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Understanding your ECG: a review

Edited by the perioperative CPD team.

Health professionals use the electrocardiograph (ECG) rhythm strip to systematically analyse the cardiac rhythm. Before the systematic process of ECG analysis is described it is important to describe the individual waveforms, segments and intervals of the ECG.

The waveforms of the ECG are produced as electricity passes through the cardiac conduction system. Electrical impulses originate from the sinoatrial (SA) node and cause contraction of the heart as they travel through the atrioventricular (AV) node, Bundle of His, right and left bundle branches and finally, the Purkinje fibres (Refer to Figure 1).

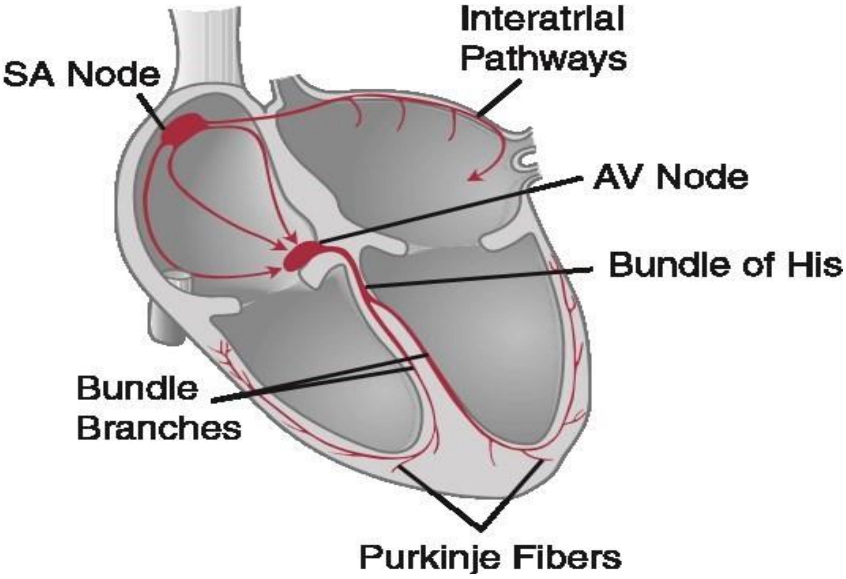


Figure 1 - The normal conduction system

Passage of electricity throughout these structures causes the heart to contract and eject blood into the systemic and pulmonary circulation.

The ECG consists of three major waveforms: The P wave, QRS complex and the T wave (Refer to Figure 2). Each waveform corresponds to a physiological event in the heart. The P wave represents atrial depolarisation, the QRS complex represents ventricular depolarisation and the T wave represents ventricular repolarisation. Repolarisation of the atria is invisible on ECG because it is hidden in the QRS complex

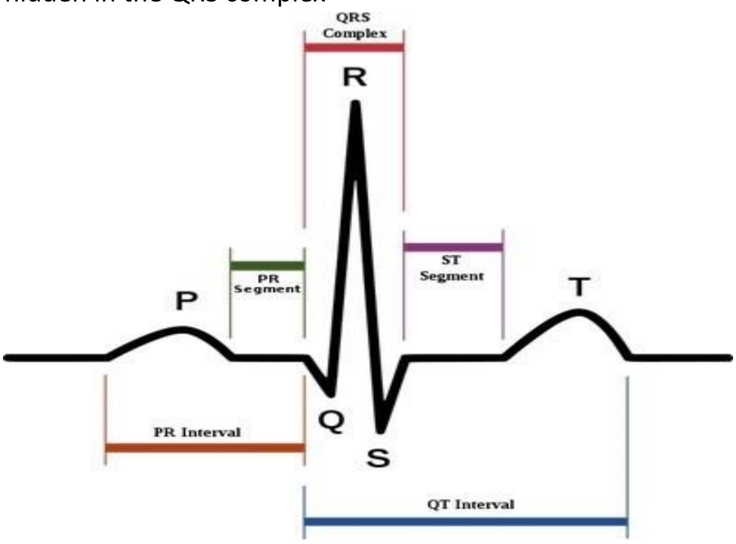


Figure 2 - The PQRST waveforms

Depolarisation indicates electricity has travelled through anatomical structures and contraction represents the mechanical response to the electricity.

