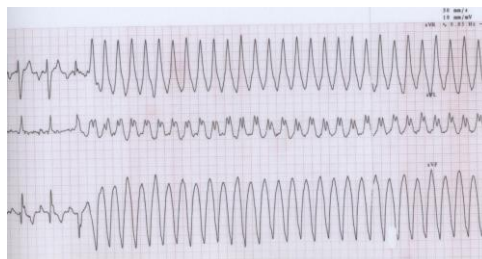# Cardiovascular Emergencies Mini Series

Session One: Arrhythmias Leading to Collapse

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ECG Friend or Foe in an Emergency?

The electrocardiogram (ECG) is one of the most feared diagnostic tools in veterinary medicine. The aim of this min series is to go back to basics and to revise what an ECG represents and how to achieve a good trace.

The Electrocardiogram

All heart cells have the capability to generate their own electricity activity (depolarise) this causes a chain of events which leads to contraction of the cell. In order for the heart to pump blood in an efficient manor, this needs to be well regulated with the atria and ventricles contracting in the correct sequence. In the normal heart, the first cells to initiate an impulse are in the sino-atrial node (SAN). The impulse generated from the SAN and passes through the atria, the atrio-ventricular node (AVN) and the ventricles. An electrocardiogram (ECG) is a graph of voltage plotted against time. It measures the electrical activity of the heart by means of positive and negative electrodes (Martin 2000). When the depolarisation wave moves towards the positive electrode a positive deflection is seen, similarly when the depolarisation wave moves away from the positive electrode a negative deflection is created. If the depolarisation wave is perpendicular to the electrode then a very small or no deflection is created. The size of the deflection is proportional to the thickness of the muscle mass which has depolarised, and the proximity of the electrode to the heart.

The normal canine ECG consists of the P, Q, R, S and T waves. The P wave corresponds to the depolarisation of the atria and the QRS complex corresponds to the depolarisation of the ventricles. The T wave represents the re-polarization of the ventricles. The Ta wave (re-polarisation of the P waves) is infrequently seen and is buried in the QRS complex. In small animals the ECG complex measurements can be used to give an indication of myocardial changes, such as ventricular enlargement.
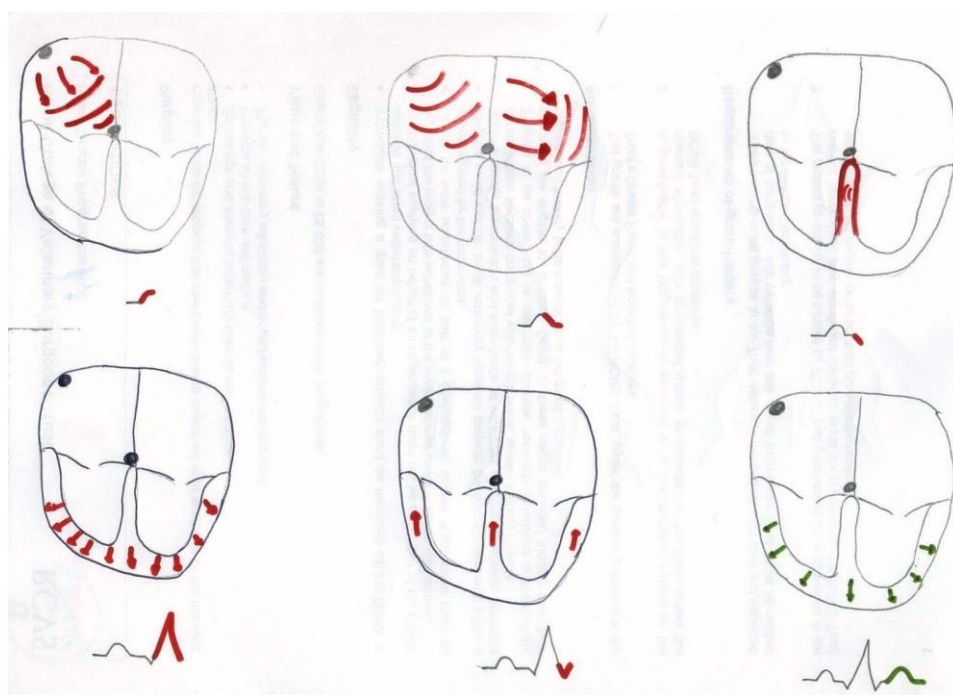
A sketch to demonstrate how the P-QRS-T complex is formed.

