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Continuous Electrocardiography in Dogs and Cats

Guilherme Albuquerque de Oliveira Cavalcanti
*Federal University of Minas Gerais,
Brazil*

1. Introduction

A new electrocardiogram (ECG) was started in 1961 when J. Norman Holter introduced a system to record the ECG of a patient during their activities for long periods of time. This method was identified as a method of continuous electrocardiography (CE), long-term electrocardiogram, dynamic electrocardiography, ambulatory electrocardiographic, or simply Holter. In subsequent years, the development of technology has introduced a great number of advances and improvements in the fidelity of the recording, size and weight of equipment, systems acquisition and data analysis. The intermittent recording capacity triggered by the owner or by the occurrence of arrhythmia, has become available. Systems to record and reproduce the CE continue to evolve and improvements in the capacity of analysis and editing of commercial systems have frequently been introduced.

The entry of the CE in veterinary medicine contributes to a better understanding of cardiac arrhythmias, to study the cardiac response to drugs and to diagnose heart disease. But before you do the examination, the classic electrocardiographic (ECG) should be performed, because this modality is able to observe the cardiac depolarization for more angles (leads) than the CE.

2. The continuous electrocardiographic in diagnosis support

The most appropriate method to evaluate the heart rate in dogs is the CE system. This test allows assessment of rhythm for 24 hours, while conventional electrocardiography can only do about 0.2% of this period. Thus, this method allows the recognition of rhythm with the animal in different types of activity (sleep, exercise, feeding) and, consequently, under different physiological states.

Currently this method is most widely using the following conditions: a) confirmation of an arrhythmia as the cause of symptoms that occur during daily activities, b) prediction of future cardiac events, c) evidence of therapeutic efficacy of antiarrhythmic agents, d) detection of myocardial ischemia (MacKie et al., 2010).

There are some arrhythmias that occur at intervals greater than 24 hours, in such cases it is recommended either to repeat the exam, or use of cardiac event recorders (CER). When the owner presses a button on the device of CER, for example in the moment when the clinical

sign occurs, the device records the moments before, during and after the clinical signs which should be evaluated. The CER device is smaller and can be used for a week or more, but requires constant observation of the animal, although there are some devices that can function as EC conventionally or as CER at the same time.

In humans, medicine is defined in three classes of indications to perform CE: Class I - there is a consensus that the CE is a useful tool and reliable examination, class II - CE is useful and reliable, but there was no consensus, class III - there is consensus that the CE is unnecessary. In all situations in which the role of CE is discussed, it should be taken in account the history and the physical examination of the patient, and the review of the usefulness of the test. The decision to conduct a CE examination and interpretation of their results cannot be performed independently.

The major use of this examination in dogs and cats is to identify the type and degree of cardiac arrhythmias.

Being the main indications:

- Animals that have unexplained episodes of syncope, collapse, transient weakness and ataxia, even without previous history of heart disease.
- Prediction of dilated cardiomyopathy (DCM) in healthy adult dogs of the predisposed breeds (mostly Doberman and Boxer).
- Animals with relatives who have sudden death with no identified cause or relatives who had DCM.
- Identification of arrhythmias with sporadic or intermittent clinical signs.
- The monitoring of the antiarrhythmic treatment.

In moments of bradycardia, usually myocytes specialized in electrical conduction, trigger stimulus that can result in repeated arrhythmias. Therefore, due to the fact that some arrhythmias begin in a moment of great parasympathetic stimulation, it is logical to think that in an examination that is performed for 24 hours, with the animal performing its daily activities, it would be superior to the classic ECG in which the animal is contained on a clinic table. However, the ECG provides a panoramic view of the heart in ten different views (leads), not being replaced by the CE examination.

3. Attaching the holter monitor

The Holter apparatus is a handheld device that runs tests and consists of an ECG recording unit that has conductors of electromagnetic waves coupled to the animal by adhesives or suction cups. The recording of the examination is decoded by a computer program that specifically allows the evaluation of cardiac rhythm throughout the recording period.

