ECG Interpretation

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Terminology
The electrocardiographic interpretation of arrhythmias due to ectopia requires an understanding of the terminology used. If this is accomplished, interpretation becomes relatively easy.

The term ‘beat’ implies that there has been an actual contraction. In ‘ECG-speak’ it is better to use the term complex or depolarisation to describe waveforms on the electrocardiograph.

Ectopic complexes may be classified by the following:

1. Site of origin. They are either ventricular or supraventricular. Supraventricular ectopics may be subclassified into either: (a) atrial (originating in the atria) or (b) junctional or nodal (originating in the AV node or bundle of His).
2. Timing. Ectopic complexes that occur before the next normal complex would have been due are termed premature, and those that occur following a pause such as a period of sinus arrest or in complete heart block are termed escape complexes.
3. Morphology. If all the ectopics in a tracing have a similar morphology to each other they are referred to as uniform and those in which there are different shapes as multiform.
4. Number of ectopics. Premature ectopic complexes may occur singly, in pairs or in runs of three or more; the latter is referred to as a tachycardia. A tachycardia may be continuous, termed persistent or sustained, or intermittent, termed paroxysmal.
5. Frequency. The number of premature ectopic complexes in a tracing may vary from occasional to very frequent. When there is a set ratio such as one sinus complex to one ectopic complex it is termed bigeminy and one ectopic to two sinus complexes is termed trigeminy.

Tachyarrhythmias

Ventricular premature complexes
Ventricular premature complexes (VPCs) are a common finding in dogs and cats. VPCs arise from an ectopic focus or foci within the ventricular myocardium. Depolarisation therefore occurs in an abnormal direction through the myocardium and the impulse conducts from cell to cell (not within the conduction tissue).

ECG characteristics
The QRS complex morphology is abnormal, i.e. unlike a QRS that would have arisen via the AV node. It is usually:
Abnormal (bizarre) in shape
Usually wide (prolonged); typically by ~50%
The T wave of a VPC is often large and opposite in direction to the QRS

Additionally a VPC is not associated with a preceding P wave (except by coincidence).
Since a VPC occurs prematurely, a normal atrial depolarisation (ie. P wave) arriving at
the AV node will meet ventricles which are refractory, thus the P wave is usually hidden
by the ventricular premature complex.

When a VPC is so premature that it is superimposed on the T wave of the preceding
complex (sinus or ectopic), i.e. the ventricles are depolarised before they have
completely repolarised from the preceding contraction, this is termed R-on-T.
A run of three or more VPCs is termed a ventricular tachycardia. Usually ventricular
tachycardia (VT) is regular with little or no variation (however there are exceptions to
this rule).

Clinical findings
Occasional premature beats will sound like a ‘tripping in the rhythm’. Depending upon
how early the beat occurs - the ‘extra’ premature beat may be heard or it might be
‘silent’ (and sound like a brief pause in the rhythm). There will be little or no pulse
associated with the premature beat (ie. a pulse deficit). If the premature beats are more
frequent, the tripping in the rhythm will start to make the heart rhythm sound more
irregular. With very frequent premature beats, the heart rhythm can sound quite chaotic,
and with a pulse deficit for each premature beat, the pulse rate will be much slower than
the heart rate. During a sustained ventricular tachycardia however, the heart rhythm will
sound fairly regular - pulses will probably be palpable, but reduced in strength,
becoming weaker with faster heart rates.

Supraventricular premature complexes
Supraventricular premature complexes (SVPCs) arise from an ectopic focus or foci
above the ventricles, i.e. in either the atria, the AV node or bundle of His. The ventricles
are then depolarised normally producing a normal-shaped QRS complex with a normal
duration.

ECG characteristics
QRS–T complexes, which have a normal morphology, are seen to occur prematurely.
The ECG features are:
• Normal QRS morphology (except with bundle branch block)
• QRS seen to occur prematurely
• P waves may or may not be identified
• If P waves are seen, they are usually of an abnormal morphology (i.e. non-
sinus) and the P–R interval will differ from a normal sinus complex.
A run of three or more SVPCs is termed a supraventricular tachycardia (SVT), it is
usually at a rate in excess of 160 per min (but can be as high as 400/min) and regular.
SVT needs to be distinguished from a sinus tachycardia.