<u>Limb Leads</u>

There are 4 cables on most veterinary ECG machines; 3 active cables and 1 earth cable, and these are connected to electrodes attached to the patient. By convention in veterinary medicine the electrodes are usually placed on the animals' limbs. The ECG machine combines the electrodes into specific combinations (leads), these include the bipolar standard limb leads I, II, III and the unipolar limb leads aVR, aVL and aVF.
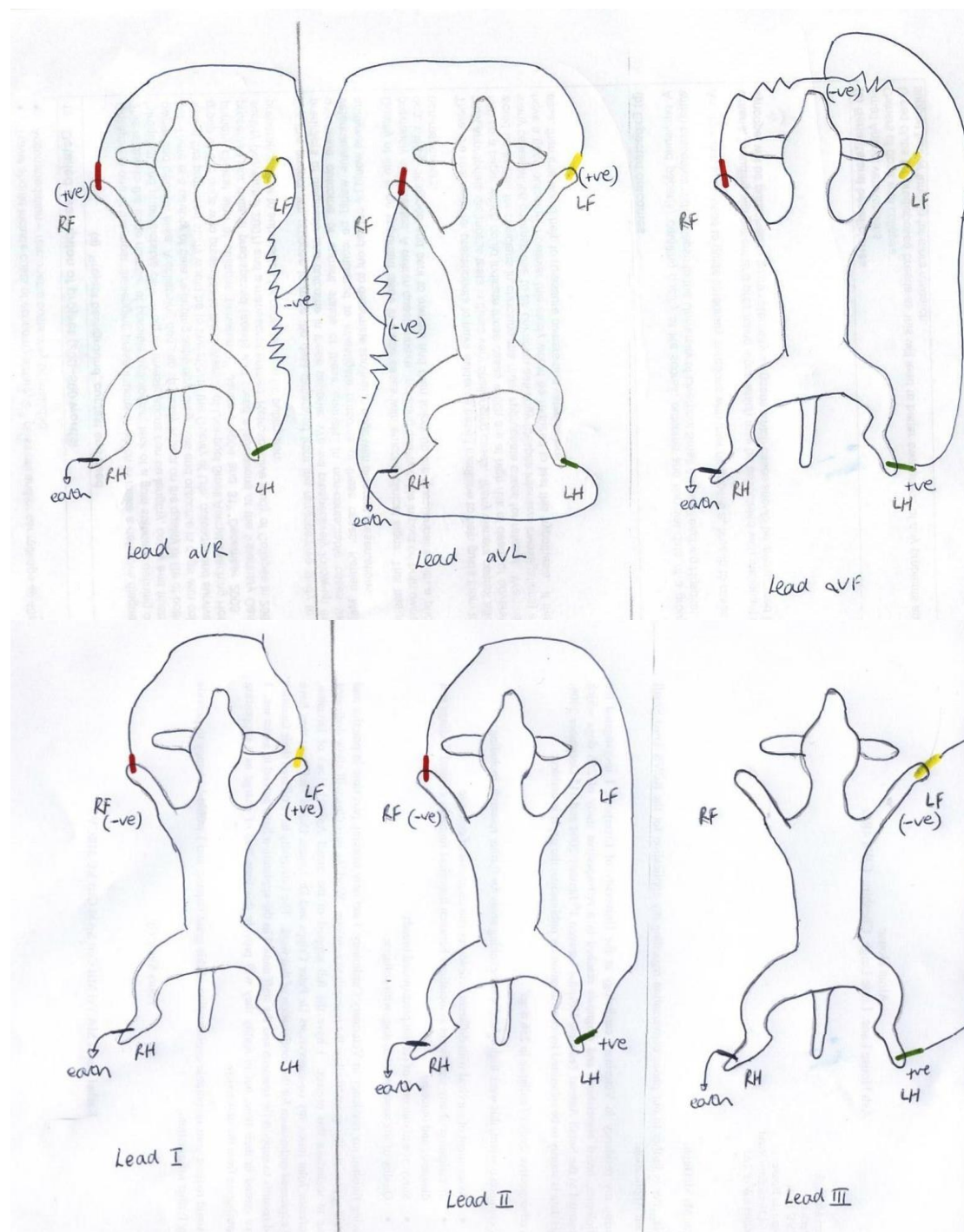
Above are sketches of how the limb leads are formed from the placement of different electrodes on the limbs.

