# Module 1.3

## *The 12-lead ECG*



*1/3/2013*

**Introduction**
Hello, my name is Maxine. I'll be your tutor. Welcome to module 1.3: The 12-Lead ECG, this is a free module and I hope you enjoy the presentation.

**Teaching philosophy**
Our teaching philosophy at Cardio Rhythms is very simple. Although our seminars are intensive, they are also very relaxed. Clinical case studies are of upmost importance in this teaching method. It fosters a more hands on approach whereby each student can effectively practise what they have just learnt in theory. The emphasis is then that the student internalises the information, rather than simply memorising facts. Our goal here is that the student is motivated, and will want to continue in their studies. At Cardio Rhythms we believe there is no such thing as a bad student. Teachers work for their students, and we are committed to making your online learning experience as rewarding as possible.

**Objectives**
Welcome to the ECG training room. Click on each of the characters for a quick review of previous topics, and the course objectives for this module. When you are ready you can enter the module here. In our other free modules we have already studied some basic anatomy & physiology, the electrical conduction system, and how waveforms are derived. We have also looked at some rhythm strips and learnt how to calculate the heart rate. In this module we will discover the purpose of a 12-lead ECG in comparison to interpreting a single lead rhythm strip. We will study the limb leads, what they convey, and how this relates to the hexaxial reference system. We will then examine correct chest lead placement, and learn how to record a 12-lead ECG. We can then perceive how this is translated onto graph paper, what areas of the heart are represented, and learn the correct anatomical terms. Finally we will look at some common recording artefacts with some additional tips to ensure a good quality recording.

**Why do we need a 12-Lead ECG?**
Here is our basic diagram of the conduction system. Shown here is our lead II, which always sits here. It faces the wave of depolarisation, and in a normal subject this gives rise to a nice positive PQRST signal. Of course, this is great if all we are doing is analysing the rhythm, but what if we want a more complete view of the heart? You can think of your ECG leads as small cameras viewing the heart from lots of different positions. The lead that sits up here (lead aVR) will have quite a different view from lead II. In a normal subject the wave of depolarisation is moving away from aVR, so the PQRST complexes are negative. Therefore, every single lead, although looking at the same wave of depolarisation, will give rise to a different PQRST complex. The main uses of a 12-lead ECG include establishing the cardiac axis, determining the site of a myocardial infarction or looking for ischaemic changes, determining a bundle branch block, and looking for signs of chamber enlargement. Hover your mouse over each indication for more information.

**Limb leads**
Before looking at an actual 12-lead recording let's go through electrode placement. Standardisation is very important because in order to compare ECGs we must make sure that we always use the same positions. Starting with the limb leads, as the title implies, an

electrode is placed on each of the limbs. Here we have the right arm, the left arm, the left leg (or F for foot), and lastly the right leg or N for neutral. The colours I have used here comply with IEC European recommendations. The American Heart Association has a different colour system, so always check the inscription on the wires before connecting. Most of the current literature in the UK recommends that the limb electrodes are placed on or close to the wrists and ankles. In other countries people are taught to place the electrodes on the upper arms and thighs. Always check with your supervisor or medical association on the correct practice for you. Whatever your method it's consistency that's important. Once the wires are attached, three of the limb connections form what is known as Einthoven's triangle. Click the triangle to find out more.

Here we have Einthoven's triangle. Three of the limb electrodes – right arm, left arm, and left leg actually give us 6 ECG lead positions. These leads view the heart in the fontal plane. Here we have our three unipolar augmented leads. AVR (augmented vector right) is at the right arm, aVL at the left arm, and aVF at the left leg (or F for foot). Then we have our three bipolar leads; lead I is the voltage between the right arm, and left arm. Lead II is the voltage between the right arm and left leg. And lead III is the voltage between the left leg and left arm. Now, this kind of diagram is very common in text books, but can be a little confusing.

Each lead has a positive and negative, but always views the wave of depolarisation from its positive pole. The augmented leads are easy to understand because the positive is situated on the right arm, left arm, and left leg respectively. However, let's put the positive and negatives poles on the bipolar leads. Now what we actually see here is that lead I views the wave of depolarisation from here. Lead II views the wave of depolarisation from here, and lead III views the wave of depolarisation from here. We can now realistically see where our triangle fits in. If we then insert our other augmented leads, so here we have aVR, then aVL, and finally aVF, we start to see the beginnings of our hexaxial reference system.

