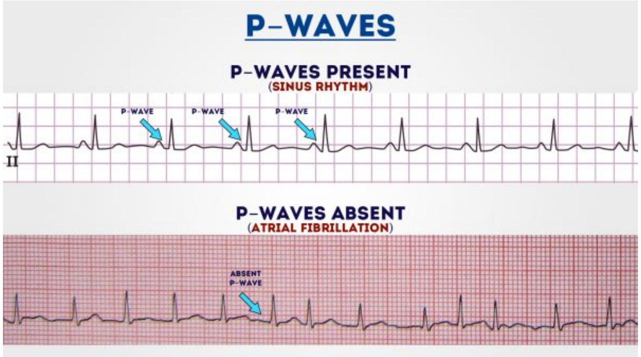
3. Do the P waves look normal? – check duration, direction and shape

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**.



P waves [1]

PR interval

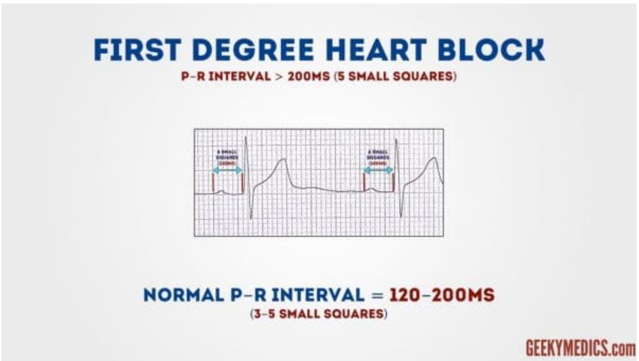
The **PR interval** should be between **120-200 ms** (3-5 small squares).

Prolonged PR interval (>0.2 seconds)

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

First-degree heart block (AV block)

First-degree heart block involves a **fixed prolonged** PR interval (>200 ms).



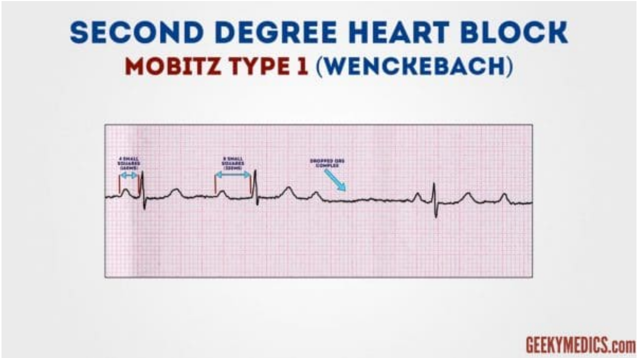
First-degree heart block (AV block)

Second-degree heart block (type 1)

Second-degree AV block (type 1) is also known as **Mobitz type 1 AV block** or **Wenckebach phenomenon**.

Typical ECG findings in Mobitz type 1 AV block include **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.



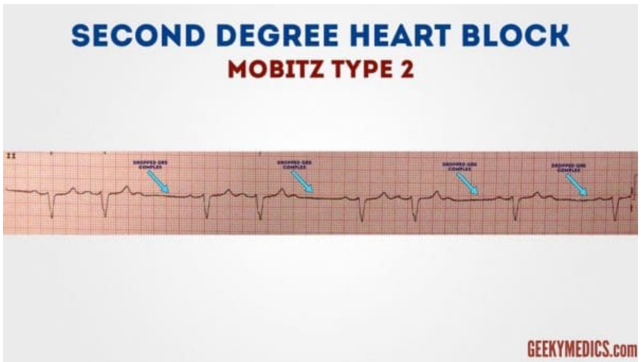
Second-degree AV block (Mobitz Type 1 – Wenckebach)

Second-degree heart block (type 2)

Second-degree AV block (type 2) is also known as **Mobitz type 2 AV block**.

Typical ECG findings in Mobitz type 2 AV block include a **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**.



Second-degree AV block (Mobitz type 2 AV block)

Third-degree heart block (complete heart block)

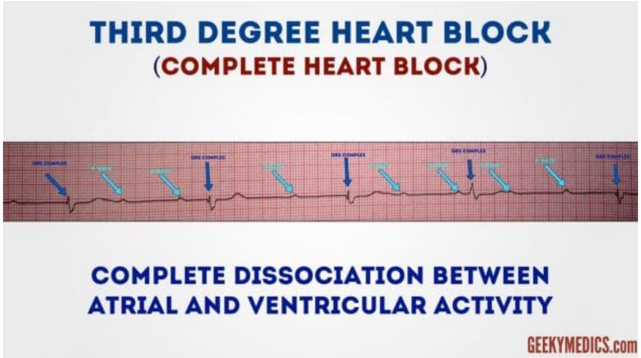
Third-degree (complete) AV block occurs when there is **no electrical communication between** the **atria** and **ventricles** due to a complete failure of conduction.