The cables are coloured and by convention, the standard attachments are; red cable on the right forelimb (RF), yellow cable on the left forelimb (LF), green cable on the left hindlimb (LH) and the black cable on the right hindlimb (RH). This is easy to remember as they are the order of 'traffic lights' going in a circle anti-clockwise around the animal's limbs. For standard measurements, the animal is placed in right lateral recumbency and electrodes placed just above the olecranon and over the patellar ligaments.
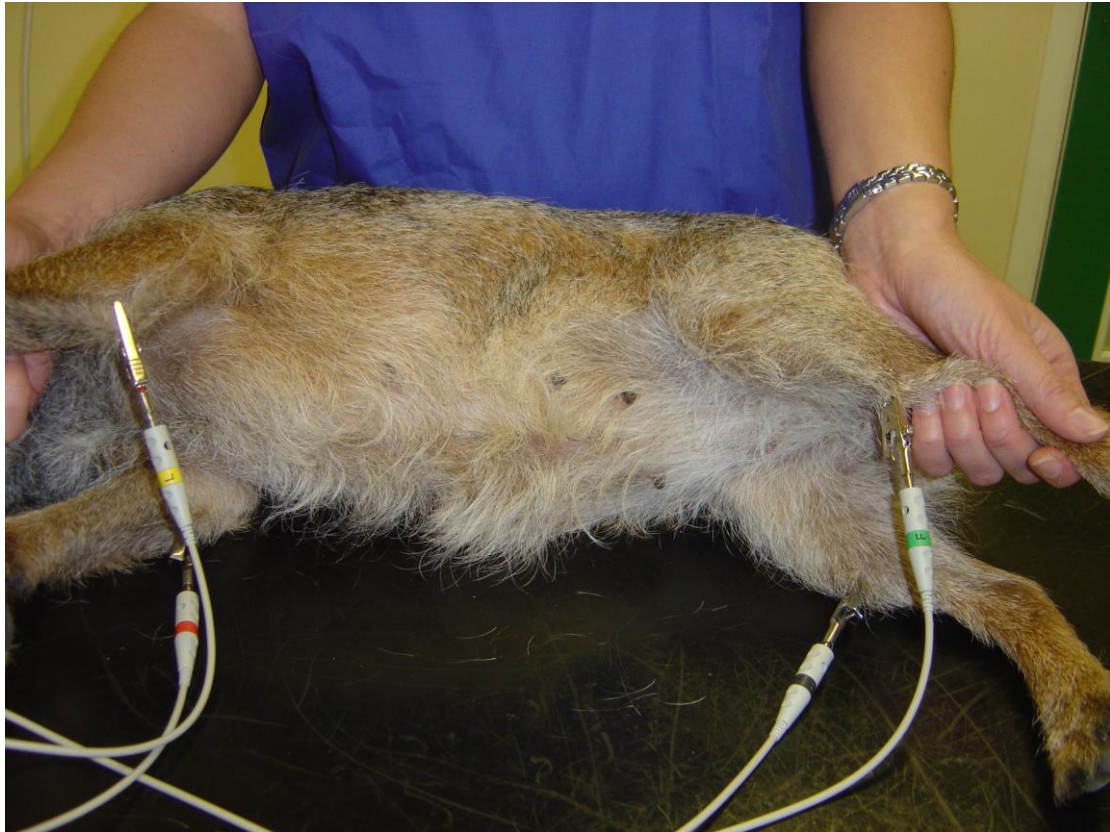
Why take an ECG?

