Evaluation of six-lead electrocardiograms obtained from dogs in a sitting position or sternal recumbency

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Objective—To compare 6-lead ECG traces in clinically normal conscious dogs in a sitting position and sternal recumbency to that of right lateral recumbency.

Animals—31 healthy dogs with no history of cardiac disease.

Procedure—Six-lead ECGs were recorded for dogs in right lateral recumbency, a sitting position, and sternal recumbency. Q-, R-, and S-wave amplitudes as well as QRS-complex duration were measured in all leads. Additionally, P-wave amplitude and duration, PR interval, ST-segment elevation or depression, and QT interval were measured in lead II.

Results—Compared with measurements in right lateral recumbency, the sitting position resulted in increased Q-wave amplitude (lead III), increased R-wave amplitude (leads I and aVL), decreased R-wave amplitude (leads III and aVF), increased S-wave amplitude (lead aVR), decreased S-wave amplitude (lead aVL), increased P-wave amplitude (lead II), and a leftward shift in the mean electrical axis. Compared with measurements in right lateral recumbency, sternal recumbency resulted in decreased Q-wave amplitude (leads I, II, and aVF), increased R-wave amplitude (leads II, III, and aVF), decreased R-wave amplitude (lead aVR), increased S-wave amplitude (lead aVR), increased P-wave amplitude (lead II), and decreased ST-segment depression (lead II). Compared with right lateral recumbency, the sitting position or sternal recumbency did not result in significant differences in PR interval, QT interval, or QRS-complex duration.

Conclusions and Clinical Relevance—Significant changes are found in ECG measurements in the sitting position and sternal recumbency, compared with right lateral recumbency. In dogs, many ECG reference range values for right lateral recumbency are not valid for ECGs obtained in the sitting position or sternal recumbency. (*Am J Vet Res* 2005;66:233–237)

Electrocardiography is commonly performed on dogs in clinical practice. Electrocardiograms are used to diagnose cardiac arrhythmias, conduction disturbances, and cardiac chamber enlargement. Electrolyte disturbances and the use of certain drugs can also cause characteristic changes to the ECG.[1-3] Results of previous studies[2,4] indicate that standard consistent recording methods are necessary to produce results that can be repeated. Thus, guidelines describing electrode placement and limb position in right lateral recumbency have been developed.[2] The current reference ranges for ECG measurements in dogs are based on those obtained from dogs in right lateral recumbency. The forelimbs are positioned parallel to each other and perpendicular to the long axis of the body. The head and neck are held flat on the table in line with the long axis of the trunk.[2,3]

However, it is often desirable to record ECGs in positions other than right lateral recumbency, either because of the temperament of the dog or the presence of tachypnea or dyspnea. Studies[5-8] on electrocardiography in dogs often use a nonstandard position. There have been a small number of studies[4,9,10,a,b] over the past 50 years that have compared ECG traces in different body positions. In the 1950s, Blouin[a] compared ECG traces of anesthetized dogs in dorsal, left lateral, and sternal recumbency with that of dogs in right lateral recumbency. Compared with right lateral recumbency, smaller QRS deflections were found in lead aVL in dorsal recumbency, lead I in left lateral recumbency, and leads I and aVR in sternal recumbency. Larger QRS deflections were found in lead III in sternal recumbency. It was hypothesized that changes in the position of the heart within the chest were the cause of these changes.[a] Findings in a 1968 study[4] revealed that changes in forelimb position dramatically altered QRS complexes. Changes in forelimb position shift the relative position of the recording electrodes with respect to the heart. This results in a change in position of the physiologic electrode with respect to the heart.[b] In the early 1970s, a study[9] compared ECGs of cats in right lateral and sternal recumbency and did not find any significant differences. In 2002, another study[10] compared standard 6-lead ECG traces in conscious dogs in right lateral recumbency, left lateral recumbency, and standing positions. Findings in this study[10] revealed a number of differences in Q, R, and S waves and the **mean electrical axis (MEA)** in ECGs obtained while standing and in left lateral recumbency, compared with those obtained in right lateral recumbency. This was caused by changes in heart position in the chest and thoracic limb position.[10]

In our experience, a number of dogs prefer to adopt a sitting position or sternal recumbency for ECG recording. To our knowledge, no previous studies have compared ECGs in conscious dogs in these positions to ECGs in conscious dogs in right lateral recumbency. The purpose of the study reported here was to compare ECGs recorded in clinically normal conscious dogs in a sitting position and sternal recumbency with ECGs recorded in dogs in right lateral recumbency. Changes to the QRS complex and MEA would be expected in

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both these positions given the expected positioning of the heart within the chest and relative position of the electrodes.