**Hexaxial reference system**

So here we have our hexaxial reference system or axis chart, and we can see here the limb leads labelled at their positive poles (the positive and negative poles of each lead, the plus and minus symbols, are displayed on the OUTSIDE of the circle). Let's position the heart in the middle. Looking at lead II again, we can see the wave of depolarisation is moving toward the lead and therefore our ECG strip demonstrates a nice positive PQRST complex. Looking at aVR, we see that the wave of depolarisation is moving away from the lead so the PQRST complex is negative. When a lead is laying perpendicular to the wave of depolarisation, the waveform may be equiphasic or biphasic; in other words half positive and half negative. Here is an example of an equiphasic waveform in lead III. If you would like to learn how to calculate cardiac axis using this chart please check out the relevant e-learning module on our website. We will be doing a quick axis check later on in this presentation. For now, let's take a look at chest lead placement on the next slide.

**The precordial leads**

The chest leads, also known as the precordial leads, view the heart in the horizontal plane, perpendicular to the limb leads. There are 6 chest leads and they have very specific placements. Again I will use IEC colour coding, but always check the inscription on your wires also. Firstly we need to find the fourth intercostal space. If counting down from the

clavicle be careful not to call this space (just below the clavicle) the first intercostal space. The first intercostal space is between the first and second rib. So in this diagram we can count down the intercostal spaces…1, 2, 3, and 4. V1 is placed in the fourth intercostal space at the right sternal edge. V2 is placed in the fourth intercostal space at the left sternal edge. Next we place V4; this is placed in the fifth intercostal space mid-clavicular line. We can then place V3 which sits midway between V2 and V4. V5 is placed at the left anterior axillary line at the same horizontal level as V4. Lastly, V6 is placed at the mid-axillary line, again at the same horizontal level as V4 and also V5.

**10 wires 12 leads**

So let's take a look at how the 12-lead ECG system is constructed onto graph paper. One common question I am asked is why if there are only 10 wires on the ECG cable this produces 12-leads. Ok well let's pretend this is our ECG graph paper. Let's lay out the 6 chest leads first as this is very straightforward – V1, V2, V3, V4, V5, and V6. Six chest wires give us six leads on the graph paper. Six wires plus the four limb wires equals ten wires in total. But remember that the right leg electrode is neutral and the other three limb connections produce 6 leads on the graph paper – these are laid out as I, II, III, aVR, aVL, and aVF. Therefore on the ECG graph paper itself there are 12 lead positions. Here is an example of a normal 12 lead ECG. You can zoom up on this and also right click and print. We will be going through each lead later, but for now just get used to how the leads are displayed – limb leads on the left, chest leads on the right, and the rhythm strip along the bottom.

**Surface areas of the heart**

Now we have sorted out our wires, electrode positions, and found out how the 12-lead is produced, the next question to ask ourselves is, which areas of the heart relate to which leads? Firstly let's learn the anatomical terms: anterior, posterior, inferior, and lateral. Click on the boxes to learn more.

**Surface areas & ECG leads**

Ok, so how do the leads relate to the anatomical terms we have just learnt? Here is a bigger picture of the heart, so let's put the limb leads into place first. Here we have our augmented leads: aVR, aVL, and aVF. And now our bipolar leads at their positive poles: I, II, and III. From what you have just learnt about surface areas, which areas do you think best relate to the limb leads? What about leads II, III and aVF? Yes, that's right we are looking at the bottom of the heart – the inferior region. What about leads I and aVL? Yes, that's right we are looking at the side of the heart – the lateral region. AVR obtains information from the right upper side of the heart, and it is reciprocal to lead II. This lead is sometimes ignored, but as we will see in later modules it can be a very useful diagnostic tool. Hover over each lead to reveal an ECG example. Click here to see how all this works for the chest leads.

The chest leads view the heart in the horizontal plane. V1 and V2 view the septum or septal region. V3 and V4 view the anterior region (the front), and V5 and V6 view the lateral region (the side). Now if we insert our average wave of depolarisation we can see that in a normal subject the impulse is moving more or less away from V1 and V2 and more toward V4, 5, and 6. This affects the R wave of the QRS. In other words the R wave gets bigger and this is known as R wave progression. Hover over each of the leads in order and you can see the R

wave progressively getting larger. So now we have established which leads look at what area, go to the next slide to see how this translates onto the graph paper.