There are many indications for taking an ECG in veterinary practice, the following list is by no means exhaustive:

- Arrhythmia –Tachycardia, Bradycardia, Irregular Rhythm
- Pulse Deficits
- Heart Murmur/Dull Heart Sounds
- Suspected Cardiovascular Disease
- Cardiopulmonary Arrest
- Collapse
- Exercise Intolerance
- Unstable Patient

How to take an ECG

A high quality ECG trace is essential to facilitate interpretation. The standardised protocol is performed in right lateral recumbency and all measurements are taken from lead II (Rishniw and others 2002). There are various ways of attaching the ECG cables to the patient, these include; metal crocodile clips (filed down, flattened or bent to reduce the animal's discomfort (Tilley 1992)), plastic crocodile clips, electrode pads or metal plates which are attached to the leg / foot. The cables are then connected to these. One study showed that the use of electrode pads can lead to more respiratory movement artefact (see below) than other methods but otherwise the results were all similar (Ferasin and others 2006). To facilitate good contact of electrodes a conduction medium is required. Surgical spirit is the most commonly used medium, however ECG gel or cream are good alternatives, this is especially important if the ECG recording is performed over 5 minutes as spirit will evaporate over this time. The conduction medium should be applied to all the clips when placed on the dog ensuring that the gel / spirit penetrates through the fur to the skin. In some thick coated dogs, clipping is required. The limbs should then be placed as the four corners of a box ensuring that the electrodes are vertically above and opposite one other.

Ideally all six leads should be run at 25mm/second in dogs and at 50mm/second in cats and tachycardic animals so the complexes can be clearly identified, some digigtal machines will now allow paper speeds of 100mm/second which is extremely useful in cats and tachycardic dogs. Lead II should then be run at 50mm/second to allow accurate measurements of the complexes to be performed. The 'sensitivity' or amplitude of the ECG is generally set at 10mm/1mV. However this should be altered to maximize the trace size. In cats this is frequently increased to 20mm/1mV and in dogs with tall R waves due to ventricular enlargement this may need to be reduced to 5mm/1mV.

Artefacts
Artefacts are abnormal deflections of the ECG recording, which are not associated with electrical activity of the heart (Martin 2000). Artefacts are common and it is important to recognise them and be able to make the necessary corrections to acquire a clean trace.

Muscle twitching / shivering
This is a frequent problem and is often due to stress.

The figure above shows an ECG with muscle tremor.

A quiet environment, comfortable bed and the use of sticky pads can be helpful to minimize stress. However, in difficult cases the filter can be used to remove the baseline noise. Many filters however will also reduce the size of the rest of the complexes and therefore it should be clearly annotated if a filter has been used.