ECG paper is designed to move through the recorder at 25mm per second. This is worth remembering because the ECG will be distorted if the machine settings are changed to slower or faster paper speeds. Rhythm strips are recorded on paper inscribed with 1mm small squares (Refer to Figure 3). A large square is marked with slightly darker lines and consists of 5 small squares. The vertical axis represents amplitude (each small square equals 1mm in height) of the waveform and the horizontal axis represents time (1mm equals 0.04 seconds).

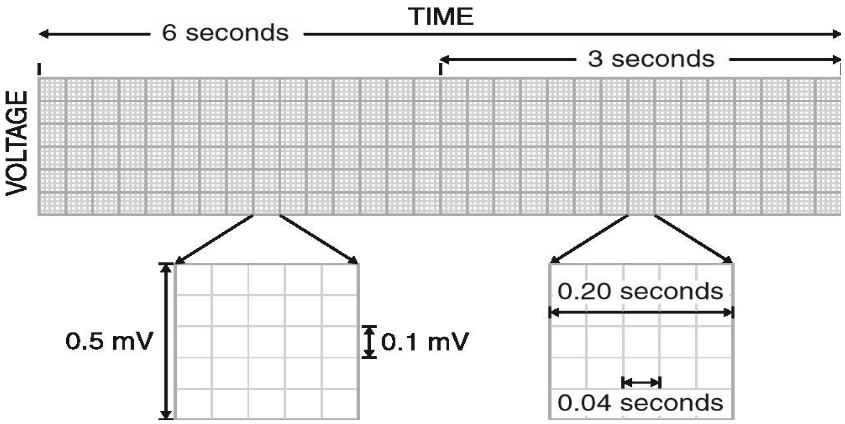


Figure 3 - ECG paper

The P wave

When P waves are abnormal we know that they could not have originated from the SA node and the impulse has travelled via alternative pathways. Sometimes, the P waves look like they have notches in them. This represents hypertrophy or dilatation of the left or right atria (occasionally both) and is most commonly caused by conditions such as pulmonary hypertension, emphysema or valvular conditions.

The PR interval

The PR interval represents the time taken for the electrical impulse to travel from the SA node and be processed within the AV node. It is measured from the beginning of the P wave to the beginning of the QRS complex (Refer to Figure 2). When measuring the PR interval consider that the QRS complex may travel upwards or downwards from the isoelectric line. Measure to the point where the line moves in either direction from the isoelectric line. Normal duration of the PR interval is 0.12 to 0.20 seconds (3 to 5 small squares). When the PR interval is within normal limits it tells us the electrical impulse has travelled through the atrial conduction system in a timely manner. Abnormally short or long PR intervals indicate travel through accessory pathways or a delay transmitting through the normal conduction pathway.

The QRS complex

The QRS complex represents ventricular depolarisation with the physiological result of ventricular contraction. It is measured immediately after the PR interval where the waveform either travels upwards or downwards from the isoelectric line to the J-point (Refer to Figure 4). The QRS complex consists of three distinct waves; the Q, R and S waves and has many configurations. Any downward deflection after the PR interval is known as the Q wave. Any upward deflection after the PR interval is known as the R wave. The downward deflection after the R wave is called the S wave.

Health professionals use the collective term ‘QRS complex’ to describe any configuration of this part of the ECG. For example, not every QRS complex actually contains a Q wave. Technically, this type of complex would be called an RS complex; however, the use of the collective term is appropriate. Normal duration of the QRS complex is 0.08 to 0.10 seconds or 2 to 2.5 small squares wide. A QRS complex wider than 0.10 seconds indicates that it has taken longer than normal for the impulse to travel through the ventricles. The most common causes of a widened QRS complex are bundle branch block, ventricular arrhythmias or origination of the electrical stimulus from an ectopic focus in the ventricle.