Clinical findings
On auscultation it is not possible to distinguish ventricular premature beats from
supraventricular premature beats. Occasional premature beats will sound like a ‘tripping
in the rhythm’, with little or no pulse associated with the premature beat. If the
premature beats are more frequent, the tripping in the rhythm will start to make the
heart rhythm sound more irregular. With very frequent premature beats, the heart rhythm can sound quite chaotic, and with a pulse deficit for each premature beat, the pulse rate will be much slower than the heart rate. During a sustained supraventricular tachycardia however, the heart rhythm will sound fairly regular - pulses will probably be palpable, but reduced in strength, becoming weaker with faster heart rates.

**Escape rhythms**
When the dominant pacemaker tissue (usually the SA node) fails to discharge for a long period, pacemaker tissue with a slower intrinsic rate (junctional or ventricular) may then discharge, i.e. they ‘escape’ the control of the SA node. This is commonly seen in association with bradyarrhythmias (e.g. sinus bradycardia, sinus arrest, AV block). Escape complexes are sometimes referred to as rescue beats, because if they did not occur death would be imminent. Since they are rescue beats they should not be suppressed by any form of treatment. Treatment should be directed towards the underlying bradyarrhythmia.

If no escape rhythm developed, i.e. there was no electrical activity of any kind, then this is termed **asystole**. It would not be dissimilar to sustained sinus arrest if no escape rhythm developed. This is a terminal event unless electrical activity returns. If there is a failure of an escape rhythm during complete heart block, i.e. there are P waves but no QRS complexes, then this is termed **ventricular standstill**. Again, if ventricular electrical activity does not return death is imminent.

Junctional escapes are fairly normal in shape (the same as a supraventricular ectopic), whereas ventricular escapes are abnormal and bizarre (the same as a ventricular ectopic). A continuous junctional escape rhythm occurs at a rate of 60–70 per min and a continuous ventricular escape rhythm occurs at a rate of less than 50 per min. Either may be seen in complete AV block.

**AV dissociation**
AV dissociation describes the situation when the atria and ventricles are depolarised by separate independent foci. This may occur due to an accelerated junctional or ventricular rhythm, disturbed AV conduction or depressed SA nodal function.

**ECG characteristics**
The ECG shows a ventricular rate that is usually very slightly faster than the atrial rate. The P waves may occur before, during or after the QRS complex. The P waves and QRS complexes are independent of each other with the QRS complexes appearing to ‘catch up’ on the P waves. Complete AV block is one form of AV dissociation, but AV dissociation does not mean there is AV block.

**Clinical findings**
The heart rhythm will sound fairly normal and the pulse should match the heart rate.

**Fibrillation**
Fibrillation means rapid irregular small movements of fibres.

**Atrial fibrillation**
This is probably one of the most common arrhythmias seen in small animals. In atrial fibrillation (AF) depolarisation waves occur randomly throughout the atria. Since AF originates above the ventricles, it could also be classified as a supraventricular arrhythmia.
ECG characteristics
The QRS complexes have a normal morphology (similar to supraventricular premature complexes described previously) and occur at a normal to fast rate. The ECG features are:

• Normal QRS morphology (except when there is bundle branch block)
• R–R interval is irregular and chaotic (this is easier to hear on auscultation!)
• The QRS complexes often vary in amplitude
• There are no recognisable P waves preceding the QRS complex
• Sometimes fine irregular movements of the baseline are seen as a result of the atrial fibrillation waves – referred to as ‘f’ waves, however these are frequently indistinguishable from baseline artefact (e.g. muscle tremor) in small animals.

Clinical findings
The heart rhythm sounds chaotic and the pulse rate is often half the heart rate, especially with fast atrial fibrillation. This is a very common arrhythmia in dogs, and can be strongly suspected on auscultation of it’s chaotic rhythm and 50% pulse deficit. Very frequent premature beats (ventricular or supraventricular) can mimic it.

Ventricular fibrillation (VF)
This is nearly always a terminal event associated with cardiac arrest. The depolarisation waves occur randomly throughout the ventricles. There is therefore no significant coordinated contraction to produce any cardiac output. If the heart is visualised or palpated, fine irregular movements of the ventricles are evident – likened to a ‘can of worms’. VF can often follow ventricular tachycardia.

ECG characteristics
The ECG shows coarse (larger) or fine (smaller) rapid, irregular and bizarre movement with no normal wave or complex.

Clinical findings
No heart sounds are heard. No pulse is palpable.
Abnormalities in the conduction system

Abnormalities in the conduction system are associated with faults in either the generation of the impulse from the SA node or abnormalities in conduction through the specialised conduction tissue, i.e. the AV node, bundle of His and Purkinje system.