Movement artefact
This is a frequent problem, if this occurs in only one leg, it is easy to identify looking at the leads affected (see the picture below).
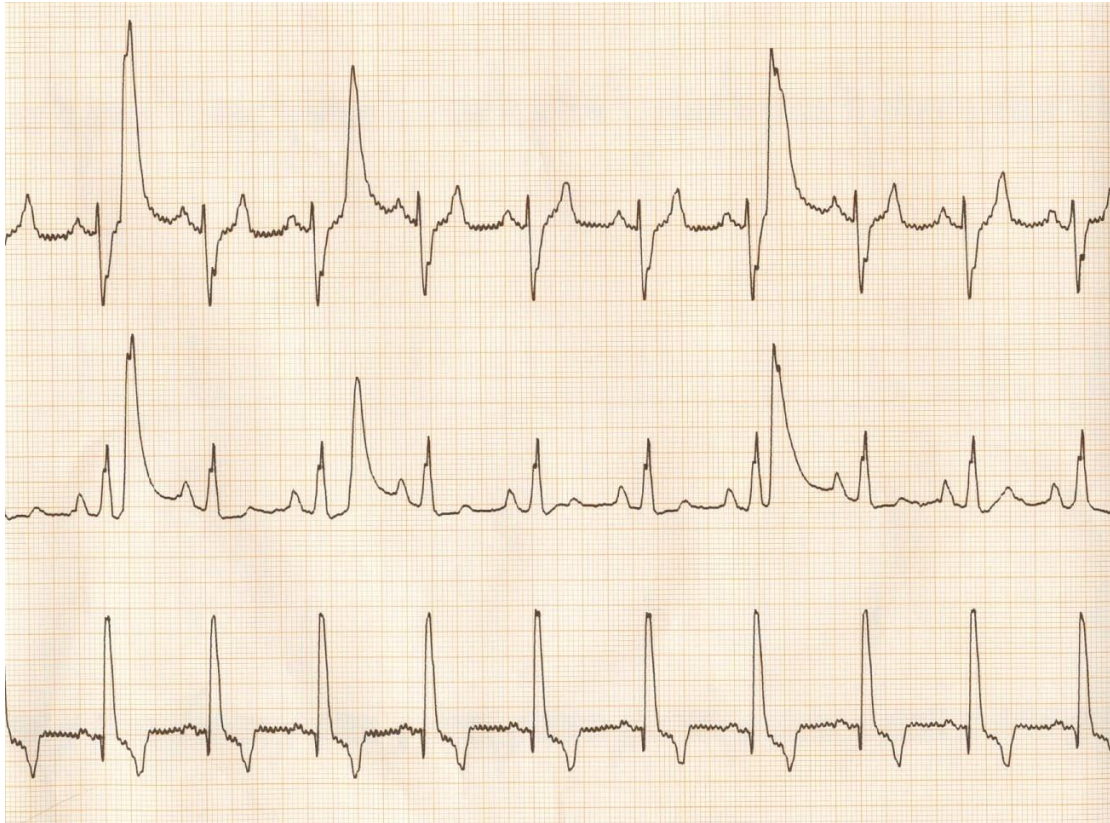
In this example the artefact is seen in leads I and II but not lead III. The common electrode to Leads I and II but not Lead III is on the right forelimb. Lead III is created by electrodes placed on the left forelimb and left hindlimb. Therefore as the artefact is seen only in leads I and II and not lead III, it can be concluded that it was movement of the right forelimb that caused this artefact.

Respiratory variation:
This is a common artefact caused by movement of the limbs as the ribcage moves during respiration. It is often difficult to eliminate however, placing a roll of tissue between the legs to separate them can often be a helpful technique. This also tends to be more of a problem if pads are used instead of clips. When the artefact is severe placing the animal in sternal recumbency will help to eliminate this problem, however it is important to recognise that there will be a difference in the complex size compared to the normal sizes in ECG taken in right lateral recumbency (Harvey and others 2005). The position of the animal for the ECG should be clearly annotated.

Purring artefact
Although not a common artefact (as many cats are too stressed to purr during the examination) some cats will still purr when stressed. This artefact appears as small, intermittent deflections around the baseline.

Electrical artefact
This is another common cause of baseline 'noise', however this is less of a problem in new machines as most are well shielded. This artefact is easy to recognise appearing as regular, small voltage waves (50 Hertz) around the baseline.