The ST segment

After ventricular depolarisation, the heart enters a brief resting state. This is represented by the ST segment which is normally flat and level with the isoelectric line (Refer to Figure 2). The junction between the QRS and the ST segment is known as the J-point. In some conditions the J-point does not meet with the isoelectric line which can make it difficult to measure the end point of the QRS width. To determine the end of the QRS complex measure to the point where the J-point occurs, and whether it is below or above the isoelectric line.

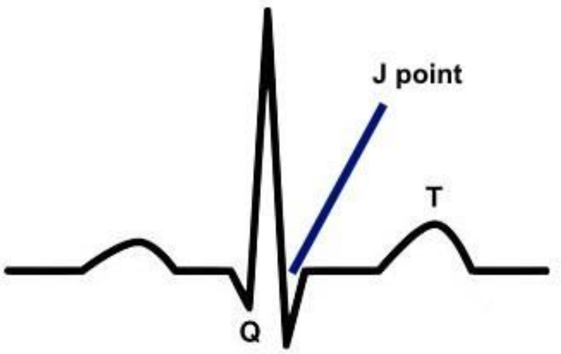


Figure 4 - QRS complex and the J-point

The T wave

The T wave represents ventricular repolarisation and is usually rounded, upright, with an amplitude of less than 5mm (Refer to Figure 2). Abnormalities in the T wave are common and may even be normal in some people. Generally, inverted, peaked or flattened T waves represent pathologies such as ischaemia and acute myocardial infarction.

T wave changes are also seen in hyperkalaemia and with certain drug toxicities.

The QT interval

Probably one of the most important aspects of the ECG is the QT interval (Refer to Figure 5). It represents the time from the beginning of ventricular depolarisation to the end of ventricular repolarisation. The importance of this interval relates to the vulnerable refractory phase that occurs during repolarisation where undue stimulation can result in life threatening arrhythmias.

The QT interval is measured from the beginning of the QRS complex to the end of the T wave. The QT interval varies inversely with heart rate. In other words, the QT interval decreases as the heart rate increases. The normal QT interval length varies with heart rate although a general normal range is 0.35 to 0.42 seconds (approximately 9 to 10.5 small squares).

A specific method to calculate the QT interval is QTc = √ RR interval (in seconds).

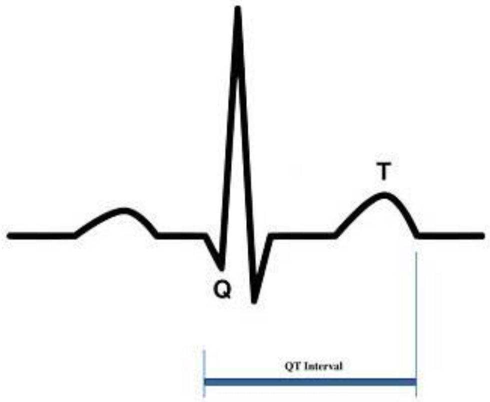


Figure 5 - The QT interval

An abnormally long QT interval indicates ventricular repolarisation time is slowed. This is dangerous because the refractory period is prolonged and may predispose the individual to lethal arrhythmias. The most common causes include electrolyte derangement, congenital syndromes, acute myocardial infarction, ischaemia and certain drug toxicities (such as amiodarone).

The U wave

The U wave is not always visible on the ECG and is best seen when the heart rate is slow. Small U waves may be associated with normal ventricular repolarisation although larger ones (greater than 2mm) may be the result of electrolyte disturbances or certain drug toxicities.

Systematic ECG analysis

The first step in ECG interpretation is recognising sinus rhythm, the normal cardiac rhythm. This allows for the identification of abnormalities and arrhythmias.