In order for the recorders to meet the standards required by the *American Heart Association*, they should be able to record undistorted signals of high and low frequency, between 0.05 and 100Hz. These systems are able to record the signal ST. The recording can be common on cassette or memory card (more usual today) that stores the fully digitized signals captured by the electrodes. The advantage of scanning equipment is to reduce the weight and size of the recorders and the elimination of mechanical parts such as motor and reduction system. The recording should be in two leads. Devices that record in three channels can replace the two channels monitors.

The systems analysis should always allow classification of the forms of waves and broad interaction with the device analyst for corrections and to eliminate possible artifacts.

The two channels apparatus have five electrodes and the three channels have seven. When using two channels device, the electrodes are fixed to the skin on the chest of the animal, according to the Ware scheme (1998):

Channel 1 - White electrode (negative): the sixth right intercostal space, two fingers above the costochondral articulation;

- Red lead (positive): the sixth right intercostal space, in the location of costochondral joint;
- Green lead (ground): the sixth right intercostal space near the sternum.

Channel 2 - Brown electrode (negative): the sixth left intercostal space, two fingers above the costochondral articulation;

- Black electrode (positive): the sixth left intercostal space toward intermediate between red and green electrodes positioned on the opposite side.

In equipment with four electrodes (Cardioflash® or Cardiolight®: www.cardios.com.br), the local standard ECG precordial examination can be adapted for CE as follows: position of red electrode in V2 place (sixth left intercostal space adjacent to the sternum), black in V4 (sixth left intercostal space in the costochondral junction location), orange electrode between black and red, and white electrode in the V1 position of conventional ECG (fifth right intercostal space near the sternum), as shown in figure 1.



Fig. 1. Left side of the figure - Animal with electrodes attached to the chest for the conduct of examination by equipment with four electrodes (See the text for more details). Note the shaved area with the setting of adhesives and the coupling of electrodes. Right side of the figure - Dog using cervical collar and being subjected to examination. Note that the device is packed in the side pocket of its waistcoat (arrows).

In the thoracic region, where the adhesive electrodes are positioned, there must be ample shaving, cleaning of the area with alcohol to remove the hair and skin oils. After the gel electrodes are fixed with adhesive tape, dry the skin (Figure 1) and it should be held with a protective bandage to prevent the electrodes to come off.

Later, you put on a denim jacket or something similar, which will remain on the animal during the exam. The CE device will be packaged in the side pocket of the jacket and the cables will remain protected (Figure 1).

There is the possibility of performing the examination without the use of waistcoat only conditioning the device with bandage. After placing the recording monitor, cervical or Elizabethan collar should be used to prevent dog bites and damages to the unit. In the literature, the use of cervical or Elizabethan collars did not influence the heart rate in healthy dogs (Cavalcanti et al., 2007). However, it is clear that some dogs tolerate the use of cervical collar better than the Elizabethan one.

The weight of the device and the size of the vest should be compatible with the size of the animal; cats should use smaller devices

4. The result of the examination

Every animal should have a sheet of notes taken during the activities along the course of the recording. It should be noted that the starting time of the examination correlates with the observed daily heart rate (HR) and, possibly, arrhythmias. The report should contain the results of the exam starting time, duration of the examination, the level of recording quality, the maximum, average and minimum HR in each hour and the same HR data on the total examination time. Some supraventricular and ventricular premature complexes may occur in healthy dogs and cats, and in humans these premature complexes increased with age. Atrioventricular blocks of first or second degrees may also occur in healthy dogs. Variations and changes unique to the T wave are not considered diagnostic of CE in small animals.

