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ECG interpretation

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ABSTRACT: Electrocardiograms (ECGs) are an important diagnostic tool for every day work in veterinary practice, yet still can be a daunting prospect for veterinary nurses. ECGs have many uses from the emergency case to post surgery recovery, from anaesthesia to monitoring drug toxicities. Gaining a better understanding of what the ECG trace should look like, appreciating how to minimise problems such as artefact, and following a simple and logical guide to interpretation, will improve confidence. Basic nursing skills such as clinical presentation and pulse and heart rate assessment, will also help guide the nurse as to the severity of the arrhythmia.

KEYWORDS: arrhythmia; ECG; electrocardiogram; sinus rhythm

Introduction

Electrocardiograms (ECGs) can have many uses in veterinary practice, but the main purpose is to determine heart rate and heart rhythm. Interpreting an ECG can be daunting, however a simple set of questions, based on a sound understanding of what should normally occur, can help clarify even the most challenging of cases. Arrhythmias are most concerning when they become haemodynamically significant or the heart muscle has become electrically unstable. Only with practice and repetition will understanding and confidence improve.

Gold standard technique

A good technique for recording an ECG is very important, because at best, interference (artefact) can hinder diagnosis, and at worst, cause misinterpretation. Artefact can be electrical interference, such as clippers, or caused by movement. To optimise the recording, the patient should be as calm as possible. Gold standard technique states that the patient should be in right lateral recumbency on a padded bed, with the limbs held slightly apart to avoid movement artefact (Figure 1). It has been suggested that positioning is not as important in cats, which could help improve patient compliance (Willis, 2010). Sternal recumbency should be used if the patient is dyspnoeic, so as not to further compromise respiratory effort. The electrodes should be placed on all four limbs (see Table 1), behind the elbows and in front of the stifles. In practice this is not always possible, for example, if a cat has a bandaged in intravenous catheter. In cases such as these, it can be enough to attach the electrodes close to the limbs. A common cause of artefact is poor contact between the patient and the electrodes. Different types of electrodes can be used, such as crocodile clips (which should be filed down to avoid causing pain), comfy clips (that have no teeth but simply attach to lose skin) or adhesive sticky pads. Patient comfort and ease of use should guide choice. A conduction agent such as electrode gel or

Figure 1. Gold standard ECG position. The patient is lying in right lateral recumbency on a padded bed. The limbs and cables are not touching and are attached in the correct colour order.

Table 1. Electrode placement for British and American machines

Electrode	Colour for British machines	Colour for American machines
Right forelimb	Red	White
Left forelimb	Yellow	Black
Left hindlimb	Green	Red
Right hindlimb	Black	Green

Adapted from p69, Willis (2010).

surgical spirit should be used to improve contact. Surgical spirit is faster acting and easier to clean, but is flammable, if defibrillation might be required.

ECG machines vary in how many cables they have, most commonly 3, 4, or 5, but some will have more. Figures 2 and 3 show how the electrodes create a triangle of leads measuring electrical potential across the heart muscle. If a machine only has three electrodes and cables, then the ECG trace can only be viewed in one of those leads, because the third electrode acts as the earth. For example, on a multi-parameter anaesthetic machine, the operator can select lead I, II or III, but not view all three at the same time. However, if the machine has four or more electrodes, then the ECG trace can be viewed in three leads (I-III) at the same time, or in six leads (aVR, aVL and aVF) because the fourth cable acts as the earth. If the machine has 6 lead capability it is advised to record the trace as such, so that a more in-depth interpretation is possible if required (Borgeat & Knowlson, 2016).

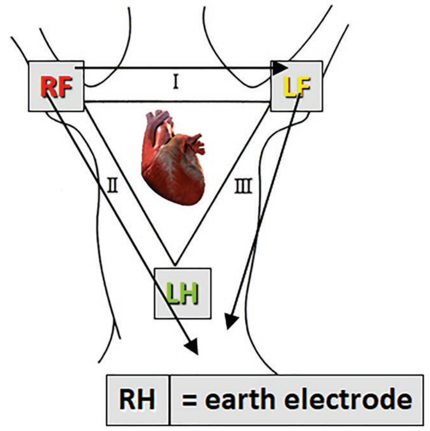

Figure 2. How ECG leads measure electrical conduction. Lead I measures the potential difference from right forelimb and left forelimb. Lead II measures the potential difference from right fore to left hind. Lead III measured the potential difference from left fore to left hind.