Sinus arrest and block
When there is a failure of the SA node to generate an impulse, i.e. the SA node has temporarily arrested – it is referred to as **sinus arrest**. Sinus block (also referred to as a sinoatrial exit block) is when the electrical impulse from the SA node to the atria is blocked. These bradyarrhythmias can result in bradycardia and/or asystole.

ECG characteristics
There is a pause in the rhythm with neither a P wave nor therefore a QRS–T complex, i.e. the baseline is flat (except for movement artifact if present). If the pause is only twice the R–R interval (or multiples of), it suggests sinus block. However, if the pause is greater than two R–R intervals (but not exact multiples of) it suggests sinus arrest. Long periods of arrest or block are often followed by ventricular ectopic escape complexes.

Clinical findings
A pause in the heart rhythm will be heard on auscultation (with no palpable pulse) and will effectively sound like the heart has briefly stopped. With sinus block it will be a very short pause and can be difficult to discern from a normal pause such as in respiratory sinus arrhythmia. With sinus arrest the duration of the pause will depend upon the duration of the period of sinus arrest and if this is occurring episodically or not.

Sick-sinus syndrome
This is a term for an abnormally functioning SA node and is probably better termed sinus node dysfunction. This ‘umbrella’ term refers to any abnormality of sinus node function including severe sinus bradycardia and severe sinus arrest. In some situations the profound bradycardia alternates with a supraventricular tachycardia, this is termed the **bradycardia–tachycardia syndrome**. Sick sinus syndrome has been reported to occur most commonly in female miniature Schnauzers at least 6 years of age and West Highland White and Cairn terriers. It has not been recorded in cats.

ECG characteristics
The electrocardiographic features are therefore quite variable and include persistent sinus bradycardia or episodes of sinus arrest without escape beats. One feature of sick sinus syndrome is that during long periods of sinus arrest there is often a failure of rescue escape beats. In the bradycardia–tachycardia syndrome there are periods of bradycardia such as sinus arrest, alternating with a supraventricular tachycardia. The bradycardia may be unresponsive to an injection of atropine.

Clinical findings
The findings on auscultation are very variable, from a markedly slow heart rate, to a variable rhythm, or with long pauses (associated with sinus arrest). The brady-tachy syndrome sounds like periods of slow heart rate alternating with periods of a very fast
heart rate, and not necessarily with any regularity. There may be pulse deficits during the tachycardic episodes and no pulse produced during the periods of arrest.

**Atrial standstill**
In atrial standstill there is an absence of any atrial activity, which can be confirmed by fluoroscopy or echocardiography (there is no A wave on an M-mode of the mitral valve or no atrial contraction inflow on Doppler studies). This occurs due to a failure of atrial muscle depolarisation, i.e. the SA node may produce an impulse, but the atria are not depolarised and remain inactive. If this occurs due to hyperkalaemia, the impulses are conducted from the SA node by internodal pathways to the AV node, thus there is a sinoventricular rhythm. If this occurs due to myocardial disease, the internodal pathways are also diseased and thus a nodal (or junctional) escape rhythm develops in these cases. Both of these rhythms look similar on ECG.

**Clinical findings**
The normal heart sounds will be heard (and associated pulse felt) in association with ventricular depolarisation. The rate will vary in each case, although generally it is slower than normal (often less than 60/min). (NB. In comparison to heart block, see following, no atrial contraction sounds are heard)

**ECG characteristics**
The electrocardiographic feature is of the absence of P waves usually with a slow (less than 60 per min) escape rhythm. The quality of the ECG has to be excellent (i.e. the baseline must be flat without any artifacts) to confidently diagnose the absence of P waves. The QRS complexes are often of a relatively normal shape (junctional escape), but sometimes with a slightly prolonged duration. In a few cases the escape rhythm can be ventricular.

**Heart block**
This is the failure of the depolarisation wave to conduct normally through the AV node, the correct term is therefore AV block. Heart block is often as a synonymous term for AV block. AV block may be partial (first or second degree block) or complete (third degree block).

**First degree AV block**
First degree AV block occurs when there is a delay in conduction through the AV node and there is usually a sinus rhythm.

**ECG characteristics**
The P wave and QRS complexes are normal in configuration, but the PR interval is prolonged.

**Clinical findings**
No abnormality will be appreciated on auscultation or palpation of the pulse, and it cannot be distinguished from a normal sinus rhythm.

