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The T wave in the V10 precordial electrocardiographic lead is negative in healthy Chihuahua dogs

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Abstract *Objectives:* The T wave polarity in the V10 precordial electrocardiographic (ECG) lead in Chihuahuas is described as positive in the veterinary literature. The aim of this study was to investigate the polarity of the T wave in the V10 precordial ECG lead in clinically healthy Chihuahuas. Our null hypothesis was that healthy Chihuahuas have a negative T wave in V10.
Animals, materials and methods: In this prospective study, 67 healthy breeder-owned Chihuahuas were used. A physical examination, 10-lead ECG and an echocardiogram were performed on each dog.
Results: No cardio-respiratory abnormalities were revealed in any of the otherwise healthy dogs. Three out of 67 ECGs were of insufficient quality because of baseline artifacts due to movement of the animal. Two other ECGs showed a nearly iso-electric T wave in the V10 lead. The remaining 62 ECGs showed negative T waves in the V10 lead. Right ventricular hypertrophy was excluded with echocardiography in all dogs.
Conclusion: In contrast to previous reports, we found that healthy Chihuahuas have negative T wave in the V10 precordial ECG lead.

Introduction

A surface electrocardiogram (ECG) is a recording from the surface of the body of changing potentials generated by the electrical activity of the heart. The ECG is primarily used as a diagnostic tool for characterizing cardiac arrhythmias and intra-cardiac conduction disturbances. However, changes on the ECG tracing may also indicate electrolyte disturbances and cardiac chamber enlargement. The ability of the ECG to detect cardiac chamber enlargement is limited because conduction from the heart to the body surface is

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heterogeneous and the surface ECG records cardiac potentials as millivolts.[1] Nowadays, cardiac chamber enlargement in dogs is primarily and more accurately documented by echocardiography. The limb leads (I, II, III, aVR, aVL and aVF) are the most commonly used leads in veterinary medicine. The precordial (i.e. chest) leads were introduced later in electrocardiographic history to measure electrical events limited to specific regions of the heart and in a plane that is perpendicular to that of the limb leads. Although precordial leads are of limited value in dogs and cats, in some cases they do provide additional information; e.g. we have the clinical impression that P-waves may be identified more easily in the left precordial leads than in the limb leads.

On an ECG the T wave is directly related to the repolarization of the ventricular myocardial cells. Because the genesis of the T wave is very complex, the determinants of T wave polarity are still poorly understood.[2–5] The characteristics of the T wave are, among others, related to the differences in the shape of the action potential in various regions of the ventricles. The relationship between the shape of the action potential and the surface ECG waveform is more complex during repolarization than depolarization, as repolarization involves the 3-dimensional shape of the heart and its surrounding conductive medium.[2] Therefore, approximations made for the description of depolarization, e.g. a localized source, uniform propagation, etc. are invariably unsuitable for describing repolarization. Furthermore, the T wave is very sensitive to changes in the environment of the heart, various drugs, nerve stimulation, changes in temperature or ion concentration.[2] Unlike in humans,[4] the T wave concordance (i.e. polarity of the T wave compared to that of the QRS complex) has no diagnostic significance in dogs, with the only documented exceptions in certain precordial leads as in V10.[6]

In 1965 Detweiler and Patterson[7] described that the T waves of normal dogs in a certain precordial ECG lead, the V10 lead, were negative. The Chihuahua breed was mentioned as an exception, as the T waves of healthy Chihuahuas were positive. Positive T waves in all the other breeds were reported to be indicative of right ventricular hypertrophy.[7] Modern, leading veterinary textbooks keep on citing this reference.[8,9]

The motivation to perform the following study was that the ECG recordings of 4 Chihuahuas that underwent an ECG examination at the authors' clinic between 2004 and 2006 had negative T waves in lead V10. The underlying heart disease was a patent ductus arteriosus in 2 dogs and myxomatous mitral valve degeneration in the other two. None of the 4 dogs had echocardiographic evidence of right ventricular hypertrophy.

The aim of this study was to investigate the polarity of the T wave in V10 precordial ECG lead in clinically healthy Chihuahuas. Our null hypothesis was that healthy Chihuahuas have negative T waves in V10.

Animals, materials and methods

Animals

This prospective study was performed on 67 breeder-owned pure breed pedigreed Chihuahua dogs. Forty-one dogs were female and 26 were male. Fifty-nine dogs had Dutch pedigrees, 7 dogs were imported from the United States of America and 1 dog was imported from Russia. Median age was 3.6 years (range 0.3 years to 13.4 years). All dogs were healthy according to the owners. Screening for cardiac abnormalities was performed by physical examination and any dog that had a cardiac murmur, detected on cardiac auscultation, was excluded from entering the study. In all dogs, physical examination, ECG and an echocardiogram were performed. The owners entered the study voluntarily. In every case owner consent was obtained. The study was performed in compliance with institutional guidelines for research on animals.