4.1 Heart rate

Athlete human beings and athlete dogs have mean HR and maximum HR lower than sedentary individuals, the physical activity modulates the sinus node causing decrease of the average of these HR (Cavalcanti et al., 2009, Martinelli et al., 2005), and increasing HR variability and the average RR interval. Endurance exercise training has been established to alter autonomic nervous system activity, resulting in an apparent increase in cardiac parasympathetic tone coupled with decreases in sympathetic activity. For example, in both humans and animals, the heart rate at submaximal workloads was reduced in trained individuals compared with sedentary controls (Smith et al., 1989). A resting bradycardia is a well-established consequence of exercise training and is, in fact, used as a marker that the exercise-trained state has been achieved. Both acetylcholine content and cholineacetyl transferase were increased in the hearts of trained rats compared with control rats (DeSchryver and Mertens-Strythagen, 1975).

The circadian variation in HR is similar to that illustrated in Figure 2. Obviously, the limits of the upper and lower HR should be calibrated in the software, according to the animal being studied.

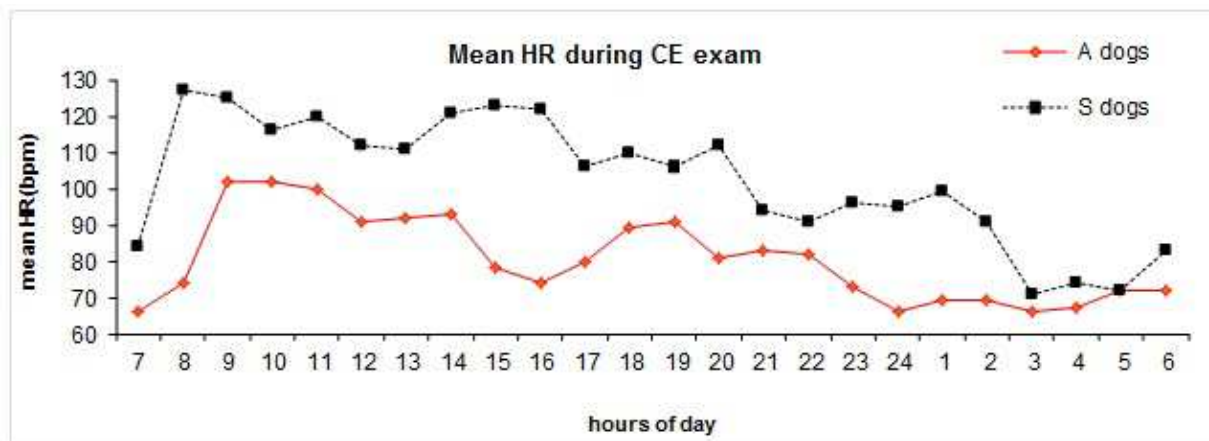


Fig. 2. Graphics show the average of the mean HR at different times of day, observed in sedentary (S) and athlete (A) dogs of the German shepherd breed. Note that the two groups of dog exhibit the same trend to increase and decrease in mean HR over 24 hours, and lower heart rates were observed from three to six hours of the morning.

4.2 Indication of the CE to evaluate clinical signs related to arrhythmias

Monitoring with the CE for 24 hours is especially useful because it provides details of the patient's heart rhythm, the total number and type of abnormal complexes, as well as the specific time of the day when they occurred. The clinician can assess the animal's activities in the period of recording and correlate exam results with clinical signs manifested at every moment.

The method of CE does the ECG recording for long periods and during the patient's daily activities. This allows us to observe spontaneous changes and those caused by activities or situations experienced by the patient's daily routine and, above all, make sure that the reported symptom related to whether or not an electrocardiographic changes. Symptoms that may be caused by changes in heart rhythm should occur often enough to be surprised while doing the recording of the ECG; however, the direct relationship is not always present and can have situations like:

- a. a) Without clinical signs and without arrhythmia
- b. b) Without clinical sign and with arrhythmia
- c. c) With clinical sign and without arrhythmia
- d. d) With clinical sign and with arrhythmia, but no correlation.