**Second degree AV block**
Second degree AV block occurs when conduction intermittently fails to pass through the AV node, i.e. there is atrial depolarisation which is not followed by ventricular depolarisation.
ECG characteristics
The P wave is normal, but there is either an occasional or frequent failure (depending on severity) of conduction through the AV node resulting in the absence of a QRS complex.

Second degree AV block can be classified further. When the P–R interval increases prior to the block it is termed Mobitz type I (also known as Wenckebach’s phenomenon). But when the P–R interval remains constant prior to the block, this is termed Mobitz type II and the frequency of the block is usually constant, i.e. 2:1, 3:1 and so on.

Clinical findings
There will be occasional pauses in the rhythm associated with the absence of ventricular depolarisation. On very careful auscultation the atrial contraction sounds (“A” sound or S4) can often be appreciated as a faint noise in association with atrial depolarisation.

Complete (third degree) AV block
Complete AV block occurs when there is a persistent failure of the depolarisation wave to be conducted through the AV node. A second pacemaker below the AV node (i.e. the block) discharges to control the ventricles. This second pacemaker may arise from:
- lower AV node or bundle branches producing a normal QRS (i.e. junctional escape complex) at approximately 60–70 per min
- Purkinje cells producing an abnormal QRS–T complex (i.e. ventricular escape complex) at approximately 30–40 per min.

ECG characteristics
On the ECG, P waves can be seen at a regular and fast rate but the QRS–T complexes are at a much slower rate, and usually fairly regular. The P waves and QRS complexes occur independently of the other. This is best demonstrated by plotting out each P wave and each QRS complex on a piece of paper.

Clinical findings
In many cases the ventricular escape rhythm associated with complete heart block is very regular (metronomically so), although slow. So a regular slow bradycardia is heard with normally a good palpable pulse (sometimes the escape rhythm is not regular). On very careful auscultation (sometimes using the bell of the stethoscope) the atrial contraction sounds (S4) can be faintly heard at a faster rate and not related to the normal lub-dub of ventricular contraction.

Intraventricular conduction defects
The bundle of His divides into left and right bundle branches, supplying the left and right ventricles respectively. The left bundle branch further divides into anterior and posterior fascicles.

As well a block occurring in the AV node (heart block), block can occur in conduction of the electrical impulse may occur in one or more of these conduction tissues (and occasionally in combination). The most commonly seen conduction defects seen in dogs are:
- right bundle branch block (RBBB)
• left bundle branch block (LBBB)

and cats is:

• left anterior fascicular block (LAFB).

These result in abnormal depolarisation patterns as there will be a delay in depolarisation of the part of the ventricles supplied by the affected conduction tissue. This is also referred to as aberrant ventricular conduction or ventricular aberrancy.

**Right bundle branch block**

Right bundle branch block (RBBB) occurs due to failure/delay of impulse conduction through the RBB. Depolarisation of the left ventricle occurs normally, but depolarisation of the right ventricular mass occurs through the myocardial cell tissue resulting in a very prolonged complex.

**ECG characteristics**

The QRS duration is prolonged (>0.07 seconds). The QRS complex has deep and usually slurred S waves in leads I, II, III and aVF and is positive in aVR and aVL. The MEA is to the right. Note that RBBB needs to be differentiated from a right ventricular enlargement pattern.

An animal with atrial fibrillation can concurrently have bundle branch block, this is often a more challenging ECG interpretation!

**Clinical findings**

The heart sounds and rhythm will sound normal with associated palpable pulses. In some dogs, with very careful auscultation a split second heart sound (S2) may be heard, due to delayed closure of the pulmonic valve.

**Left bundle branch block**

Left bundle branch block (LBBB) occurs due to failure of conduction through the LBB. Depolarisation of the right ventricle occurs normally and depolarisation of the left ventricle is delayed and occurs through the myocardial cell tissue resulting in a very prolonged complex.

**ECG characteristics**

The QRS duration is very prolonged (>0.07 seconds). There are positive complexes in leads I, II, III and aVF and negative in aVR and aVL. LBBB needs to be differentiated from a left ventricular enlargement pattern.

**Clinical findings**

The heart sounds and rhythm will sound normal with associated palpable pulses.

**Left anterior fascicular block**

Left anterior fascicular block (LAFB) occurs due to failure of conduction through the anterior fascicle of the LBB. It is not an uncommon finding in cats but is rare in the dog.