Electrocardiography

The dogs were held in right lateral recumbency with manual restraint. The 10-lead ECG included the 3 standard bipolar limb leads (I, II and III), the 3 augmented unipolar limb leads (aVR, aVL and aVF) and 4 unipolar precordial leads (CV5RL or rV2, CV6LL or V2, CV6LU or V4 and V10). All ECG electrodes were attached to the animal's skin with crocodile clips. Commercially available ECG gel was used to obtain good conduction between the skin and the crocodile clips. The electrodes for the precordial leads were placed according to the description of Detweiler and Patterson,[7] in the following four positions: CV5RL, the 5th right intercostal space near the edge of the sternum; CV6LL, the 6th left intercostal space near the edge of the sternum; CV6LU, the 6th left intercostal space at the costochondral junction; V10, over the dorsal spinous process of the 7th thoracic vertebra.[7] ECGs were performed

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without sedation and were recorded using 25 and 100 mm/s paper speeds and a 10 mm/mV sensitivity on ECG paper.

The T wave was defined as negative if the deflection was below the baseline, and positive if the deflection was above the baseline. In cases of biphasic T waves, the sum of the negative and positive deflections was taken.

Echocardiography

B-mode, M-mode, color and spectral Doppler echocardiographic examinations were performed from the right parasternal window. The reason for performing an echocardiogram was to exclude a clinically silent right ventricular eccentric or concentric hypertrophy. The echocardiograms were performed in right lateral recumbency without sedation by a board certified veterinary cardiologist (VS). Because no reference values for the right ventricular dimensions (in the Chihuahua) are available in the literature,[10,11] we chose to follow the criteria of Johnson and others[12] to define a normal diastolic right ventricular lumen and wall thickness: ''right ventricular chamber size was reported as normal if it was less than or equal to one half of the size of the left ventricle in the right parasternal long-axis view of the left ventricular outflow tract'' and ''right ventricular wall thickness less than one half of left ventricular free wall thickness was recorded as normal''.[12] The left ventricular free wall thickness was measured in diastole and compared to published reference values.[10]

Statistics

The confidence interval was calculated with the following formula[13]:

$$\pi_{1,2} = \frac{p + \frac{z^2}{2n} \pm z\sqrt{\frac{p(1-p)}{n} + \frac{z^2}{4n^2}}}{1 + \frac{z^2}{n}}$$

n = number of dogs ($n = 62$), p = the fraction of dogs with a positive T wave ($p = 0$), z = value when confidence of 95% is taken into account ($z = 1.96$).

Results

No clinically silent right ventricular concentric or eccentric hypertrophy was detected with echocardiography in any of the 67 dogs. The only abnormality that was found with echocardiography in a few of the otherwise healthy dogs were thickened mitral valve leaflets and trivial mitral valve regurgitation with color Doppler echocardiography.

Three out of the 67 ECGs were of insufficient quality for interpretation of the T waves in V10 lead because of baseline artifacts due to movement of the animals. Two other ECGs showed a nearly iso-electric T wave in the V10 lead. The remaining 62 ECGs showed negative T waves in the V10 lead (Fig. 1).

The chance that we missed healthy Chihuahuas with positive T waves in V10 is smaller than 5.8% (confidence interval according to standard procedure) when a population of 62 dogs ($n = 62$) is taken into account.[13]

Discussion

In this study, none of the clinically healthy Chihuahuas showed positive T waves in the precordial V10 ECG lead. This is in contradiction to earlier reports. In 1971, Hill developed a valid method for the ECG diagnosis of right ventricular hypertrophy in dogs.[6] Thirty-six abnormal ECG criteria were considered, of which 12 were finally selected. With the presence of a minimum of 3 out of 12 criteria, a diagnostic accuracy of 92.9% was obtained to detect abnormal dogs without false positives. In normal dogs, only 11.4% had one of these criteria, whereas none had two or more criteria. The polarity of the T wave was found to have diagnostic significance only in leads CV5RL and V10. In normal dogs, 87.1% had a negative T wave in V10 and 98.5% had a negative T wave in CV5RL. The exact number of dogs with right ventricular hypertrophy and a positive T wave in V10 was not mentioned in this study, but the combination of a negative T wave in CV5RL and a positive T wave in V10 occurred in 14.3% of dogs with right ventricular hypertrophy.

We speculate that the Chihuahuas in the study of Detweiler and Patterson[7] probably had either a clinically silent right ventricular hypertrophy or were normal dogs with a positive T wave in V10. It is not known whether these Chihuahuas had other ECG criteria of right ventricular hypertrophy as described by Hill.[6] Also, it is unknown how many Chihuahuas were involved in Detweiler and Patterson's study.[7]Because 40 years ago echocardiography was not available, it is possible that a clinically silent right ventricular hypertrophy in the Chihuahuas of the study of Detweiler and Patterson was missed.