Materials and Methods

Animals—Electrocardiograms were recorded from 31 dogs sourced from the hospital population of the Veterinary Specialist Group and the Unitec Institute of Technology Veterinary Hospital, Auckland, New Zealand. Informed consent from the owners of these dogs was obtained. Many dogs belonged to staff or students. Other dogs were in the clinic for elective surgical procedures or to obtain follow-up radiographs several months after orthopedic surgery. No Doberman Pinschers, Boxers, Cocker Spaniels, Great Danes, or Newfoundlands were included in this study. All dogs had normal findings on physical and cardiovascular examination and no history of clinical signs that would suggest cardiac disease. The mean weight of dogs was 22.5 kg (range, 5 to 39.2 kg). The mean age was 3.81 years (range, 0.5 to 14 years).

ECG recording procedures—Two different ECG machines[c,d] were used to record the traces in this study. The ECGs of 5 dogs were recorded on the first ECG machine[c] with a paper trace output at 50 mm/s and 10 mm/mV. Filters used with this machine include a modified digital notch 50-Hz filter and a digital 35-Hz (6 decibel/octave) filter. The ECGs of the remaining dogs were recorded on the second ECG machine.[d] Filters used on this machine included a 50-Hz as well as a low-frequency muscle filter. The trace was then digitally sampled at 500 samples/s/channel. Both machines were used in the same location.

Standard 6-lead ECGs were recorded (leads I, II, III, aVR, aVL, and aVF). Flattened alligator clips were attached to the skin at or just distal to the elbow joints and at the level of or just proximal to the stifle joints. Methylated spirits was applied to improve contact. Care was taken to ensure that the clips remained in the same location for each position measured. Any clips dislodged while manipulating the positioning of dogs were replaced, and methylated spirits was reapplied. All 31 dogs were conscious and nonsedated when ECGs were recorded in right lateral recumbency and the sitting position. Of the 31 dogs, 25 also had ECGs recorded in sternal recumbency. The remaining 6 dogs would not tolerate this position. Right lateral recumbency was maintained by manual restraint of dogs on their right sides. Forelimbs were extended so that the humeri were perpendicular to the long axis of the torso. Hind limbs were held in a neutral semiflexed position. Dogs adopted a sitting position with their hind limbs fully flexed and minimally abducted. The forelimbs were fully extended and parallel. The head was held so it was in line with the torso and with the mandible parallel to the ground. Most dogs adopted this

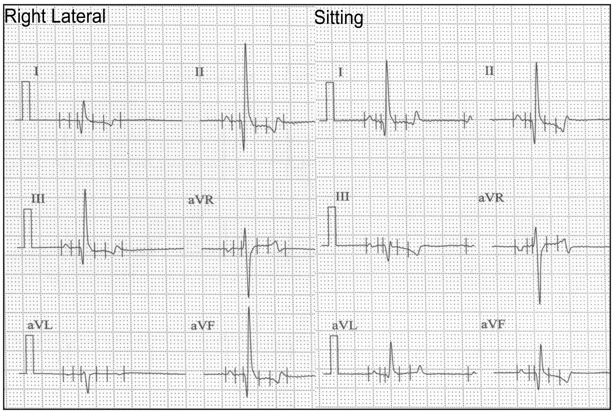

Figure 1—Six-lead ECG traces from a dog in right lateral recumbency (left panel) and the sitting position (right panel). Notice the increased Q-wave amplitude in lead III, increased R-wave amplitude in leads I and aVL, decreased R-wave amplitude in leads III and aVF, increased S-wave amplitude in lead aVR, and decreased S-wave amplitude in lead aVL in the sitting position, compared with right lateral recumbency. Paper speed = 50 mm/s. 1 cm = 10 mV.

