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Spontaneous Arrhythmias and Conduction Disturbances in Domestic Animals

James W. Buchanan
University of Pennsylvania, jwb@vet.upenn.edu

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Appendix 6.6 of James W. Buchanan's dissertation Chronic Valve Disease and Left Atrial Splitting in the Dog

Spontaneous Arrhythmias and Conduction Disturbances in Domestic Animals

Abstract
Most of the common arrhythmias and conduction disturbances have been reported in domestic mammals. Prevalence data, however, are not available from unselected population samples, and little information is at hand on long-term studies of individual cases. A discussion of some of these disturbances, therefore, must necessarily rely more heavily upon clinical impression than is desirable. Data have been published on normal electrocardiograms in different species, which, coupled with published case series, individual case reports, and observations made at the Heart Station of the University of Pennsylvania School of Veterinary Medicine, provide the basis for this presentation. This information suggests that certain arrhythmias and conduction disturbances occur commonly in some species and should be regarded as normal variants.

In animals, departures from the normal regular sinus rhythm characteristic of adult humans apparently result from a relatively greater vagal influence on the cardiac pacemaker and conduction tissues. This certainly accounts for respiratory sinus arrhythmia in dogs. In horses, high resting vagal activity is considered accountable for sinus arrhythmia (respiratory and non-respiratory), wandering pacemaker, varying P-R interval, SA block, and incomplete AV block with dropped beats. Although these arrhythmias and conduction disturbances may occur with primary heart disease, or disease primarily affecting vagal activity, their frequent occurrence in the absence of detectable heart disease and also their disappearance with increased heart rate following exercise, excitement, or atropine, support the view that vagal activity rather than primary heart disease accounts for the majority of occasions in which they are observed. Frequently, more than one of the preceding arrhythmias are observed in one individual in the same or subsequent tracings; therefore frequency data often reflect some overlapping. It is useful, however, to present them individually when discussing more specific information.

Disciplines
Cardiology | Medicine and Health Sciences | Veterinary Medicine

Comments
Appendix 6.6 of James W. Buchanan's dissertation Chronic Valve Disease and Left Atrial Splitting in the Dog

SPONTANEOUS ARRHYTHMIAS AND CONDUCTION DISTURBANCES IN DOMESTIC ANIMALS

James W. Buchanan

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SPONTANEOUS ARRHYTHMIAS AND CONDUCTION DISTURBANCES IN DOMESTIC ANIMALS*

James W. Buchanan
Comparative Cardiovascular Studies Unit
University of Pennsylvania
School of Veterinary Medicine, Philadelphia, Pa.

Most of the common arrhythmias and conduction disturbances have been reported in domestic mammals. Prevalence data, however, are not available from unselected population samples, and little information is at hand on long-term studies of individual cases. A discussion of some of these disturbances, therefore, must necessarily rely more heavily upon clinical impression than is desirable. Data have been published on normal electrocardiograms in different species, which, coupled with published case series, individual case reports, and observations made at the Heart Station of the University of Pennsylvania School of Veterinary Medicine, provide the basis for this presentation. This information suggests that certain arrhythmias and conduction disturbances occur commonly in some species and should be regarded as normal variants.

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Normal Rhythms in Animals

Sinus Arrhythmia

Slight variations in P-P intervals are often present in electrocardiograms of normal animals even though the sinus rhythm is basically regular. In dogs,

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respiratory sinus arrhythmia is the normal resting adult rhythm. In some instances the variation in rhythm may be quite marked; however, gradually changing P-P intervals distinguish it from intermittent sinus arrest or block. It can be pointed out, however, that the presence of sinus arrhythmia as an underlying normal mechanism quite often makes the interpretation of canine electrocardiograms more difficult than human tracings showing certain arrhythmias, such as SA block. Sinus arrhythmia may also produce interesting patterns in superimposed arrhythmias such as ventricular tachycardia. Variation in the sinus rate above and below the ventricular rate results in a type of atrioventricular dissociation which could be described as an "expiratory" paroxysmal ventricular tachycardia during the slow phase of sinus arrhythmia.[1] A dog has also been observed in which right bundle branch block was present during the rapid phase of sinus arrhythmia and absent when the P-P interval exceeded a critical duration during the slower phase. This case might be described as having an "inspiratory" right bundle branch block. Sinus arrhythmia usually disappears in adult dogs when the heart rate exceeds 120 beats per minute. Studies on purebred dogs indicate significant breed variability in the degree of resting sinus arrhythmia and heart rate. The two measurements in the above studies show correlation, but exceptions were noted. For example, Wirehaired Terriers and Basenjis both had equally rapid heart rates but Basenjis showed much more arrhythmia. Beagles had about as much arrhythmia as Basenjis, but their heart rates were much slower.[2] Sinus arrhythmia has not been observed in puppies under four weeks of age.[3]