1. Determine the ***regularity***
2. Calculate the ***heart rate***
3. Identify and examine the ***P wave***
4. Measure the ***PR interval***
5. Measure the ***QRS complex***

Refer to Table one below.

Sinus Rhythm	
Rhythm	Regular
Rate	60 - 100
QRS complex	0.08 - 0.10 seconds
P wave	Rounded, upright
PR interval	0.12 - 0.20 seconds

Table 1 – ECG analysis

Figure 6 - Normal sinus rhythm

1. Rhythm

Determine the regularity using paper or callipers. When using paper, mark the tips of two R waves and slide the paper along to see if the marks match up with the next R waves. Variations of more than three small squares between QRS complexes indicate irregularity.

2. Heart rate

If the heart rate is regular count the small squares between two R waves and divide the number into 1500. Alternatively, count the number of large squares between two R waves and divide into 300. These calculations are important to derive accurate heart rates but not clinically practical. Simple resources to use in the clinical field include cardiac monitors, an actual pulse check or heart rate rulers.

If the heart rate is irregular count the number of R waves in a six-second rhythm strip (30 large squares and often indicated by vertical markers) and multiply by ten. Calculate the rates of all the rhythms that appear on the strip. For example, sinus rhythm with a burst of self-limiting ventricular tachycardia will require rate calculation for both rhythms.

3. Measure the QRS complex

Measure the width of the QRS complex from the point where the complex leaves the isoelectric line to the J-point.

3. Identify and examine the P wave

Examine the P waves of the rhythm strip. There should be one for every QRS complex and they should appear upright and rounded.

5. Measure the PR interval

Measure the length of the PR interval by counting the small squares from the beginning of the P wave to the beginning of the QRS complex.

Rhythm interpretation is straightforward however mastering this skill requires practice and the use of a systematic process.

VARIOUS ECG RHYTHMS

Normal Sinus Rhythm

- Rhythm - Regular
- Rate - (60-99 bpm)
- QRS Duration - Normal
- P Wave - Visible before each QRS complex
- P-R Interval - Normal (<5 small Squares.
  Anything above and this would be 1st degree block) What you want your patient ECG to look like

Sinus Bradycardia

- Rhythm - Regular
- Rate - less than 60 beats per minute
- QRS Duration - Normal
- P Wave - Visible before each QRS complex
- P-R Interval - Normal
- Usually benign and often caused by patients on beta blockers

A heart rate less than 60 beats per minute (BPM). This in a healthy athletic person may be 'normal', but other causes may be due to increased vagal tone from drug abuse, hypoglycaemia and brain injury with increase intracranial pressure (ICP) as examples

Sinus Tachycardia

- Rhythm - Regular
- Rate - More than 100 beats per minute
- QRS Duration - Normal
- P Wave - Visible before each QRS complex
- P-R Interval - Normal
- The impulse generating the heart beats are normal, but they are occurring at a faster pace than normal. Seen during exercise

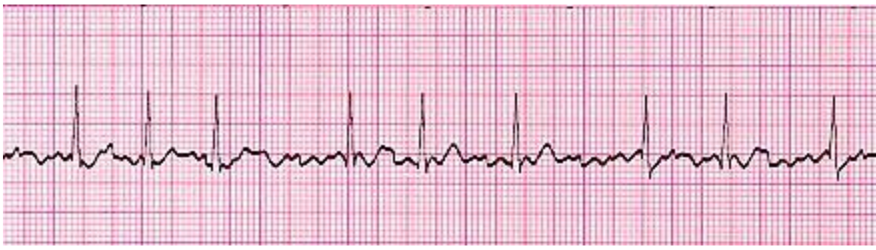
An excessive heart rate above 100 beats per minute (BPM) which originates from the SA node. Causes include stress, fright, illness and exercise. Not usually a surprise if it is triggered in response to regulatory changes e.g. shock. But if there is no apparent trigger then medications may be required to suppress the rhythm

Supraventricular Tachycardia (SVT) Abnormal

- Rhythm - Regular
- Rate - 140-220 beats per minute
- QRS Duration - Usually normal
- P Wave - Often buried in preceding T wave
- P-R Interval - Depends on site of supraventricular pacemaker
- Impulses stimulating the heart are not being generated by the sinus node, but instead are coming from a collection of tissue around and involving the atrioventricular (AV) node.