It is most frequently caused by electrical cables in the local vicinity, therefore it is important to minimise the amount of electrical equipment (fridges, clippers, computers) near the ECG machine. This artefact can best be avoided by switching off electrical appliances.

Poor contact
Good electrical contact is essential to achieve a good ECG. Clipping is generally unnecessary in most dogs and cats where spirit or an ECG gel massaged into the coat is usually sufficient. It can often take a few minutes to achieve good contact whilst the conduction agent reaches the skin, so it is often worth connecting the electrodes to the patient before setting up the ECG machine.

Achieving a high quality ECG trace will enable easier and more rapid interpretation of the ECG. A systematic and careful approach will lead to the acquirement of high quality ECG traces.

How to approach an ECG
When reading an ECG the following questions should be answered:
1. Is the rhythm regular, regularly irregular or irregularly irregular?
   ▪ Regular rhythm – there is an equal time period between each complex.
   ▪ Regularly irregular – there is a regular repeating pattern to the complexes. For example, the complexes are speeding up and /or slowing down in a predictable and repeating pattern. This would be typical for respiratory sinus arrhythmia.
   ▪ Irregularly irregular – There is no predictable pattern to the complexes. This is typical of atrial fibrillation or ECGs with premature beats.
This can be achieved by just eyeballing the ECG. If an arrhythmia appears to be present, then using callipers or a piece of card can be used to see if the interval between successive P waves and / or successive QRS complexes is regular.

2. What is the heart rate?
The heart rate can be counted in various ways as outlined below:
   ▪ The easiest method to measure heart rate, is to count the number of R waves in 6 seconds (15cm for 25mm/second paper speed (fig 3) and 30cm for 50mm/second paper speed) and then multiply by ten. If there are different numbers of P waves and R waves (e.g. 3rd degree atrio-ventricular block) then count both separately.
   ▪ Count the number of small boxes between two consecutive R waves and then divide 1500 by that number if paper speed is 25mm/second or divide that number by 3000 if paper speed is 50mm/second. When counting the heart rate using the R-R interval, it is important to ensure that the heart rate is regular otherwise this method will be inaccurate.
   ▪ Rate rulers can be used which again will give an instantaneous rate, which will be inaccurate if the heart rhythm is irregular (fig 4).

3. Is there a P wave for every QRS complex?

4. Is there a QRS complex for every P wave?

5. What is the QRS morphology?
   ▪ Normal 'narrow' complexes indicate normal conduction through the ventricles and therefore are supraventricular in origin (fig 5).
   ▪ Wide bizarre complexes usually indicate abnormal conduction through the ventricles which are usually ventricular in origin (rarely supraventriular origin conducted abnormally).