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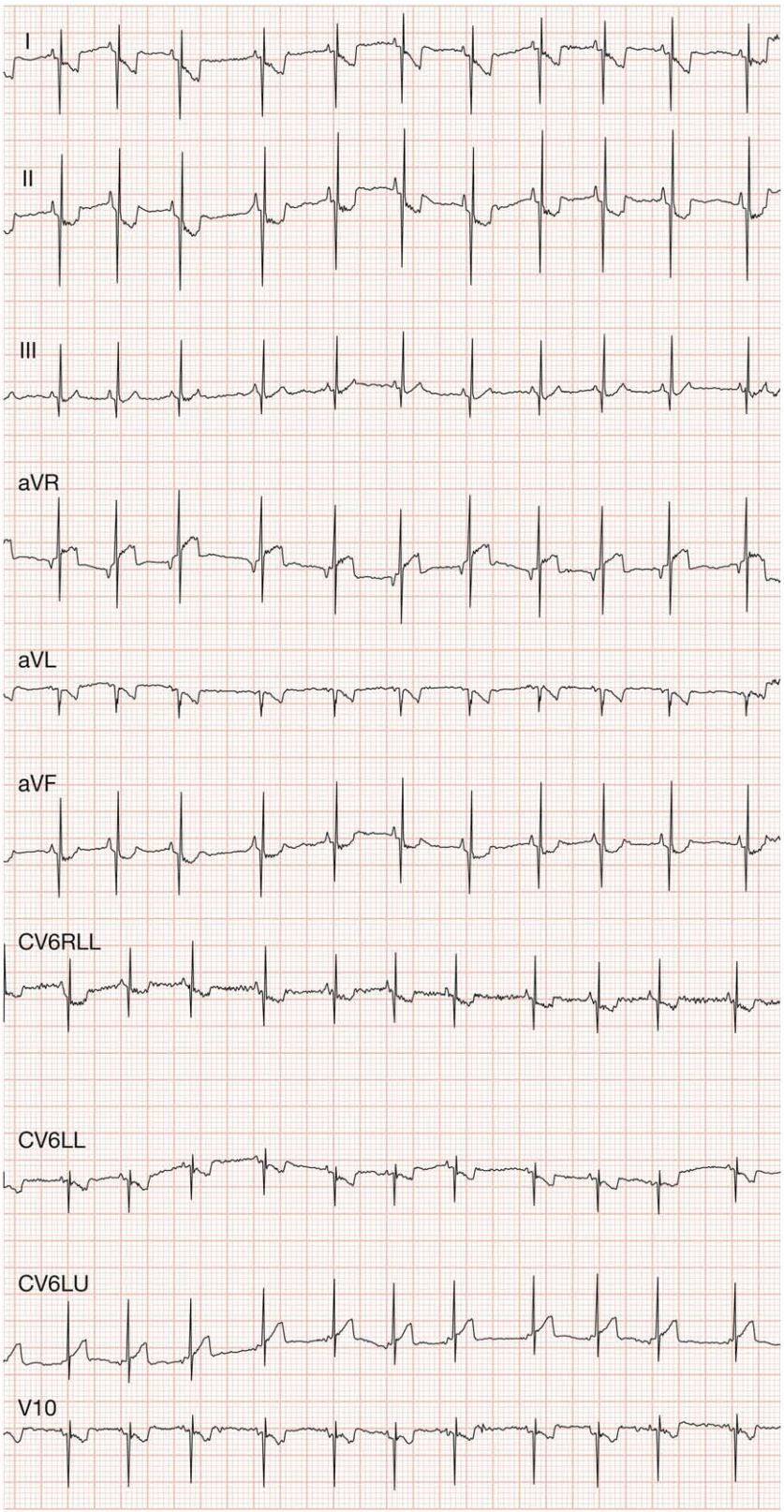

Figure 1 10-lead ECG from a Chihuahua. Paper speed 25 mm/s; sensitivity 10 mm/mV. Note the negative T wave in V10.

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The age of the dogs also influences the T wave polarity.[14–16] During the first postnatal weeks, the electrocardiographic pattern resembles that seen in pathologic right ventricular hypertrophy because the right ventricular mass exceeds that of the left ventricle. A drop in right ventricular pressure to adult levels occurs in 5–6 weeks after birth and as a consequence a relative increase of the left ventricular mass takes place. In contrast to human infants, in which the T wave in the right precordial leads are usually positive the first 24 h after birth,[14] the T waves in V10 produced in normal puppies are often negative.[16] In one study, 16 healthy pups were compared to 20 other pups that were normal littermates from dog families with congenital heart disease.[16] In the first group, T waves in V10 were all negative like in adult dogs. In 82% of the second group, T waves in V10 at birth were positive and at 12 weeks of age this pattern was retained in 10.5% of these pups. No reason for this difference was found. In our study no dog was younger than 12 weeks of age.

Despite the fact that ECG has become an invaluable, routinely used diagnostic tool in human as well as in veterinary medicine, ironically, the genesis and the determinants of T wave polarity are still incompletely understood.[3–5] Moreover, as the T wave is sensitive to miscellaneous changes, various causes of inverted T wave deflection may easily remain undetected.

In conclusion, in contrast to the previous report, we found that healthy Chihuahuas have negative T waves in the V10 precordial ECG lead.

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