**Surface areas & ECG leads**

Here we have a normal 12-lead ECG. The rhythm strip is situated at the bottom, and here we can see the strip is recorded using lead II. Moving back to the 12-lead, our six limb leads are displayed on the left and our six chest leads on the right - as we would expect in a normal subject lead aVR is negative. V1 is also predominately negative, and the R wave progresses, gets bigger, as we move through the chest leads toward V6. Now, let's put in our surface areas: the inferior region is II, III, and aVF, the septal region is V1 and V2, the anterior region is V3 and V4, and the lateral region is V5 and V6, but also includes the high lateral leads I and aVL. So what we have done here is simplified our 12-lead ECG into a rhythm strip and four main regions; if you can start to look at your 12-lead like this, interpretation will start to get a lot easier. Hover over the areas to revise your lead areas.

**Quick 12-lead ECG guide & axis check**

If you are a beginner there is a lot more to learn about 12-lead ECG abnormalities before you can make a comprehensive interpretation. However, there are some small steps you can begin to make. Firstly get comfortable with rhythm analysis. Most 12-leads have a rhythm strip that makes interpreting your rhythm clearer than if you only have two or three complexes to look at. Here we have a nice regular rhythm, the rate is normal at 60 BPM, and there is one P wave to every QRS; in other words sinus rhythm. Once the rhythm is established you can then start analysing your 12-lead.

One of the things I always check first is the polarity of aVR and V1. In a normal subject both these leads should show negative QRS complexes. If aVR is positive you should check that your right and left arm placements are correct. The next thing I like to do is a quick axis check. It is not as accurate as using the hexaxial system, but the quick method works well as a rough guide. We only need the limb leads to calculate the axis. This works well for leads I and II, and also I and aVF. Personally I like to use leads I and II. If both leads are positive the axis is normal. If lead I is positive and lead II negative (leaving each other) the axis is left. If lead I is negative and lead II positive (reaching each other) the axis is right. If both leads are negative the axis is extreme (this is usually the case if the limb leads are on the wrong way, or the patient has dextrocardia). So if we bring back our normal ECG we can clearly see that leads I and II are positive, which means the axis is normal.

**Recording artefacts**

Before ending this module, let's take a look at some common recording artefacts: technical dextrocardia, wandering baseline, muscle tremor and electrical interference. Click on the titles for some more information and examples.

Technical Dextrocardia:

A technical dextrocardia is when the operator inadvertently swaps the left and right arm wires. The term "dextrocardia" is used because these changes mimic what a true dextrocardia would show in the limb leads. We can see that leads I and II are negative, which alone would indicate an extreme axis deviation, but perhaps the most obvious sign is

that aVR is positive. When the leads are put back into their correct positions, these changes revert to normal.

Wandering Baseline:
Wandering baseline tends to be caused by poor electrode/skin contact. For instance, I've seen this when a patient is perspiring, or has a very hairy chest, or if oil based lotion has been applied; in other words anything that hinders the electrode from adequately adhering to the skin. The best solution is to clean and dry the skin thoroughly, maybe use a light abrasive and reapply your electrodes.

Muscle Tremor:
If the patient is not relaxed or moves during the recording a muscle artefact may result. This type of artefact may also occur if the patient has an underlying condition such as Parkinson's disease. Try and keep the patient warm and comfortable during the procedure; get them to breath normally, and assure them that the procedure will not hurt. For uncontrollable tremors it may be necessary to reposition your limb leads, for example, from the wrists to the forearms, or use the filter button on your machine, but remember any deviation from your normal recording technique should always be noted. For example, if you use the filter it should be recorded on the ECG.

Mains interference:
This is what happens when the ECG machine picks up AC interference from nearby electrical equipment. AC interference can be a particular problem in departments such as critical care and emergency departments especially when there is machinery present around the bedside. It can also occur when the ECG wires are tangled. Ensure that your wires are straight and that they are not touching any other electrical equipment. If this doesn't work ask the nurse looking after the patient if it is possible to switch off any electrical equipment that may be causing the problem.

**Ensuring a good quality recording**
There are lots of things to consider when recording an ECG; it's not quite as simple as some like to make out. If good quality standardised ECG recording is not maintained, then it is possible to misdiagnose. I've attached the UK Cardiological Science & Technology guidelines in the resources section, which is in the top right hand corner. The slide is a summary of the salient points.

**See you soon**
You have reached the end of this free module, and I very much hope you enjoyed the presentation. We have more free stuff available on our website. If you have any questions please do not hesitate to contact the team. Alternatively you can post any comments or questions on our blog or any of our social media outlets. If you have time, please complete the survey on the next slide. Thanks for listening and keep in touch.