Typical ECG findings include the **presence of P waves** and **QRS complexes** that have **no association with each other**, due to the atria and ventricles functioning independently.

Cardiac function is maintained by a **junctional** or **ventricular pacemaker**.

Narrow-complex escape rhythms (QRS complexes of <0.12 seconds duration) originate **above the bifurcation** of the **bundle of His**.

Broad-complex escape rhythms (QRS complexes >0.12 seconds duration) originate from **below the bifurcation of the bundle of His**.



Complete heart block (3rd degree) [4]

Tips for remembering types of heart block

To help remember the various types of AV block, it is useful to know the anatomical location of the block within the conducting system.

First-degree AV block:

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

Second-degree AV block:

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

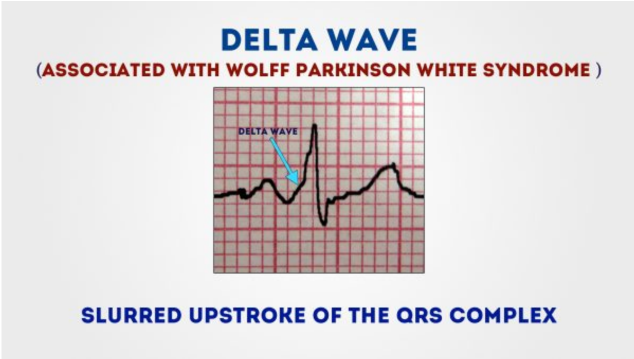
Third-degree AV block:

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

Shortened PR interval

If the **PR interval** is **shortened**, this can mean one of two things:

- Simply, the P wave is originating from somewhere closer to the AV node so the conduction takes less time (the SA node is not in a fixed place and some people's atria are smaller than others).
- The atrial impulse is getting to the ventricle by a **faster shortcut** instead of conducting slowly across the atrial wall. This is an **accessory pathway** and can be associated with a **delta wave** (see below which demonstrates an ECG of a patient with Wolff Parkinson White syndrome).

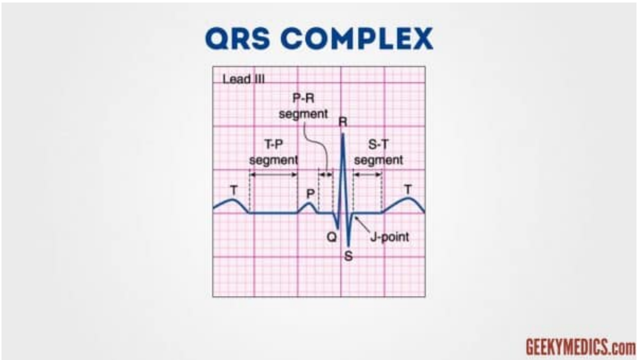


Delta wave [5]

QRS complex

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

- Width
- Height
- Morphology



Various components of an ECG

Width

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 normal conduction system of the heart. Similarly, a bundle branch block results in a broad QRS complex because the impulse gets to one ventricle rapidly down the intrinsic conduction system then has to spread slowly across the myocardium to the other ventricle.

Height

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

- **Small complexes** are defined as < 5mm in the limb leads or < 10 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.

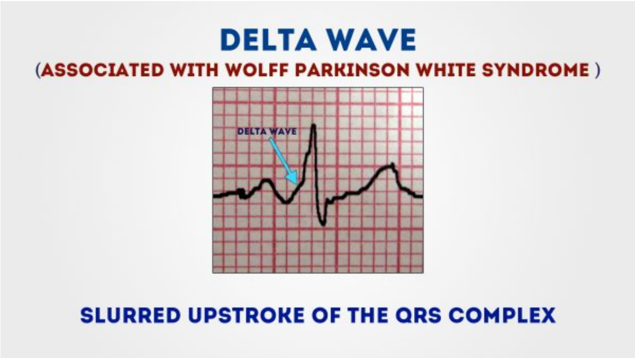
Morphology

To assess **morphology**, you need to assess the individual waves of the QRS complex.

Delta wave

The mythical '**delta wave**' is a sign that the ventricles are being activated earlier than normal from a point distant to the AV node. The early activation then spreads slowly across the myocardium causing the slurred upstroke of the QRS complex.

Note – the presence of a delta wave does NOT diagnose Wolff-Parkinson-White syndrome. This requires evidence of tachyarrhythmias AND a delta wave.