Table 1—Mean ± SD values of ECG parameters obtained from 31 dogs in the sitting position (n = 31) or sternal recumbency (25) that were significantly ($P < 0.05$) different from measurements obtained from the same dogs in right lateral recumbency (31).

ECG parameters	Values: Mean (± SD)	P value
P-wave amplitude, lead II (mV)		
Right lateral recumbency	0.18 ± 0.08	NA
Sitting position	0.20 ± 0.06	0.01
Sternal recumbency	0.24 ± 0.05	< 0.001
Q-wave amplitude, lead I (mV)		
Right lateral recumbency	0.20 ± 0.19	NA
Sternal recumbency	0.10 ± 0.11	0.048
Q-wave amplitude, lead II (mV)		
Right lateral recumbency	0.30 ± 0.22	NA
Sternal recumbency	0.12 ± 0.17	< 0.001
Q-wave amplitude, lead III (mV)		
Right lateral recumbency	0.14 ± 0.12	NA
Sitting position	0.20 ± 0.18	0.044
Q-wave amplitude, lead aVF (mV)		
Right lateral recumbency	0.14 ± 0.16	NA
Sternal recumbency	0.20 ± 0.10	< 0.001
R-wave amplitude, lead I (mV)		
Right lateral recumbency	0.60 ± 0.36	NA
Sitting position	1.21 ± 0.50	< 0.001
R-wave amplitude, lead II (mV)		
Right lateral recumbency	1.48 ± 0.60	NA
Sternal recumbency	1.77 ± 0.55	< 0.001
R-wave amplitude, lead III (mV)		
Right lateral recumbency	0.99 ± 0.59	NA
Sitting position	0.48 ± 0.46	< 0.001
Sternal recumbency	1.22 ± 0.56	0.006
R-wave amplitude, lead aVR (mV)		
Right lateral recumbency	0.24 ± 0.18	NA
Sternal recumbency	0.10 ± 0.10	0.001
R-wave amplitude, lead aVL (mV)		
Right lateral recumbency	0.17 ± 0.21	NA
Sitting position	0.55 ± 0.37	< 0.001
R-wave amplitude, lead aVF (mV)		
Right lateral recumbency	1.23 ± 0.58	NA
Sitting position	0.94 ± 0.51	< 0.001
Sternal recumbency	1.49 ± 0.54	0.001
S-wave amplitude, lead aVR (mV)		
Right lateral recumbency	1.02 ± 0.39	NA
Sitting position	1.34 ± 0.48	< 0.001
Sternal recumbency	1.18 ± 0.33	0.004
S-wave amplitude, lead aVL (mV)		
Right lateral recumbency	0.27 ± 0.31	NA
Sitting position	0.08 ± 0.15	< 0.001
ST segment, lead II (mV)		
Right lateral recumbency	–0.033 ± 0.12	NA
Sternal recumbency	0.020 ± 0.18	0.028
Mean electrical axis (°)		
Right lateral recumbency	68.77 ± 17.71	NA
Sitting position	38.32 ± 19.34	< 0.001

NA = Not applicable.

position naturally or with minimal intervention. Sternal recumbency was adopted by dogs being placed in sternal recumbency with their hind limbs fully flexed and abducted minimally. The forelimbs were parallel and placed in a natural position so that the humeri were parallel to each other. The head was held so that the mandible was parallel to the ground.

Measurements—Variables measured from all 6 leads included Q-wave amplitude, R-wave amplitude, S-wave amplitude, and QRS-complex duration. Further measurements taken from the lead II trace included P-wave amplitude, P-wave duration, PR interval, ST-segment elevation or depression, and QT interval. The ECG traces recorded on the first machine[c] were measured manually. A mean of 5 complexes for each dog in each position was measured. The digital traces produced by the second machine[d] were measured by the computer software that is available with the machine. The computer averages complexes over 10 seconds. Measurements were checked manually by an investigator and adjusted if necessary.

The MEA was measured for 31 dogs in right lateral recumbency and the sitting position and for 25 dogs in sternal recumbency. Mean measurements from the Q, R, and S complexes in leads I and III were used to calculate the MEA by use of standard tables.[3]

Tremor artefact was examined by the use of 1 trained and 1 untrained individual examining the traces in a blinded fashion. They were asked which trace appeared to have more baseline movement (tremor artefact).

