Canine electrocardiography

What is an electrocardiogram?

An electrocardiogram (ECG) is a test that records the electrical activity of the heart as a graphic display on graph paper, known as a trace. The electrical impulses are recorded as waves or deflections and one heartbeat is usually recorded as a grouping of waves known as the P-QRS-T complex. Clip-on electrodes attached to the limbs and various points on the thorax pick up the electrical impulses produced by a beating heart, which can be detected in the heart itself and in the body surrounding it. Electrocardiography has now been standardised to enable traces to be compared.

An ECG trace

What is an ECG used for?

The ECG is used primarily to measure heart rate and rhythm and to identify any damage to the heart. Electrocardiography is very important in evaluating rhythm disturbances (arrhythmias) and may indicate heart enlargement (cardiomegaly). The ECG may assist the detection of abnormalities in electrolyte balance and metabolic disturbances and is also used to monitor the efficacy of cardiac drug therapy. It is used in isolation as a diagnostic aid, during anaesthesia as a monitoring tool and in conjunction with echocardiography (diagnostic ultrasound examination of the heart) to assist with the timing of events.

Limitations of the ECG

While the ECG can be a useful screening tool for serious heart disease, it is important to remember that it does not detect all heart problems. Although the ECG is very good at detecting disturbances in heart rhythm, it is relatively insensitive at detecting how well the heart is pumping and more specific anatomical changes such as chamber enlargement.

Because the ECG only records a short period of heart activity it is most effective at detecting continuous arrhythmias. Intermittent rhythm abnormalities that occur predominantly at night or while under physical or psychological stress, may be missed on routine examination. If a longer duration of ECG is required, a smaller machine known as a Holter monitor can be attached to the dog and is worn for a 24 hour period (24 hour ambulatory ECG recording), to provide information on heart function while the animal is active and in its home environment.

Insert picture of 24 hour ambulatory ECG with Holter monitor
The role of ECG in heart disease

Current veterinary thinking advocates a proactive approach in the early diagnosis and treatment of heart disease to improve both quality and length of life. Diagnostic aids such as electrocardiography allow earlier and more comprehensive examinations of patients with suspected heart disease and ECGs can help identify problems much earlier in the course of the disease, before symptoms and signs appear, increasing the scope of therapeutic and surgical interventions and preventing or delaying the progression to heart failure.

When should you do an ECG?

Following a full medical history, physical examination, risk assessment and auscultation (listening to heart and lung sounds with a stethoscope), an ECG may be considered the appropriate ‘next step’ in making a definitive diagnosis.

Performing an electrocardiogram on a dog

1. **Positioning of the dog**
   Dogs are usually imaged while lying on their right side (right lateral recumbency) on an insulated surface. One or two people will be required to restrain the animal depending on its size. It is important that the elbows and stifles are positioned directly opposite each other. Sedation is not usually required as most animals soon settle, and chemical restraint may alter the ECG findings.

2. **Positioning of the leads**
   Some ECG machines use four limb leads only, others include chest leads. Although some ECG machines come with 10 or 12 leads for human use, a full set of leads for a canine ECG totals 8 (4 limb leads and 4 chest leads), so some leads may not be used.
The attachment areas are wetted with surgical spirit to improve conduction and electrodes are clipped to loose skin in the appropriate positions. Hair removal is not usually required.

**Limb lead positioning**

<table>
<thead>
<tr>
<th>Color</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>right fore leg</td>
</tr>
<tr>
<td>Yellow</td>
<td>left fore leg</td>
</tr>
<tr>
<td>Green</td>
<td>left hind leg</td>
</tr>
<tr>
<td>Black</td>
<td>right hind leg</td>
</tr>
</tbody>
</table>

**Einthoven’s Limb Leads**

<table>
<thead>
<tr>
<th>Lead</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>compares right fore leg with left fore leg</td>
</tr>
<tr>
<td>II</td>
<td>compares right fore leg with left hind leg</td>
</tr>
<tr>
<td>III</td>
<td>compares left fore leg with left hind leg</td>
</tr>
<tr>
<td>Earth</td>
<td>right hind leg</td>
</tr>
</tbody>
</table>

**Wilson’s Central Terminal**

Uses unipolar leads to compare one limb lead with the average of the other two.