**ECG characteristics**

The QRS complex is normal in duration but there are tall R waves in leads I and aVL, deep S waves (>R wave) in leads II, III and aVF. The MEA is markedly to the left; approx. 60° in the cat.

A cat with atrial fibrillation can also concurrently have fascicular block.
Clinical findings
The heart sounds and rhythm will sound normal with associated palpable pulses.

Intermittent ventricular aberrancy
This is sometimes seen when a supraventricular premature depolarization reaches the bundle branches before one or other has fully repolarisation (usually the right bundle branch), i.e. is still partially depolarized, which results in a functional block. Because the QRS complex is premature and bizarre in shape it mimics a VPC.

If a supraventricular tachycardia (SVT) is associated aberrant ventricular conduction, this will mimic a ventricular tachycardia (VT). Thus the term a broad complex tachycardia is sometimes used to describe this ECG finding.

ECG characteristics
The QRS complex is bizarre and prolonged, often a right bundle branch block morphology) and is premature. It can be very difficult to distinguish from a true VPC. If there is a preceding P wave visible (and not hidden by the previous T wave) then this might help to confirm it was a supraventricular complex.

An SVT with aberrancy will mimic a VT.

Clinical findings
Sounds like premature beat, and will have a pulse deficit. An SVT with aberrancy will simply produce a tachycardic sounding heart with weak pulses.
Artifacts

Artifacts are abnormal deflections reproduced on an ECG recording that are not associated with the electrical activity of the heart. They have the potential to either mask the ECG or mimic ECG activity: producing an artifact-free tracing is of paramount importance.

Electrical interference
Electrical interference produces fine, rapid and regular movements on the baseline of the ECG recording. They are often associated with interference due to electrical cables (electromagnetic waves) within the room in which the recording is being made. They can be transmitted by the person restraining the animal who acts as an aerial or through the power-line of the ECG machine. The fine deflections usually occur at a rate of 50 per second (Hz) (60 per second in America).

To correct this problem:
Ensure the clip-to-skin connections are good and are insulated (isolated), poor connections will permit electrical interference to manifest.
Ensure the animal is insulated from the surface by placing a rug under it.
Ensure the ECG machine is earthed (to the building), or try not to run on the mains supply but on battery.
Try insulating the handler from the dog by having them wear gloves.

Muscle tremor artifact
This can look a little similar to electrical interference, but the fine deflections in this instance are not regular but fairly random. It can be produced by the animal trembling or shaking, or by trying to record the ECG in a standing animal. Purring in a cat will also result in baseline ‘trembling’!

To correct this problem:
Ensure the limbs are relaxed and supported.
Find a position in which the animal will relax best, preferably not standing.
Try holding the limbs to minimise the tremor.
To stop a cat purring: dab a little spirit on the cat’s nose using cotton wool.

Movement artifact
This is a more exaggerated form of tremor artifact, but in this case the deflections are not fine but variable and large. The stylus moves up and down the paper. It can be associated with respiratory movement or if the animal is moving or struggling.

To correct this problem:
Correction of this is similar to tremor artifact.
Try to get the animal to relax and remain still.
Ensure the ECG cables are not moving with movement of the animal, e.g. respiratory movement (see page 38), or because the clips are not stable and secure.
Recording an ECG

The connectors (electrodes)
To connect the ECG cable to the animal’s skin requires a connector – this is called an electrode. Since animals have a coat of hair, the commonly used human sticky adhesive electrodes are not convenient for everyday regular use. This is because a patch of hair would have to be shaved, the adhesive electrode applied and it still usually does not stick to animal skin! Therefore, it needs to be held in place by wrapping a bandage around the limb and electrode.

There are small metal plate electrodes – paediatric limb electrodes, that can be used instead of crocodile clips, but need to be positioned on the limb by means of tape, bandage or rubber band.

The most commonly used electrode to connect the ECG cable to the animal’s skin is a crocodile clip. While these provide an excellent electrical connection, their bite can be painful to less stoical animals. To minimise the pain of crocodile clips the teeth can be filed down a little and the clips bent outwards (until they are atraumatic but still stay in place). Or a small conductive plate can be soldered into the tip of the teeth.

Making the connection
This is the single most important part of ECG recording to obtain a good diagnostic quality tracing. Since crocodile clips are the most commonly used form of electrodes, the following discussion will be based on these. But if you have decided to use an alternative electrode, then adapt the description accordingly.