Statistical analysis—To compare the values for the ECG of dogs in the sitting position and sternal recumbency with that of right lateral recumbency, the difference value for every variable tested was computed (ie, right lateral recumbency value – sitting value and right lateral recumbency value – sternal recumbency value). The null hypothesis that the mean of the observed difference value did not differ significantly from 0 was then tested by use of a 1-sample *t* test for data with a normal distribution. Next, data from the ECGs of 5 dogs recorded on the first ECG machine[c] were excluded, and the *t* test was repeated to ensure the results were not affected by type of ECG machine. Because right lateral recumbency is the standard position for measuring ECGs in dogs, no value was found in comparing the sitting position with sternal recumbency. Additionally, R-wave amplitude in ECGs recorded in the various positions was compared between dogs that weighed ≤ 15 kg and among dogs that weighed > 15 kg by use of an independent *t* test. For all tests, significant differences between variables were defined by values of $P < 0.05$.

Results

Q-wave amplitude was significantly ($P = 0.044$) greater in lead III in the sitting position, compared with right lateral recumbency (**Figure 1**; **Table 1**). R-wave amplitude was significantly greater in leads I and aVL ($P < 0.001$ for both leads) and significantly lower in leads III and aVF ($P < 0.001$ for both leads) in the sitting position, compared with right lateral recumbency. S-wave amplitude was significantly ($P < 0.001$) greater in lead aVR and significantly ($P < 0.001$) lower in lead aVL in the sitting position, compared with right lateral recumbency. P-wave amplitude was significantly ($P = 0.01$) greater in lead II (**Table 2**), although the mean difference was small (0.024 mV), in the sitting position, compared with right lateral recumbency. The MEA was significantly ($P < 0.001$) shifted to the left in the sitting position, compared with right lateral recumbency. Mean MEA in the sitting position was 38.2° (range, 0° to 71°). No significant difference was found in complex durations between the sitting position and right lateral recumbency.

Q-wave amplitude was significantly lower in leads I, II, and aVF ($P = 0.034$, $P < 0.001$, and $P < 0.001$, respectively) in sternal recumbency, compared with right lateral recumbency (**Figure 2**; Tables 1 and 2). R-wave amplitude was significantly greater in leads II, III, and aVF ($P < 0.001$, $P = 0.006$, and $P = 0.001$, respectively) and significantly lower ($P = 0.001$) in lead aVR in sternal recumbency, compared with right lateral recumbency. S-wave amplitude was significantly ($P = 0.004$) greater in lead aVR in sternal recumbency, compared with right lateral recumbency. P-wave amplitude was significantly ($P < 0.001$) greater in lead II, although the mean difference was small (0.054 mV), in sternal recumbency, compared with right lateral recumbency. ST-segment depression was significantly ($P = 0.022$) less in lead II in sternal recumbency, compared with right lateral recumbency. However, the mean difference was also small (0.06 mV). The MEA did not differ significantly between sternal recumbency and right lateral recumbency. Mean MEA in sternal recumbency was 65.6° (range, 26° to 82°). No significant difference was found in complex durations or R-wave amplitude between dogs ≤ 15 kg and dogs > 15 kg.

Observations regarding baseline tremor did not differ between the trained and untrained individuals. An increase in baseline tremor was observed for 58% (18/31) of dogs in the sitting position, 28% (7/25) of

Table 2—Reference table from our study of mean values of ECG parameters obtained in lead II of dogs in right lateral recumbency, compared with mean values obtained from the same dogs in the sitting position or sternal recumbency.

ECG parameters in lead II	Positioning of dogs: Right lateral recumbency (n = 31)	Sitting position (31)	Sternal recumbency (25)
P-wave amplitude (mV)	0.18	0.20 (increase)	0.24 (increase)
P-wave duration (s)	0.04	0.04 (NC)	0.04 (NC)
PR interval (s)	0.11	0.11 (NC)	0.11 (NC)
Q-wave amplitude (mV)	0.30	0.28 (NC)	0.12 (decrease)
R-wave amplitude (mV)	1.48	1.50 (NC)	1.77 (increase)
S-wave amplitude (mV)	0.08	0.07 (NC)	1.0 (NC)
QRS-complex duration (s)	0.06	0.06 (NC)	0.06 (NC)
ST segment (mV)	–0.03	–0.03 (NC)	0.02 (increase)
QT interval (s)	0.19	0.19 (NC)	0.19 (NC)

NC = No change.