6. Mean Electrical Axis (MEA)
The MEA can help identify conduction disturbances or ventricular enlargement. In order to calculate the MEA multiple simultaneous leads must be used. There are several methods to calculate the MEA:-
   ▪ 'Eyeballing' method, this involves selecting the lead which is isoelectric, ie the height of the positive deflection is similar to the height of the negative deflection. The MEA is then perpendicular to this lead.
   ▪ The vector method involves calculating a vector for 2 leads and then plotting them on a graph to indicate the MEA.
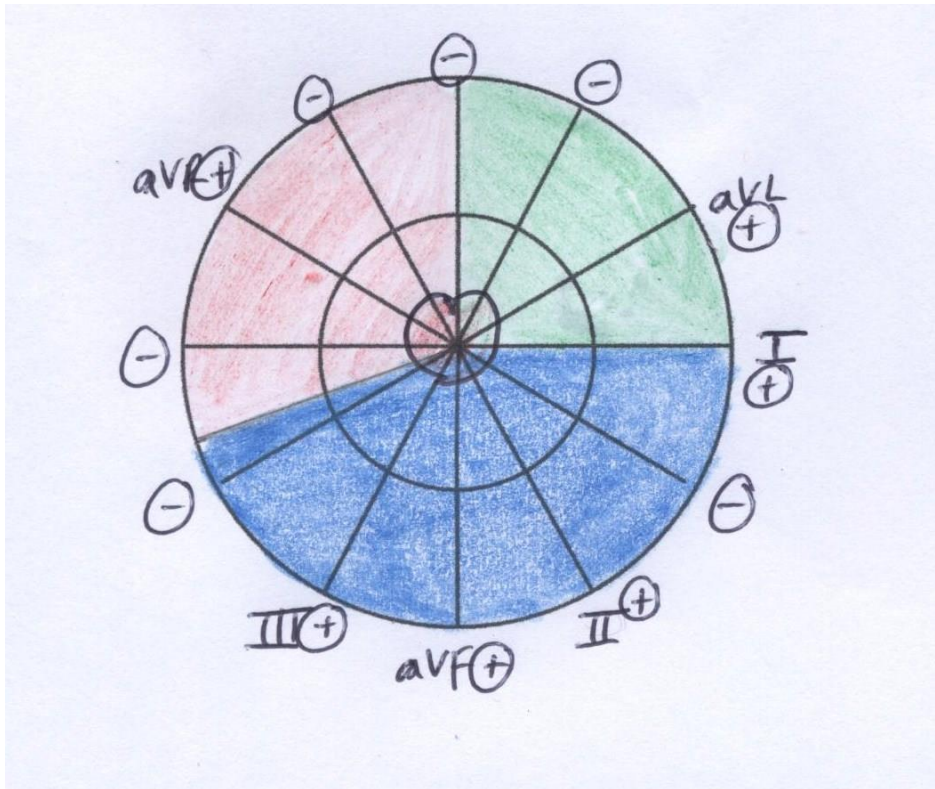
The blue shaded area represents the normal MEA in the dog.
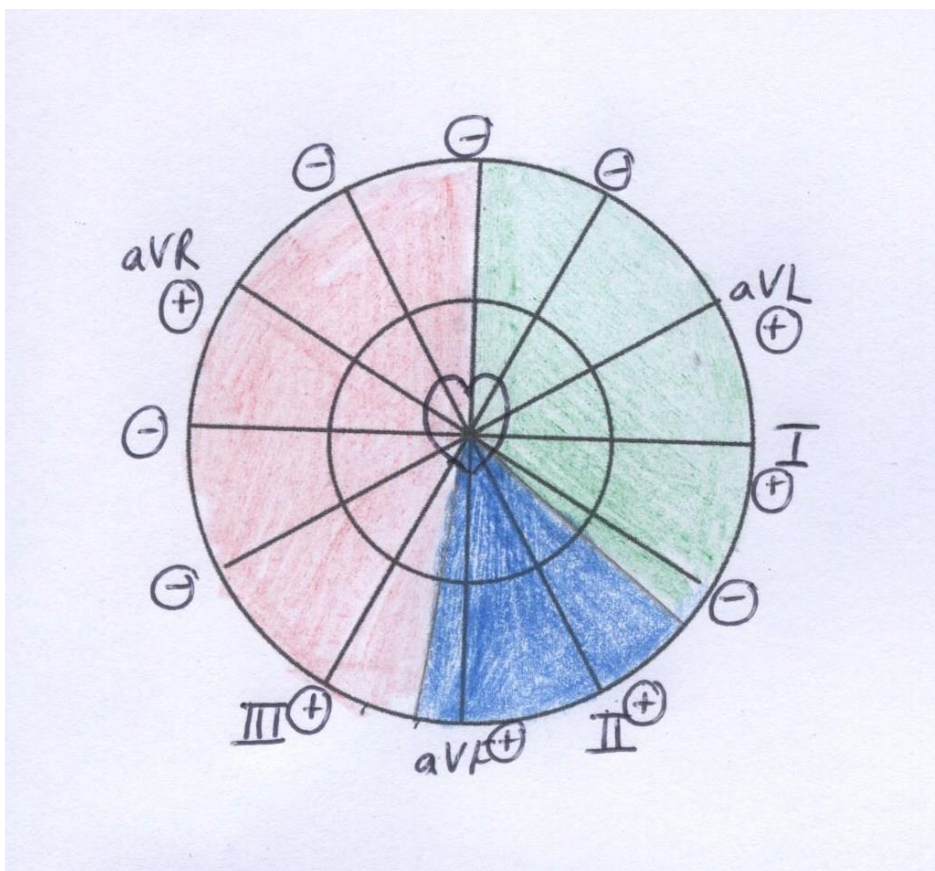
The blue shaded area represents the normal MEA in the cat.