Using spirit
It is often sufficient with crocodile clips to pick up a fold of skin between finger and thumb (rolling the skin to feel its edge through a hairy coat) and with the other hand open the crocodile clip maximally, part the hair and attach the clip to the skin. To obtain good conduction between skin and crocodile clip requires the addition of a conducting medium – spirit is often adequate. Spray with a little spirit (or alcohol), just sufficient to wet the crocodile clip and through the hair to the skin.

However, spirit evaporates after 5–10 min, so this method would not suffice if the ECG recording takes longer than this (such as during anaesthetic monitoring). Additionally, if spirit does not produce a good-quality, artifact-free recording, then an alternative method needs to be considered.

Using gel
Shave the site where the crocodile clip is to be placed. Either: (1) rub a little gel (ECG gel is ideal, but ultrasound gel or K-Y jelly are cheap alternatives) on to the skin and then attach the crocodile clip as above; or (2) attach the crocodile clips then rub the gel on the clip and around it onto the skin. This ‘way round’ is usually easier, as your fingers are not too slippery to open the crocodile clips thereafter!

Where to place the electrodes
The site of attachment of the electrodes is on each of the four limbs, using the correct ECG cable on the correct leg. Where exactly on the leg is not too critical. Essentially a
good loose fold of skin is required preferably with little hair. In each animal you need to pinch the skin at various sites on the limbs to find the best site.

Forelegs
In the author’s experience, the flexor angle of the elbow is a useful site. An alternative site is caudal and just dorsal to the elbow. However, since this is close to the chest, respiratory movement can result in movement of the cable and clip, thus the ECG recording may be spoiled by movement artifact. Another site is halfway between the elbow and carpus, on the palmer aspect of the leg.

Hind legs
In the author’s experience, the flexor angle of the hock (or sometimes just above this) is a useful site. Alternative sites are either above or below the knee, on the dorsal aspect of the limb.

When using adhesive electrodes
Adhesive electrodes usually need to be held in place by a bandage, therefore shave sites on the forelegs above the carpus and on the hind legs above or below the hock.

Adhesive electrodes can also be placed on the central pad (of the paw) in small animals – this provides a satisfactory site of contact, although instability of the electrode can result in some movement artifact. This can be a useful site in other domestic small and exotic animals seen by the veterinary practitioner.

Isolating the electrodes
Once all the electrodes have been attached it is essential to ensure that each electrode, the skin to which it is attached and the conducting medium (e.g. the spirit or gel), are not touching any other part of the animal, the handler or the table. This has the potential to cause electrical shorting and introduce artifacts into the ECG recording.

How to position the ECG cables
In addition to the above, it is prudent not to place the crocodile clips such that the ECG cable runs over the animal which can lead to respiratory movement artifact (as mentioned above) or to then twist the cable and ultimately the clip and skin – even stoical animals may not tolerate this. When applying the crocodile clip have the ECG cable positioned away from the animal and resting on the table (or ground).

Positioning the animal
To minimise the electrical activity of skeletal muscles the animal must be relaxed and resting. If the animal trembles, shakes, pants or purrs, then all this activity will be manifest on the ECG resulting in baseline artifact. This may hide small ECG complexes such as P waves, especially in cats, or mimic ECG activity. Thus a good-quality ECG will have minimal movement and there should be a nice steady baseline in between each ECG complex.

If the animal would be put at risk (e.g. if it was in respiratory distress) by making it adopt a position (as follows) that it would not tolerate, then an ECG should be recorded in what ever position is achievable.

Dogs
Dogs are preferably placed in right lateral recumbency. In many dogs a recumbent position will reduce skeletal muscle electrical activity. And the normal values for the dog ECG have been determined based on this position. If measurement of amplitudes are not critical, such as when examining primarily an arrhythmia, then recording an ECG while the dog lies, sits or even stands is acceptable, provided a good-quality tracing with minimal baseline movement artifact can be obtained.

Cats
The normal values for cats have not been determined in a lateral recumbent position, thus recumbent positioning is less important. Many cats will often sit in a hunched position quite still – but each individual cat is different and the veterinary surgeon must determine how each cat prefers to keep still. In fractious cats (if the electrodes can be placed!) putting the cat back in a basket together with the electrodes attached and ECG cables until it settles is a useful method. When, or if, the cat settles, the ECG can be recorded while the cats sits in the basket. However, this method should, of course, be aborted if the cats starts to bite the ECG cables. Often cats do resent the crocodile clips, in which case, shaving a patch of hair and bandaging in place adhesive electrodes or metal plates, although more time consuming, is easier!