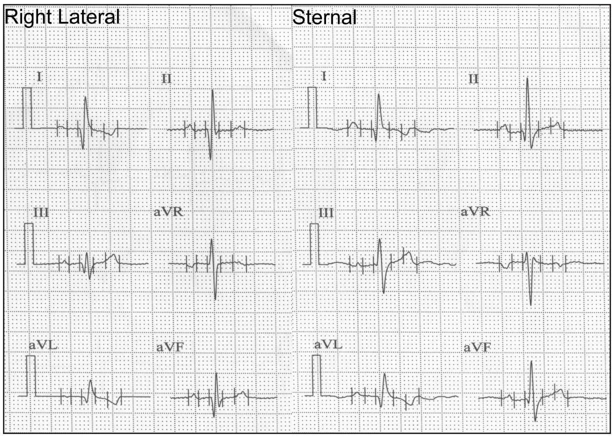

Figure 2—Six-lead ECG traces from a dog in right lateral recumbency (left panel) and sternal recumbency (right panel). Notice the decreased Q-wave amplitude in leads I, II, and aVF, increased R-wave amplitude in leads II, III, and aVF, decreased R-wave amplitude in lead aVR, and increased S-wave amplitude in lead aVR in a sternal position, compared with right lateral recumbency. Paper speed = 50 mm/s. 1 cm = 10 mV.

dogs in sternal recumbency, and 13% (4/31) of dogs in right lateral recumbency. No observable difference was found among positions for 6% (2/31) of dogs.

Discussion

As hypothesized, changes in body position results in a number of changes of the QRS complex of clinically normal dogs. In the sitting position, the MEA shifted to the left with increased R-wave amplitude in leads I and aVL, decreased R-wave amplitude in lead aVF, increased Q-wave amplitude and decreased R-wave amplitude in lead III, and decreased S-wave amplitude in lead aVL, compared with right lateral recumbency. It is interesting that no significant QRS-complex changes were found in lead II (the most diagnostically important lead) in sitting position, compared with right lateral recumbency.

In sternal recumbency, the MEA did not significantly differ from the MEA of right lateral recumbency. Increased amplitude of the R wave occurred in leads II, III, and aVF, with decreased Q wave in leads I, II, and aVF in sternal recumbency, compared with right lateral recumbency.

These QRS-complex changes in the sitting position and sternal recumbency, compared with right lateral recumbency, are likely to be a result of the heart position within the chest cavity as well as change in the position of the physiologic electrode with forelimb position. Results of a previous study[10] comparing ECGs in dogs in a standing position and left lateral recumbency with that of right lateral recumbency revealed a significant left shift of MEA in a standing position but no significant change in MEA in left lateral recumbency. In a standing position, compared with right lateral recumbency, the change in thoracic limb position moves the electrodes caudally and dorsally with respect to the heart, distorting leads I and II so that the MEA shifts to the left. In a standing position, the heart is also positioned to the left relative to that in right lateral recumbency. In left lateral recumbency, the heart would be positioned even more toward the left with an expected increased shift of MEA to the left. The absence of a further leftward shift of MEA in left lateral recumbency is explained by realignment of the left caudally directed vectors (leads I and aVF) so that they parallel lead II. Although vectors were increased, MEA was not changed.[10] Similar to a standing position, a sitting position would result in a leftward positioning of the heart as well as movement of the thoracic limb electrodes dorsally and caudally with respect to the heart, thus changing the physiologic electrode that is formed by limb insertions to the trunk. This change in the position of the physiologic electrode represents a change of the lead axis with respect to the representative dipole of the heart.[b] The recorded magnitude of the depolarizing wave is therefore increased or decreased depending on how much of the wave is moving toward or away from the positive electrode. In our study, this resulted in R-wave amplitude increases in leads I and aVL and subsequent leftward shift of the MEA in the sitting position, compared with right lateral recumbency.