<table>
<thead>
<tr>
<th>Lead</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVR</td>
<td>compares right forelimb with the average of the other two limb leads</td>
</tr>
<tr>
<td>AVL</td>
<td>compares left forelimb with the average of the other two limb leads</td>
</tr>
<tr>
<td>AVF</td>
<td>compares left hindlimb with the average of the other two limb leads</td>
</tr>
</tbody>
</table>
Chest lead positioning

VI - placed on the right side of thorax at the costochondral junction in the fifth intercostal space
VII - placed on left side of thorax below the costochondral junction in the sixth intercostal space
VIII - placed on left side of thorax above the costochondral junction in the sixth intercostal space (above VII)
V10 - placed over the dorsal spinous process of the last thoracic vertebrae (T/D7)

A canine ECG requires fewer chest leads than for humans, so you may have some leads left over. This is normal but you may find it easier to tape the spares together to keep them out of the way.

3. Starting the trace
Once the dog is positioned correctly and fairly relaxed, you can start the trace. The machine can be adjusted for manual or automatic start. Automatic start is used in most cases but manual start can be used if you want to change the voltages or look at something in more detail, such as doing a longer lead 2.

4. Paper speed
A paper speed of 50 mm per second is usually suitable for most tests, but 25 mm per second may be useful for slower heart rates or looking at something in more detail.

5. Calibration
Machine sensitivity can be adjusted from 0.5 cm to 2 cm/millivolt (mV) depending on the height (excursion) of the components of the complex
- Normal complexes - 1 cm/mV
- Very small complexes - 2 cm/mV
- Very large complexes - 0.5 cm/mV

6. Filters
The filters can be used to improve the quality of the trace if there is interference through the mains electricity or the animal keeps moving.

7. Heart beat monitor
Most machines have a heartbeat monitor which bleeps in time to the heartbeat. This may be useful for determining changes in heart rate and deciding the best time to start the ECG, by confirming when an initially stressed dog is...
starting to relax for example, with an audibly slowing heart rate. The monitor can be turned off if desired.

Do we need to indicate with arrows the:
Manual and automatic function
Paper speed controls
Calibration / Sensitivity controls
Filters
Heartbeat monitor

8. Unwanted movement
If the animal moves at any time during the ECG recording it must be written on the trace at the exact time it occurred, so as not to invalidate the test results.

9. Suggested routine for recording an ECG
- 10 seconds on each of Einthoven’s limb leads (Lead I, II and III) at paper speed 50 mm/sec
- 10 seconds on each of Wilsons Central Terminal leads (AVR, AVL, AVF) at paper speed 50 mm/sec
- 30-60 second rhythm strip on lead II at paper speed 50 mm/sec, or 25 mm/sec if possible

10. Test duration
The average test takes about 5-10 minutes

Top tips for getting a good ECG trace
- Ensure the dog is as relaxed as possible. Although an anxious animal may have a faster heart rate than normal, the ECG results should not be affected
- Restrain the animal correctly, ensuring the elbows and stifles are lined up
- ECG readings can vary significantly between different body positions so try and place the animal in the same position when performing follow up examinations
- If a dog requires follow up tests, it is more likely to cooperate if its last ECG experience was not an unpleasant one
- Use the chest leads as well as the limb leads wherever possible to maximise the amount of information gained
- Ensure the clips are well attached and that the areas have been wetted with surgical spirit
- Remember to detail any movements of the animal on the trace itself at the time of occurrence
- Lead 2 is the most important in analysis and usually creates the biggest wave
- Using Z fold paper makes the handing and storage of traces easier

Interpreting an ECG

A cardiac cycle is a full sequence of events in the heart and includes one complete heartbeat. It includes systole (the period when the heart contracts and pumps out blood, ‘lub’), diastole (the period when the heart relaxes and fills with blood, ‘dub’) and the intervals between.

The heart beat is triggered by electrical impulses. Cardiac depolarisation is the loss of difference in electrical charge between the inside and the outside of the plasma membrane of a cardiac muscle cell, and occurs when the heart muscle cells contract. Cardiac repolarisation is the restoration of the
difference in electrical charge between the inside and outside of the plasma membrane of a cardiac muscle cell and occurs when the heart muscle cells relax.