Chemical restraint
All sedative and tranquilliser drugs have a variable effect on the heart and/or autonomic tone. Drugs can therefore change the rate and rhythm of the heart directly or through effects on the autonomic tone. So, if you are performing an ECG to determine what the arrhythmia is that you heard, then there is a possibility that this will change if a chemical restraint is used. Ideally, therefore, any form of chemical restraint should be avoided prior to recording an ECG. If chemical restraint cannot be avoided, then based on physical examination, determine the rate and rhythm before and after using the drugs, and any differences should be taken into account when interpreting the ECG recording.

Setting up and preparing the ECG machine
This will vary a little between different ECG machines and adjustments to the following guidelines (which are based on a standard ECG machine) should be allowed.

Paper speed
Select the paper speed. Options are usually 25 or 50 mm/s, and sometimes 100 mm/s. The paper speed selection is partly dependent on the animal's heart rate. As a guide: for normal heart rates in dogs set the speed at 25 mm/s, but if there is a fast heart rate (and routinely for cats) set the paper speed at 50 mm/s. In ECG machines with a computer-type print-out which produces a steppiness in the lines (i.e. pixel effect), measurement of ECG complex durations is best achieved at 100 mm/s.

Calibration
This is usually set at 1 cm/mV. However, if the complexes are very small this can be increased to 2 cm/mV and if the complexes are very large it can be reduced to 0.5 cm/mV. The calibration should be marked on the ECG paper by briefly running the ECG paper and pressing the 1 mV marker button – found on most standard ECG recorders.

Filter setting
Ideally, if good connections have been made, this can usually be left off, i.e. no filter. Additionally amplitude measurement should always be performed in an unfiltered tracing, as the dampening effect of the filter will reduce the amplitude of the complexes.
by a variable, although small, amount. If primarily examining for an arrhythmia and there is baseline artifact that cannot seem to be avoided, then filtering can reduce the baseline artifact and make reading of the ECG tracing easier.

Positioning the stylus
During the recording the stylus should be positioned (if this is manually operated on the ECG machine) so that the whole of the ECG complex is within the ‘graph lines’ of the ECG paper. If the ECG produces particularly large complexes that run-off the ‘graph paper’ (or outside the limits of the stylus or paper) this is referred to as clipping. Remember then to move the stylus, up or down, so that the whole of the ECG tracing is within the graph paper (and not extending into the white margins) or alternatively reduce the calibration – whichever is more appropriate.

Recording an ECG – a suggested routine

Ten seconds of all six limb leads
Run the ECG on each of the six bipolar leads, I, II, III, aVR, aVL and aVF, each for approximately 10 seconds. In order to ensure that each lead is well centred within the ‘graph lines’ of the ECG paper, briefly pause the ECG paper (with the stylus still moving) when switching the ECG machine from one lead to the next, until the stylus can be re-positioned as described above.

A rhythm strip
Switch back to lead II and record a long rhythm strip, 30–60 seconds, depending on each individual case requirement. If you have auscultated an occasional abnormal beat, then the ECG rhythm strip will need to be run until that abnormal beat is repeated. If lead II does not produce a good-quality tracing with satisfactorily large complexes, then run a rhythm strip on a lead that does. Or if you are searching for P waves (which can often be small and hard to see) then run the limb lead in which these are best shown.

A representative rhythm strip!
If you auscultated what you thought was an arrhythmia, but it is not revealed on the ECG rhythm strip, then simultaneously auscultate the animal while continuing to run the ECG recording. It might be that the abnormality is only intermittently present, in which case you may have to continue to auscultate the animal until the arrhythmia is heard and hopefully captured on ECG. Maybe the arrhythmia is still audible on auscultation but not recognised on the ECG – in this case the ECG tracing should be sent to a cardiologist for interpretation. Or, the abnormal heart sounds heard may not be an arrhythmia, but, for example, could be a gallop sound. In summary, ensure that the ECG recording obtained is representative of what you found on physical examination.

Label the tracing
Ensure the ECG recording is well labeled (unless the ECG machine does this automatically), either for future reference, or for other colleagues within your practice to be able to examine the recording, or in case you need to submit the tracing to a cardiologist for interpretation.

Recommended Reading