The sinus complex

Conventional ECG interpretation starts with reading lead II. It is important to understand the anatomy of the conduction system and recognise the components of a normal, or sinus rhythm. The sinus complex consists of the following (see Figure 4):

P wave – This is where the sinoatrial (SA) node pacemaker cells fire, spreading across the atria depolarising (contracting), the atrial myocardium. As the atria are a smaller muscle mass than the ventricles, the deflection on the ECG trace is small.

P-R interval – The electrical impulse slowly passes through the atrioventricular (AV) node to allow for coordinated ventricular contraction. No myocardium is depolarised at this point, so the ECG trace goes back to baseline.

Q wave – Early impulses pass through the AV node via the left bundle branch. There is a small deflection on the ECG trace, as depolarisation moves from left to right across the intraventricular septum.

R wave – The His-Purkinje fibre network is fully activated by the impulse, which depolarises the ventricles simultaneously. This is the largest muscle movement and is reflected as the largest wave on the ECG trace.

S wave – Finally, the basal parts of the ventricular walls are depolarised.

S-T segment -The complex returns to baseline.

T wave – The ventricles repolarise, or relax, ready for the next contraction.

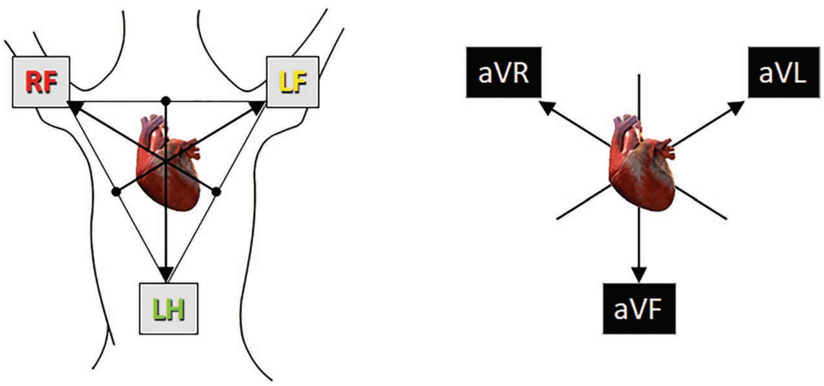

Figure 3. Diagram showing how the 6 lead ECG is formed. Lead aVR measures the potential difference from left forelimb and left hindlimb to the right forelimb. Lead aVL measures potential difference from right fore and left hind to left fore. Lead aVF measures potential difference from right fore and left fore to left hind.

Systematic approach to ECG interpretation

To help guide ECG interpretation a systematic approach can be applied using a set of questions.

Question 1: What is the heart rate?

Establishing whether the heart rate is fast, slow or normal, will focus interpretation on a set of specific answers. Table 2 shows the possibilities.

Questions 2 – 4: Is there a P wave for every Q wave, a Q wave for every P wave, and are they consistently and reasonably related?

As illustrated above, every complex should have a P wave and a QRS wave, and that should happen every time. If it does not always happen, or happens inconsistently, another set of possibilities, used in conjunction with question 1, are raised. Figure 5 shows some of the possibilities.

Question 5: What is the QRS morphology?

Determining the appearance of the QRS wave can help establish the origin of the complex. As seen in Figure 4, the R wave should be tall and narrow. Time is displayed horizontally on the ECG trace, so the complex should be narrow because the impulse uses the existing His-Purkinje network. If the complex originated in the atrium and has occurred prematurely,

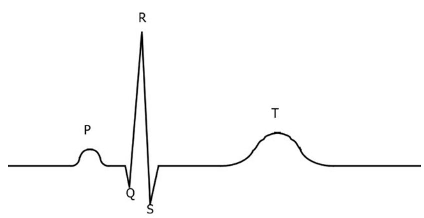

Figure 4. The labelled sinus complex, as seen in lead II.

Table 2. Common rhythms by rate.

Tachycardia	Rate within the expected range for situation/breed/species	Bradycardia
Sinus tachycardia	Sinus rhythm	Sinus bradycardia
Atrial fibrillation	Sinus arrhythmia	Escape rhythms
Atrial tachycardia	Atrial fibrillation	Atrioventricular (AV) block
Ventricular tachycardia	Atrioventricular block	Sinoatrial (SA) block/arrest
	Ventricular premature complexes (VPCs)	Atrial standstill
	Atrial premature complexes (APCs)/ supraventricular complexes (SVPCs)	