An MEA which lies in the red shaded area, right axis deviation, suggests **either** right sided enlargement or a conduction deficit such as right bundle branch block. An MEA which lies in the green shaded area would indicate a left axis shift as seen with **either** left sided enlargement or a conduction deficit such as left bundle branch block. In order to differentiate a conduction deficit versus right or left sided enlargement further tests such as echocardiography and / or radiographs would be required.

Complex size
The size and timing of the complexes can be measured and compared to normal values for dogs and cats. There are multiple factors which will affect complex size; these include: extra cardiac morphology, for example obesity will lead to small complex size. Other extra-cardiac factors include body position, correct lead placement. All standard reference measurements have been obtained from animals in right lateral recumbency and therefore this position should be routinely used. Standard reference ranges are listed in table 1.

Having answered these questions, normal ECGs can be differentiated from abnormal ECGs. In future articles, examples will be given of all the common ECG diagnoses.

References and further Reading
Harvey, A. M., Faena, M., Darke, P. G. & Ferasin, L. (2005) Effect of body position on feline electrocardiographic recordings. *J Vet Intern Med* **19**, 533-536
Martin, M. (2000) Small Animal ECGs, 1 st Edition Blackwell Science Ltd.
Rishniw, M., Porciello, F., Erb, H. N. & Fruganti, G. (2002) Effect of body position on the 6-lead ECG of dogs. *J Vet Intern Med* **16**, 69-73
Tilley, N. S. (1992) Essentials of canine and feline electrocardiography. 3rd edn. Eds Tilley L.P. Lea & Febiger, Philadelphia.

Parameter to be measured	Reference range for dogs	Reference range for cats
Heart rate	70-160 bpm (adult dogs) 60-140 bpm (giant breeds) Up to 180 bpm (toy breeds) Up to 220 bpm (puppies)	120 – 240 bpm
Normal rhythm	Normal sinus rhythm, Sinus arrhythmia, wandering pacemaker	Normal sinus rhythm
P wave width	0.04 seconds 0.05 seconds (giant breeds)	0.04 second
P wave height	0.4 mV	0.2 mV
PR interval	0.06 – 0.13 seconds	0.05 – 0.09 seconds
R wave height	2.5 mV (small breeds) 3 mV (large breeds)	0.9 mV
R wave duration	0.05 seconds (small breeds) 0.06 seconds (large breeds)	0.04 seconds
QT interval	0.15 – 0.25 seconds	0.12 – 0.18 seconds
ST segment	No marked depression or elevation	No marked depression or elevation
T wave	Can be negative, positive or biphasic	Can be negative, positive or biphasic

Table 1 shows the Reference ranges for complex sizes in dogs and cats (Tilley 1992). Abbreviations: beats per minute (bpm).

References and Further Reading
Ferasin, L., Amodio, A. & Murray, J. K. (2006) Validation of 2 techniques for electrocardiographic recording in dogs and cats. *J Vet Intern Med* **20**, 873-876
Harvey, A. M., Faena, M., Darke, P. G. & Ferasin, L. (2005) Effect of body position on feline electrocardiographic recordings. *J Vet Intern Med* **19**, 533-536
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