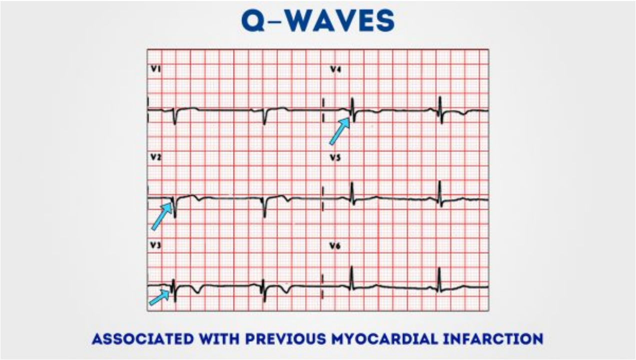
Delta wave [5]

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.



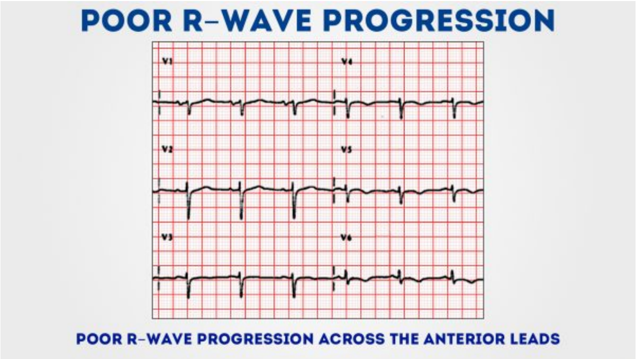
Q waves (V2-V4), with T wave inversion suggestive of previous anterior MI [6]

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 [7]

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 also being raised (this is known as “high take-off”).

High take-off (or benign early repolarisation to give its full title) 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).

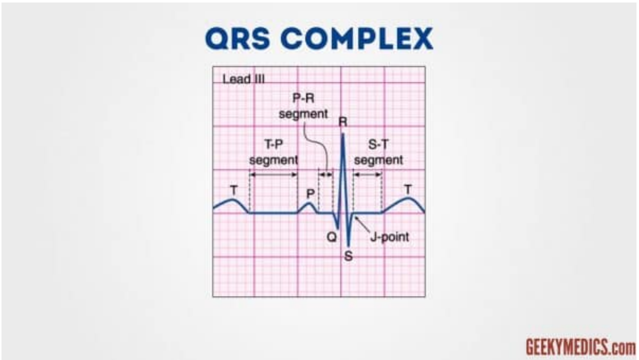
- The ECG abnormalities do not change! During a STEMI, the changes will evolve – in benign early repolarisation, they will remain the same.

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.

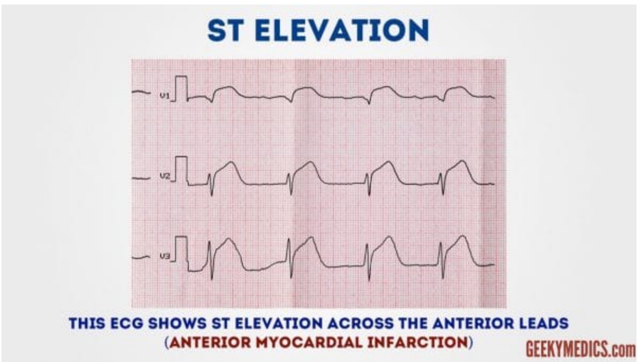


Various components of an ECG

ST-elevation

ST-elevation is 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**.

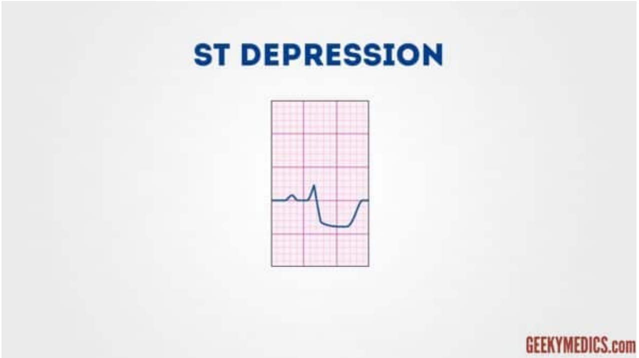
It is most commonly caused by **acute full-thickness myocardial infarction**.



ST elevation in the anterior leads

ST depression

ST depression ≥ 0.5 mm in **≥ 2 contiguous leads** indicates **myocardial ischaemia**.