A narrow complex tachycardia or atrial tachycardia which originates in the 'atria' but is not under direct control from the SA node. SVT can occur in all age groups.

Atrial Fibrillation

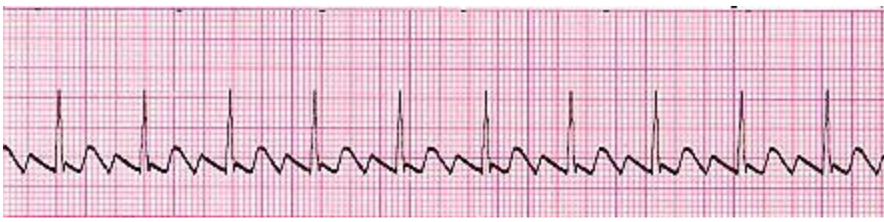


- Rhythm - Irregularly irregular
- Rate - usually 100-160 beats per minute but slower if on medication
- QRS Duration - Usually normal
- P Wave - Not distinguishable as the atria are firing off all over
- P-R Interval - Not measurable
- The atria fire electrical impulses in an irregular fashion causing irregular heart rhythm

Many sites within the atria are generating their own electrical impulses, leading to irregular conduction of impulses to the ventricles that generate the heartbeat. This irregular rhythm can be felt when palpating a pulse.

It may cause no symptoms, but it is often associated with palpitations, fainting, chest pain, or congestive heart failure.

Atrial Flutter



- Rhythm - Regular
- Rate - Around 110 beats per minute
- QRS Duration - Usually normal
- P Wave - Replaced with multiple F (flutter) waves, usually at a ratio of 2:1 (2F - 1QRS) but sometimes 3:1
- P Wave rate - 300 beats per minute
- P-R Interval - Not measurable
- As with SVT the abnormal tissue generating the rapid heart rate is also in the atria, however, the atrioventricular node is not involved in this case.

1st Degree AV Block

Rhythm - Regular
- Rate - Normal
- QRS Duration - Normal
- P Wave - Ratio 1:1
- P Wave rate - Normal
- P-R Interval - Prolonged (>5 small squares)

1st Degree AV block is caused by a conduction delay through the AV node but all electrical signals reach the ventricles. This rarely causes any problems by itself and often trained athletes can be seen to have it. The normal P-R interval is between 0.12s to 0.20s in length, or 3-5 small squares on the ECG.

2nd Degree Block Type 1 (Wenckebach)

- Rhythm - Regularly irregular
- Rate - Normal or Slow
- QRS Duration - Normal
- P Wave - Ratio 1:1 for 2,3 or 4 cycles then 1:0.
- P Wave rate - Normal but faster than QRS rate
- P-R Interval - Progressive lengthening of P-R interval until a QRS complex is dropped

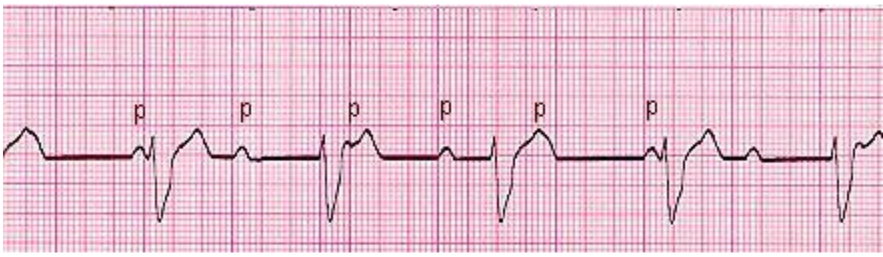
Another condition whereby a conduction block of some, but not all atrial beats getting through to the ventricles. There is progressive lengthening of the PR interval and then failure of conduction of an atrial beat, this is seen by a dropped QRS complex