In the situation "a" it is impossible to establish any relationship and the examination should be repeated depending on the severity of the clinical suspicion, in "b", though symptoms do not occur, the type of arrhythmia observed may suggest a possible correlation with the sign mentioned above; in "c", discards the possibility of a relationship of symptoms with arrhythmia and another cause should be investigated, in "d", each case must be individualized, because we have patients that fall in both "b" and "c".

4.3 Supraventricular arrhythmias

The CE detects the same supraventricular arrhythmias than the ECG, however there are some considerations to be taken.

The presence of supraventricular arrhythmias is typically observed in less than 25% of healthy small animals within 24 hours. The evaluation of this type of arrhythmia should be cautious; the software which reads the tapes are calibrated to values of human waves and sinus arrhythmia of normal dogs may be misinterpreted as supraventricular premature complex, and even if there are trembling in the baseline sinus, arrhythmia associated with the software can be interpreted incorrectly, such as atrial fibrillation. Solid memory devices (e.g. Memory card) work similarly to cassette and offer the advantage to be programmed to work with range of values of dogs and cats ranges, minimizing the number of premature supraventricular complexes false positive in the exam. So when the reading is done, someone familiar with sinus arrhythmia of dogs must be present to review this arrhythmia.

4.4 Sinus Pauses (SP)

The long SP (more than 2 seconds) or in high quantity may be a factor in the initiation of arrhythmias. The SP generally occurs when the animal's FC is the lowest. Among the breeds studied: 40% of healthy German shepherd dogs had SP. All healthy Doberman and Boxer dogs and 70% of healthy dogs of the English cocker spaniel breed also presented it, so the frequency of SP varies among healthy individuals of different breeds. The median frequency of SP also varies among different breeds, English cocker spaniel, German shepherd, Boxer and Doberman dogs, showed median SP, respectively, 3, 32.5, 366 and 141 in 24 hours. The average of greater SP is more similar: 2.5, 2.87, 3.5 and 3.3, respectively. Therefore, these preliminary studies, the median of PS varies among breeds more than the average of greater SP. The SP occurs with a wide variation among the numbers of healthy individuals and may be higher than 5 seconds at times of low HR in normal dogs.

4.5 Ventricular arrhythmias

The EC detects the same changes of the ECG ventricular depolarization, but measured by a prolonged period and it identifies the different morphologies of normal and premature ventricular complexes (PVC) and is useful in predicting the DCM and in the identification of intermittent arrhythmias.

The presence of multiple PVC, single or repeated (mainly paroxysmal ventricular tachycardia) is associated with episodes of syncope or weakness. In more than half of the Boxer dogs who have syncope, the examination identifies at least 50 PVC in 24 hours.

Also, there is variation in the amount of PVC in dogs of different breeds; the occurrence is 26% for animals of the Beagle breed, 10% for the Doberman dogs, 20% in German shepherd and 40% in English cocker spaniel. However, between 50 and 70% of healthy Boxer dogs, have presented ventricular ectopic activity.

Doberman dogs that have more than 50 PVC in 24 hours have a higher risk of developing DCM, and it is considered abnormal if the presence of PVC is greater than 100 in 24 hours, especially if PVC are repeated or multiform. Based on studies a table was made (Table 1) for the evaluation of EC exams in Doberman pinschers. And Boxer dogs that present more than 91 PVC in 24 hours may have represented dogs with arrhythmogenic right ventricular cardiomyopathy or other disease processes that could have resulted in the development of ventricular arrhythmias (Stern et al., 2010).

Frequency of premature ventricular complexes in 24 hours	Interpretation
None	Annual reassessment of the CE, if the animal is of a predisposed family
Less than 50	May be the initial DCM, annual reassessment required.
Between 50 and 100	Suspect animal, reevaluation every three to six months.
More than 100	Likely to be suffering from DCM, reevaluation of 3 to 6 months.