To identify whether an ECG is normal or not you need to examine each of the wave components in one complete cardiac cycle.

- **P wave** – atrial depolarisation
- **PR interval** – delayed conduction through the AV node
- **QRS complex** – ventricular or depolarisation
- **ST segment** – period between ventricular depolarisation and repolarisation
- **T wave** – ventricular repolarisation

Go through the ECG systematically and record what you find.

**ECG parameters measured from lead II**

- Heart rate (adult dogs 70-160 beats per minute (bpm), giant breeds 60-140 bpm, toy breeds 70-180bpm, puppies 70-220 bpm)
- Heart rate is calculated as cycles per minute (atrial rate is estimated by the number of P waves, ventricular rate is estimated by the number of R waves)
- Are P waves visible and is there a P wave for every QRS complex?
- P wave duration (≤0.04 seconds (s))
- P wave amplitude (≤0.4 mV)
- PR interval (0.06-0.13 s)
- Is the difference between the P wave and QRS complex constant? (small differences are normal but they should not exceed 0.01-0.02 s)
- Are all the P waves and QRS complexes similar?
- QRS complexes, are they narrow (normal) or wide (abnormal, known as bizarre)?
- QRS complex duration (large breeds ≤0.06 s, small breeds ≤0.05 s)
- ST segments, are they normal, depressed or elevated? (≤0.2 mV depression and ≤0.15 mV elevation)
- R wave amplitude (large breeds ≤3.0 mV, small breeds ≤2.5 mV)
- T waves (≤ ¼ of R wave height)
- QT interval (0.15 - 0.25 s at normal heart rate)
- Mean electrical axis +40° - +100°

**Chest leads**

<table>
<thead>
<tr>
<th>V1</th>
<th>T +ve</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII</td>
<td>Max S 0.8 mV, Max R 2.5 mV</td>
</tr>
<tr>
<td>VIII</td>
<td>Max S 0.7 mV, Max R 3 mV</td>
</tr>
<tr>
<td>V10</td>
<td>T –ve (except in Chihuahuas)</td>
</tr>
</tbody>
</table>


To calculate heart rate on an ECG trace:

- Paper speed 50 mm/sec: 3000 divided by measured distance between 2 complexes
- Paper speed 25 mm/sec: 1500 divided by measured distance between 2 complexes
The ECG ruler can be used for measuring the various components of the complex

? Insert pictures of abnormal cardiac arrhythmias

What if the ECG does not show an obvious abnormality?

Consider:

1. Chest x-ray, to:
   - Rule out other diseases
   - Assess the lung fields
   - Look for signs of congestion
   - Identify any cardiac enlargement (remember that enlargement may be due to dilation or hypertrophy)
   Nb. A chest x-ray is essential to confirm suspected cardiac enlargement on ECG

2. Echocardiogram
   - Cardiac ultrasound, a non-invasive diagnostic tool which provides qualitative and quantitative information on cardiac function and additional information on blood flow through the heart

3. Other tests
   - Haematology
   - Electrolytes
   - Biochemistry
   - Urinalysis
   - Pro-BNP levels

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Why Record An ECG
- Cardio-respiratory work up
- Syncope, Weakness Lethargy, Fitting or Collapse
- Cardiac Murmur
- Pulse Abnormalities
- Cyanosis
- Cardiac arrhythmia on Auscultation
- Prolonged CRT
- Cardiomegaly on X-ray
- Dullness on chest Percussion
- Dyspnoea
- Chronic coughing or obstructive pulmonary disease

- Electrolyte Disturbances
- Gastric Torsion or Dilatation
- Pyometra or other toxic infection
- RTA especially if chest injuries
- Renal or Post Renal Problems
- Endocrine Problems esp. Hyperthyroidism in cat
- Pre-operative, Operative
- Pre-Breeding
- Geriatric Programs
- Increased Data Base on apparently normal patients
- Serial ECGs as an aid to prognosis and diagnosis
- Evaluating Effects of drugs esp cardiac drugs