ST depression

T waves

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

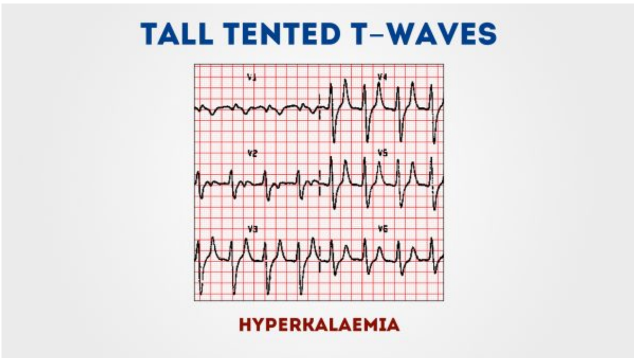
Tall T waves

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

- **> 5mm** in the **limb leads** AND
- **> 10mm** in the **chest leads** (the same criteria as 'small' QRS complexes)

Tall T waves can be associated with:

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



Tall tented T waves [8]

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:

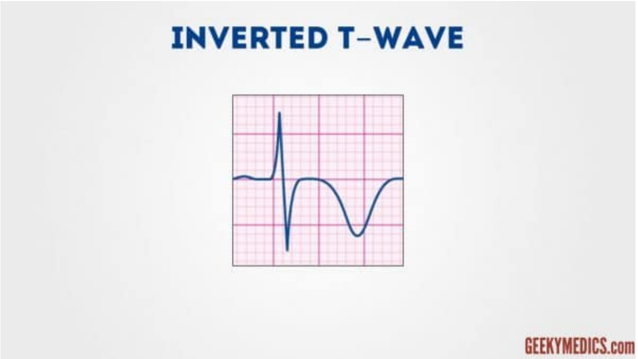
- Ischaemia
- Bundle branch blocks (V4-6 in LBBB and V1-V3 in RBBB)
- Pulmonary embolism
- Left ventricular hypertrophy (in the lateral leads)

- Hypertrophic cardiomyopathy (widespread)
- General illness

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 context of your patient.



Inverted T wave

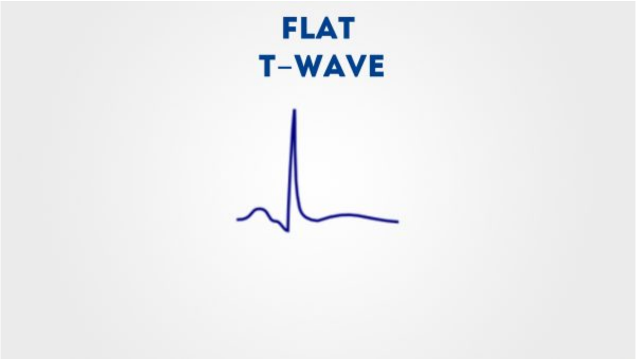
Biphasic T waves

Biphasic T waves have **two peaks** and can be indicative of **ischaemia** and **hypokalaemia**.

Biphasic T wave [9]

Flattened T waves

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



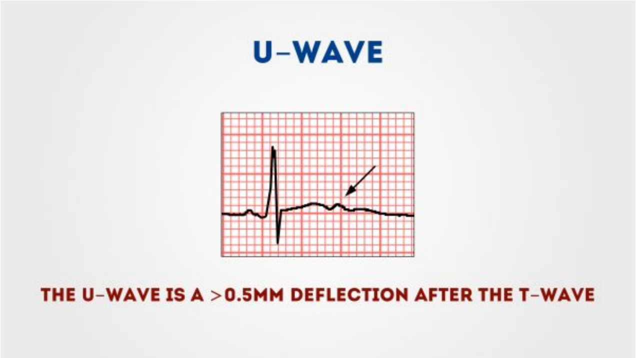
Flattened T wave [9]

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 [10]

Document your interpretation

You should **document your interpretation** of the ECG in the patient's notes (check out our guide to documenting an ECG).

References

1. James Heilman, MD. Fast atrial fibrillation. Licence: CC BY-SA 3.0.
2. Michael Rosengarten BEng, MD.McGill. Right axis deviation. Licence: CC BY-SA 3.0.
3. James Heilman, MD. Mobitz type 2 AV block. Licence: CC BY-SA 3.0.
4. James Heilman, MD. Complete heart block. Licence: CC BY-SA 3.0.
5. James Heilman, MD. Delta wave. Licence: CC BY-SA 3.0.

6. Michael Rosengarten BEng, MD.McGill. Q-waves. Licence: CC BY-SA 3.0.
7. Michael Rosengarten BEng, MD.McGill. Poor R-wave progression. Licence: CC BY-SA 3.0.
8. Michael Rosengarten BEng, MD.McGill. Tall tented T-waves. Licence: CC BY-SA 3.0.
9. CardioNetworks. T-wave morphology. Licence: CC BY-SA 3.0.
10. James Heilman, MD. U-wave. Licence: CC BY-SA 3.0.
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