Table 1. Recommendations for interpretation of CE exam in Doberman dogs (Goodwin, 1998).

Sudden death has been reported in young dogs of German shepherd breed, very similar to the illness of sudden death in human babies. Both are characterized by paroxysmal ventricular tachycardia at moments of parasympathetic influences, as in deep sleep and after exercise. Any animal displaying episodes of ventricular tachycardia has high risk of sudden death.

This familiar arrhythmia in German shepherd dogs usually decreases after seven months of age, but can be detected in animals older than 5 years and are considered affected, the animals showing more than 240 PVC during the examination. Death was observed in 15 to 20% of affected animals and usually occurs at the age of 4-8 months (Moise et al., 1997). In Brazil, there are no reports of this hereditary disease that has been observed in North America.

4.6 CE Indication for detection of myocardial ischemia

The study of myocardial ischemia by CE was made possible by technical advances in recording systems, with enhancements to the registry of the ST segment. As the ST as a sign of low frequency response, its correct detection and registration will depend on the frequency range of recorders, which should be between 0.05 and 100 Hz. The analysis system should be able to do it automatically, exposing the behavior of the ST segment graphically in time function, with the possibility of observation and interaction of events by the analyst. In general, the electrocardiogram is superior to CE in detecting myocardial ischemia due to greater number of variations of electrode placement.

In veterinary medicine, myocardial ischemia due to obstruction of large coronary vessels is uncommon and ST segment changes may occur in cases of hypertrophic left ventricle due to obstruction of small vessels. No healthy dogs of the Boxer, English cocker spaniel, Doberman and German shepherd breeds have shown significant change in the ST segment.

The ventricular arrhythmia is a common consequence of myocardial infarction and is easily identified and quantified in dogs with induced myocardial infarction and examined by CE. Moreover, it is known that at the time of greatest oxygen demand of the heart muscle (e.g. during exercise, stress ECG) ST changes are best identified in humans and the same occurs in dogs subjected to experimental infarction and evaluated by CE, moreover, the CE has a higher ability to detect small myocardial infarction in dogs than the resting ECG.

The ST segment analysis by electrocardiography is inadequate when there is left bundle branch block or Wolff-Parkinson-White syndrome or QRS complex with very low amplitude. Moreover, in large variations in the morphology of the QRS complex, the ST segment assessment should be undertaken with caution, even if it is caused by change of posture. It is noteworthy that a normal examination does not exclude ischemic heart disease, even by the natural variability of ischemic injury.

4.7 Evaluation of therapeutic procedures results

The diagnosis of cardiac arrhythmias and evaluation of therapeutic results requires prolonged observation of the ECG; in addition, the long-term ECG enables clarity of paroxysmal symptoms that may occur after a therapeutic procedure. The aggravation of preexisting arrhythmias or the emergence of new arrhythmias (proarrhythmia) is a phenomenon that can occur during treatment, especially the drug induced treatment, and the CE exam can provide information, even in asymptomatic cases. The CE should not be routinely done in the monitoring of patients with artificial pacemakers; however, it constitutes a powerful tool in the elucidation of paroxysmal symptoms in this group of patients.

In veterinary medicine, it is considered efficient the drug that causes a decrease of at least 70% in the number of premature supraventricular complexes. In dogs of the Doberman breed with DCM and treated with tocinamida, the total number of CVPs decreased between 70 and 80%, and the ventricular tachycardia 90%, which can be defined as therapeutic success in the treatment of DCM in PVC (Calvert et al., 1996).

4.8 Heart rate variability

Several types of analysis of the variability of intervals between R waves are provided by the examination. The RR variability is a way to evaluate the cardiac autonomic system functioning, and high variability of RR indicates a good heart function.

The analysis of HR variability is achieved through the study of parameters for time domain and frequency, provided directly by the computer analysis program. Although there are certain parameters in the time domain that can be analyzed by the ECG, the best method for this analysis is the CE, because this evaluation is made considering more data and obtains more consistent results.