Results of another study[4] in dogs that compared the effect of forelimb position in right lateral recumbency on MEA revealed a right axis shift in MEA with forelimbs in a position similar to that of sternal recumbency used in our study. This forelimb position would move the thoracic limb electrodes cranially and slightly distally relative to the heart, again changing the physiologic electrode. In our study, no change was found in the MEA in sternal recumbency, compared with right lateral recumbency. A possible explanation for this finding is that sternal recumbency results in a heart position to the left with an expected left shift of the MEA. It is possible that the effect of forelimb position and heart movement have cancelled each other with no significant change of MEA.

In our study, P-wave amplitude was significantly increased in the sitting position and sternal recumbency, compared with P-wave amplitude in right lateral recumbency. Ours is the first study that has documented changes in P wave with body position. The mean P-wave amplitudes were still within the reference range developed for right lateral recumbency of < 0.4 mV. It is possible that the use of sternal recumbency or the sitting position brought the electrodes closer to the atrium than occurred in right lateral recumbency. However, the mean difference in P-wave amplitude between right lateral recumbency and the sitting position or sternal recumbency is small, and given the fact that the mean values for sitting position and sternal recumbency were within normal reference limits, the difference is not clinically important. P-wave measurements were not performed on leads other than lead II.

In our study, ST-segment depression in sternal recumbency was slightly decreased, compared with ST-segment depression in right lateral recumbency. The mean ST-segment depression in sternal recumbency was still within the reference range developed for right lateral recumbency. Although the mean ST-segment depression in sternal recumbency was significantly different from that in right lateral recumbency in our study, the mean difference was small. The ST segment represents the early phase of ventricular repolarization (ie, the time from the end of the QRS complex to the onset of the T wave).[3] Elevation or depression of the ST segment outside of the reference range is a nonspecific finding. It is associated with a number of abnormalities, including myocardial ischemia, acute myocardial infarction, hyperkaliemia, hypokalemia, heart trauma, pericarditis, and cardiac trauma.[3] As with the P wave, amplitude changes in the ST segment are unlikely to be clinically important.

Compared with sternal recumbency or right lateral recumbency, baseline tremor was observed in a greater number of dogs in the sitting position. Previously, investigators[11] have found increased baseline tremor in a standing position, compared with left lateral or right lateral recumbency. Sitting dogs may be expected to be more relaxed than those in right lateral or sternal recumbency. This result may have been affected by the fact that a number of dogs did not naturally sit and needed to be placed in that position. It is also not possible to hold the limbs still to reduce fine muscle tremor in a sitting position as it is in right lateral recumbency. Right lateral recumbency is the position of choice to reduce tremor artefact.

As with previous studies[4,9,10] that evaluated the effects of body position on ECGs, results of our study may have been affected by the use of filters. Results of another study[11] in cats indicate that the use of high- and low-pass filters will affect the amplitude of various ECG waves. Because the same filters were used in all positions of recorded ECGs in our study, the effect applies to all data. Filters are more likely to affect the low-amplitude waves. A greater difference in the lead II P-wave amplitude may have been recorded if filtering had not been used. In the previous study[11] performed on cats, P-wave amplitudes in lead II were significantly decreased when filters were used.

In conclusion, ours is the first study in conscious dogs examining the differences in the ECG trace in a sitting position and sternal recumbency to that of right lateral recumbency. In clinical practice, ECGs are often recorded in positions other than right lateral recumbency. Results of our study indicate that ECGs recorded in the sitting position and sternal recumbency in dogs have significant differences in wave amplitudes, compared with those of ECGs recorded in right lateral recumbency. This finding has implications for clinicians who are using ECGs to detect heart chamber enlargement. Compared with right lateral recumbency, the sitting position resulted in the least amount of changes in the QRS complexes of lead II, suggesting that this would be the best nonstandard position to use in dogs. Wave duration and intervals were unchanged in the sitting position and in sternal recumbency, compared with right lateral recumbency. This implies that detecting conduction disturbances and other arrhythmias in these positions is valid. Further investigation could include evaluating ECG characteristics in the different positions in dogs with cardiac disease. Criteria for diagnosing common cardiac diseases could then be established.

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