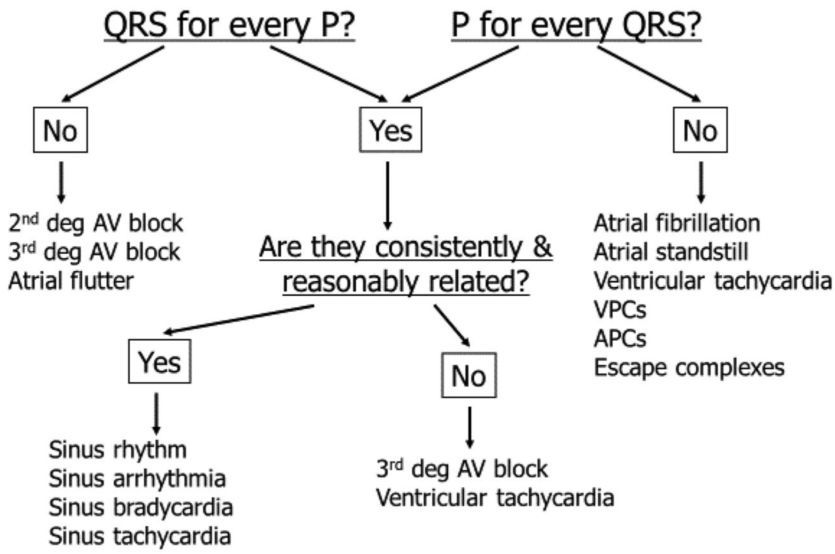

Figure 5. Rhythms associated with the P-QRS relationship

before the SA node has fired, the complex would still pass down the established His-Purkinje network, therefore giving a narrow complex, but without a P wave. Alternatively, if the complex originated in the ventricles, the impulse has to depolarise the ventricular myocardium cell by cell, therefore taking longer before reaching the His-Purkinje network. This gives the complex a wider appearance on the timeline of the ECG. Figures 6 and 7 show examples of atrial and ventricular premature complexes.

Why can arrhythmias occur?

Normal function of cardiac myocytes is maintained by four main components, the structural integrity of the cell itself, by the composition of the interstitial fluid which bathes the myocyte, and by its own neural and blood supply. Arrhythmias occur when a disease process results in disruption of any of these regulatory factors. Some of the most common causes of arrhythmias are heart disease, exposure to drugs or toxins, hypoxia, hyper or hypothermia, inflammation, autonomic imbalance, or metabolic abnormalities. The main concern with arrhythmias is that the heart rates becomes too fast or too slow. Life threatening arrhythmias occur for two main reasons. Firstly, the patient can become haemodynamically unstable as a result of a decrease in arterial blood pressure. If the heart cannot relax and fill as it should, it will not be able to maintain adequate blood pressure. The second reason is that the arrhythmia can become electrically unstable, putting the patient at increased risk of ventricular arrhythmias or asystole. Life threatening arrhythmias can be identified by absent or weak pulses, cold extremities, pallor and collapse. Cardiopulmonary resuscitation (CPR) may be necessary, and so veterinary surgeon assistance should be sought immediately.

Common arrhythmias seen in veterinary practice

Tachyarrhythmias

The most common atrial arrhythmia seen in small animal medicine is atrial fibrillation (Martin, 2007). It usually occurs as a result of left sided heart disease, when the atrial myocardium has become stretched. Whilst urgent, patients can often cope with this arrhythmia as they can often maintain adequate blood pressure. Atrial fibrillation is characterised by a chaotic sounding heart rhythm, no discernible P waves, and tall and upright complexes (Figure 8).

Ventricular tachycardia (VT) is characterised by wide and bizarre complexes and no discernible P waves (Figure 9). It is a concerning arrhythmia because ventricular

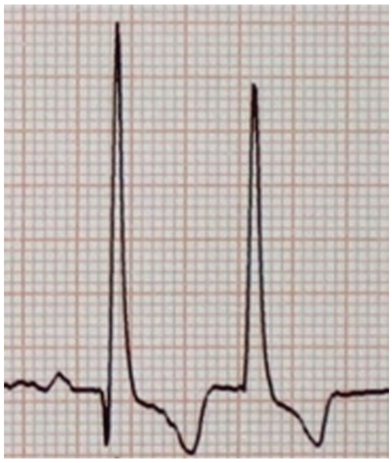

Figure 6. An example of an atrial complex. Note the 2nd complex is smaller than the 1st complex, but its morphology is still tall and narrow. This complex has occurred before the SA node fired, as there is no P wave associated with this complex.

beats are less efficient, the heart does not have time to relax and fill properly, and can therefore become haemodynamically and/or electrically unstable, leading to life threatening ventricular fibrillation. VT can be caused by structural heart disease, systemic disease or drugs (Dennis, 2010).