The following variables are evaluated in the time domain: mean NN (mean of all normal RR intervals of the exam), SDNN (standard deviation of all normal sinus R-R intervals), SDANN (standard deviation of the averaged normal sinus R-R intervals for all 5-minute segments of the entire recording), SDNN index (mean of the standard deviations of all normal R-R intervals for all 5-minute segments of the entire recording), rMSSD (root mean square of the sum of squared difference of adjacent normal RR intervals throughout the exam) and pNN50 (the percentage of adjacent R-R intervals that varied by more than 50 ms).

In the frequency domain, the following variables are assessed: HF (high frequency), which comprises 0.15 to 0.4 Hz or 2.5 to 6.6 s / cycle; LF (low frequency), consisting of 0.0033 to 0.04 Hz or 5min/ciclo the 25s, ULF (ultra low frequency), which includes values less than 0.0033 Hz, and the ratio between the LF and HF components (LF / HF).

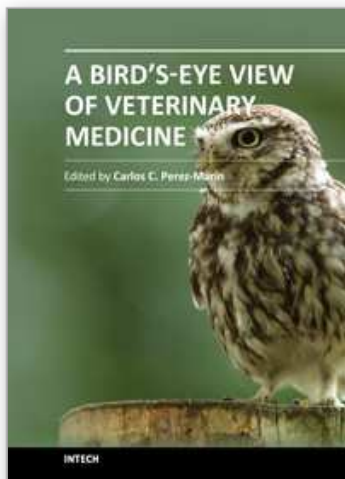
Human beings studies of HR variability in the spectral domain have shown that the spectral power contained in certain frequency bands reflects, in part, the sympathetic and parasympathetic modulation of sinus node activity. Studies using selective autonomic blockade have shown that power in the frequencies of HR variability > 0.15 Hz can be attributed to parasympathetic modulation, whereas power in frequencies < 0.15 Hz are related to both sympathetic and parasympathetic modulation, thus spectral analyses of HR variability have been used in a variety of settings and pathologies to assess autonomic modulation. Rapid changes in sympathovagal control are known to occur in the setting of exercise and recovery from exercise. Exercise is characterized by a decrease in parasympathetic tone and an increase in sympathetic tone, resulting in an increase in heart rate. During recovery from exercise, HR gradually decreases as parasympathetic tone returns and sympathetic tone withdraws.

In human medicine the variability of RR intervals provides useful information in defining patient prognosis after acute myocardial infarction, in the person with DCM, as well as to stratify the risk of sudden death in diabetic patients. It is known that the variability decreases in the presence of heart failure in dogs with chronic myxomatous mitral valve (Crosara et al., 2010) and in advanced DCM (Calvert and Wall, 2001), and a study of HR variability in cats has not been found yet. Perhaps with more studies, HR variability will be more used in Veterinary Medicine

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A Bird's-Eye View of Veterinary Medicine

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Veterinary medicine is advancing at a very rapid pace, particularly given the breadth of the discipline. This book examines new developments covering a wide range of issues from health and welfare in livestock, pets, and wild animals to public health supervision and biomedical research. As well as containing reviews offering fresh insight into specific issues, this book includes a selection of scientific articles which help to chart the advance of this science. The book is divided into several sections. The opening chapters cover the veterinary profession and veterinary science in general, while later chapters look at specific aspects of applied veterinary medicine in pets and in livestock. Finally, research papers are grouped by specialisms with a view to exploring progress in areas such as organ transplantation, therapeutic use of natural substances, and the use of new diagnostic techniques for disease control. This book was produced during World Veterinary Year 2011, which marked the 250th anniversary of the veterinary profession. It provides a fittingly concise and enjoyable overview of the whole science of veterinary medicine.

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Phone: +86-21-62489820
Fax: +86-21-62489821

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