2nd Degree Block Type 2

- Rhythm - Regular
- Rate - Normal or Slow
- QRS Duration - Prolonged
- P Wave - Ratio 2:1, 3:1
- P Wave rate - Normal but faster than QRS rate
- P-R Interval - Normal or prolonged but constant

When electrical excitation sometimes fails to pass through the A-V node or bundle of His, this intermittent occurance is said to be called second degree heart block. Electrical conduction usually has a constant P-R interval, in the case of type 2 block atrial contractions are not regularly followed by ventricular contraction

3rd Degree Block



- Rhythm - Regular
- Rate - Slow
- QRS Duration - Prolonged
- P Wave - Unrelated
- P Wave rate - Normal but faster than QRS rate
- P-R Interval - Variation
- Complete AV block. No atrial impulses pass through the atrioventricular node and the ventricles generate their own rhythm

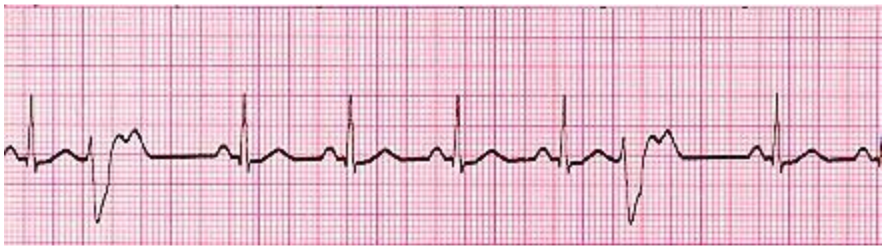
3rd degree block or complete heart block occurs when atrial contractions are 'normal' but no electrical conduction is conveyed to the ventricles. The ventricles then generate their own signal through an 'escape mechanism' from a focus somewhere within the ventricle. The ventricular escape beats are usually 'slow'

Bundle Branch Block

- Rhythm - Regular
- Rate - Normal
- QRS Duration - Prolonged
- P Wave - Ratio 1:1
- P Wave rate - Normal and same as QRS rate
- P-R Interval – Normal

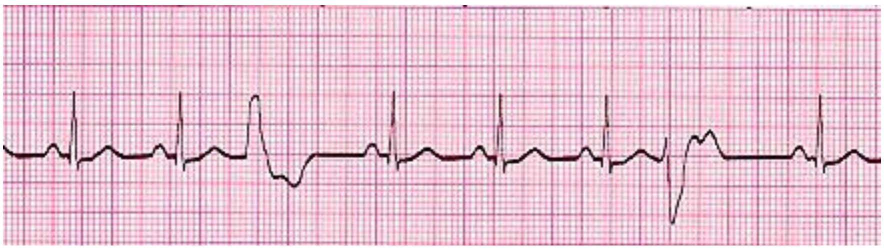
Abnormal conduction through the bundle branches will cause a depolarization delay through the ventricular muscle, this delay shows as a widening of the QRS complex. Right Bundle Branch Block (RBBB) indicates problems in the right side of the heart. Whereas Left Bundle Branch Block (LBBB) is an indication of heart disease. If LBBB is present then further interpretation of the ECG cannot be carried out.

Premature Ventricular Complexes



- Rhythm - Regular
- Rate - Normal
- QRS Duration - Normal
- P Wave - Ratio 1:1
- P Wave rate - Normal and same as QRS rate
- P-R Interval - Normal

Due to a part of the heart depolarizing earlier than it should. Also you'll see 2 odd waveforms, these are the ventricles depolarising prematurely in response to a signal within the ventricles.(Above - unifocal PVC's as they look alike if they differed in appearance they would be called multifocal PVC's, as below)