Bradyarrhythmias

Atrioventricular (AV) block occurs when there are disturbances in the conduction of the impulse, and has three main categories. First degree AV block is characterised by a delay in conduction from the SA node through the AV node, resulting in a delay between P wave and the QRS complex. Second degree AV block occurs where some P waves are not conducted at all (Figure 10). In practice it is often seen with anaesthesia or sedation, but can also result from excessive vagal tone or organic disease of the conduction system (Ware, 2007). Third degree AV block happens when there is no communication between the atria and the ventricles at all (Figure 11). The ventricular complexes associated with this arrhythmia are known as escape complexes. This is an electrically unstable arrhythmia because the escape rhythm could fail at any time. Or it can be haemodynamically significant because of the bradycardic rate.

Atrial standstill occurs when the SA node fires, but the impulse is not conducted (Figure 12). It is characterised by a lack of P waves, bradycardia and tall T waves. QRS complexes can be tall and narrow or wide and bizarre. It can be seen with hyperkalaemia, such as an Addisonian crisis or a blocked bladder (Dennis, 2010). Patients can present with haemodynamic

Figure 7. An example of a ventricular premature complex.

Figure 8. Atrial fibrillation. Note the lack of obvious P waves.

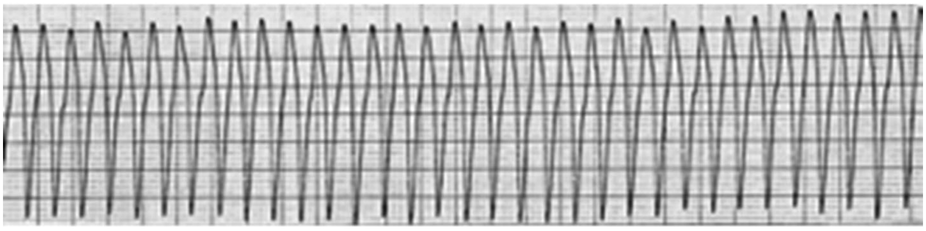

Figure 9. Ventricular tachycardia.

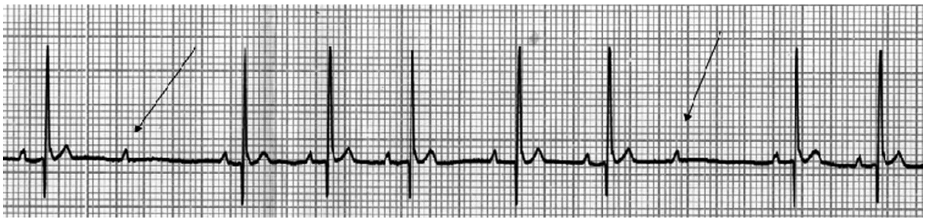

Figure 10. Second degree AV block. Arrows point to unconducted P waves.

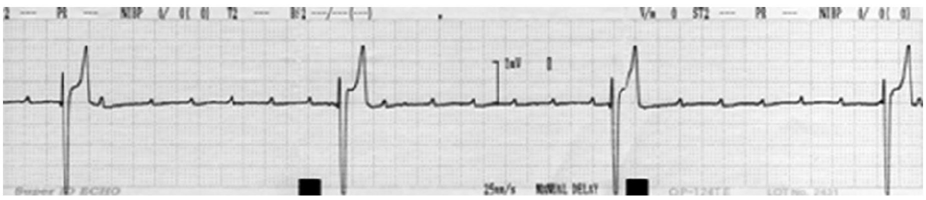

Figure 11. Third degree AV block. Note how there is no communication between the atria and ventricles.

Figure 12. Atrial standstill. Note the absence of P waves and tall T waves.

compromise, and the underlying disease process needs to be rectified.

Nursing considerations

ECGs should be used for emergencies, monitoring anaesthesia, post-surgical cases, if an arrhythmia is suspected, abnormalities auscultated on physical examination, and to assess anti-arrhythmic drug therapy. However, whilst a solid understanding of ECG interpretation and the impact of arrhythmias is beneficial, it is also important to look at the patient and the clinical signs being exhibited and be prepared for potential deterioration. If the patient has collapsed and pulses are absent, nurses should instigate CPR protocols immediately. If the patient is under anaesthesia and the heart rate and ECG show signs of pain or being too deep, then consider altering the amount of inhalation agent or increasing analgesia, under the direction of the veterinary surgeon. Confidence can only grow with repeated use of the ECG machine, and practice with interpretation.

Conclusion

ECG interpretation can be daunting because some arrhythmias can be life threatening. However, observing the clinical presentation of the patient, and basic nursing skills, such as identifying pulse quality will assist the nurse with triaging the situation. If there is any concern, veterinary surgeon advice should be sought. Practice with the ECG machine and its settings will help to improve confidence, and using a logical systematic technique will help interpretation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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