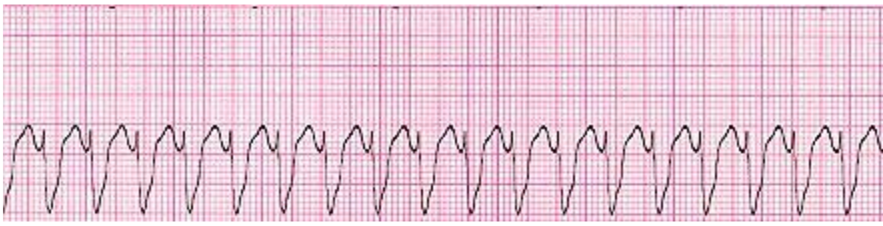


Junctional Rhythms

- Rhythm - Regular
- Rate - 40-60 Beats per minute
- QRS Duration - Normal
- P Wave - Ratio 1:1 if visible. Inverted in lead II
- P Wave rate - Same as QRS rate
- P-R Interval – Variable

In junctional rhythm the sinoatrial node does not control the heart's rhythm - this can happen in the case of a block in conduction somewhere along the pathway. When this happens, the heart's atrioventricular node takes over as the pacemaker.

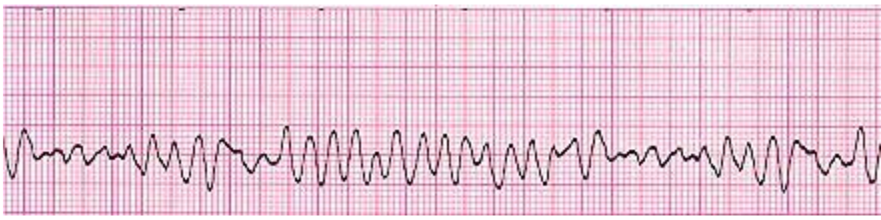
Ventricular Tachycardia (VT) Abnormal



- Rhythm - Regular
- Rate - 180-190 Beats per minute
- QRS Duration - Prolonged
- P Wave - Not seen

Results from abnormal tissues in the ventricles generating a rapid and irregular heart rhythm. Poor cardiac output is usually associated with this rhythm thus causing the patient to go into cardiac arrest. Shock this rhythm if the patient is unconscious and without a pulse

Ventricular Fibrillation (VF) Abnormal



- Rhythm - Irregular
- Rate - 300+, disorganised
- QRS Duration - Not recognisable
- P Wave - Not seen
- This patient needs to be defibrillated!! QUICKLY

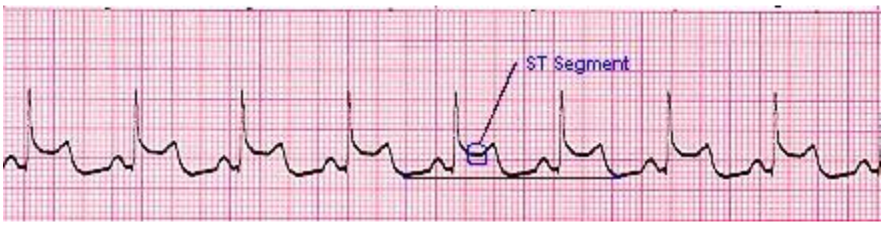
Disorganised electrical signals cause the ventricles to quiver instead of contract in a rhythmic fashion. A patient will be unconscious as blood is not pumped to the brain. Immediate treatment by defibrillation is indicated. This condition may occur during or after a myocardial infarct.

Asystole – Abnormal (really!)

- Rhythm - Flat
- Rate - 0 Beats per minute
- QRS Duration - None
- P Wave - None
- Carry out CPR!!

A state of no cardiac electrical activity, as such no contractions of the myocardium and no cardiac output or blood flow are present.

Myocardial Infarct (MI)



- Rhythm - Regular
- Rate - 80 Beats per minute
- QRS Duration - Normal
- P Wave - Normal
- S-T Element does not go isoelectric which could indicate infarction. However this is **NOT** diagnostic unless associated with a 12 lead ECG