In electrocardiograms showing sinus arrhythmia, the *P* wave often increases in amplitude during the rapid beats associated with inspiration; however, the P-R interval is not altered.[4] Although confirmatory studies have not been done, the variation in *P* amplitude associated with respiratory sinus arrhythmia may be due to variable alteration of the several electrophysiologic properties of the atrial myocardium affected by increased vagal tone, as well as wandering of the pacemaker within the SA node. Changes in the *P* wave disappear along with the sinus arrhythmia when the heart rate is increased due to excitement or atropine.

Respiratory as well as nonrespiratory sinus arrhythmia is not uncommon in horses, and nonrespiratory sinus arrhythmia is always present in incomplete atrioventricular block with dropped beats.[5] The European mole has a very rapid, irregular ventricular rate which was thought for many years to be caused by atrial fibrillation as a normal mechanism. Investigation showed, however, that a rapid, highly irregular sinus arrhythmia was the underlying mechanism.[6]

Wandering Pacemaker

Wandering pacemaker in domestic mammals refers to changes in the amplitude and contour of the *P* waves which may be sudden or gradual. Of

the domestic species, this arrhythmia is most often observed in horses. Some investigators regard it as an indication of myocardial ischemia.[7,8] Others consider it a normal variant.[9,10] In a series of 48 normal horses, 16 were found to have wandering pacemaker.[11] Additional evidence that wandering pacemaker is a normal variant in horses is the fact that the sinuatrial node is large and horse-shoe shaped.[12] Considerable change in the *P* wave would seem possible, therefore, with a change in the site of the pacemaker with the SA node. That vagal influence can cause changes in the site of the pacemaker within the SA node has been demonstrated in dogs, where vagal stimulation may shift the site of the pacemaker from the head to the tail of the SA node.[13] Some changes in the P-R interval may be seen in wandering pacemaker; however, the P-R interval rarely shortens markedly nor does the *P* wave vector change enough to indicate a shift to the AV node as is sometimes seen in man and dogs. Some factor in addition to a respiratory vagal reflex may be involved in horses with wandering pacemaker, since *P* wave changes may occur independently of respiratory sinus arrhythmia when both are present in the same animal. This has been cited as evidence that the pacemaker wanders out of the SA node and away from vagal influence.[7] In dogs, the *P* wave changes are regularly associated with respiratory sinus arrhythmia. In both species, wandering pacemaker and sinus arrhythmia normally disappear with increased heart rate.

In 52 out of 70 preparations of the right atrium of cats, a second pacemaking area was found between the orifices of the caudal vena cava and the coronary sinus. The frequency of impulse formation in this area was usually slower than that of the SA node, but in about 20 per cent the reverse was true.[14] While the role of this secondary pacemaker in intact animals has not been evaluated, it may account for the frequency with which short P-R intervals and AV dissociation occur in cats. It has not been described in other species; however, such a secondary pacemaker could account for some of the *P* wave changes observed.

SA Block in Horses

SA block has been reported in horses with heart disease; however, it has also been observed in the absence of demonstrable heart disease. The diagnosis of this arrhythmia is frequently complicated by the presence of sinus arrhythmia; thus the usual criterion of a twice normal P-P interval is often hazardous to apply and usually cannot be reliably used in animals to differentiate sinus arrest from SA block. For this reason the number of cases of this arrhythmia which have been reported is probably far less than its actual occurrence. Three instances of SA block were found in a series of 82 normal horses at rest.[9] On this basis it is regarded as a less common manifestation of high resting vagal tone in this species, which may or may not be associated with primary heart disease.

Incomplete AV Block with Dropped Beats in Horses

Incomplete AV block with dropped beats occurs in about 15 per cent of normal horses at rest. Detailed studies of 33 horses with this arrhythmia established pathological significance in only 20 per cent of the cases.[5] In the remainder, the mechanism was regarded as a manifestation of physiological high vagal tone since it disappeared with either exercise or atropine. This arrhythmia in horses usually resembles the Wenckebach or type 1 variety. A basically progressive lengthening of the P-R interval occurs; however, the P-R interval immediately preceding the dropped beat is not always the longest one in the sequence. The change in P-R interval, therefore, appears to be influenced more in horses by beat to beat variation in vagal tone than by a cumulative increase in AV nodal refractoriness as in man, which results in Wenckebach periods with regularly increasing P-R intervals up to the dropped beat. In a series of 46 horses with incomplete AV block and dropped beats, only one animal exhibited the type 2 variety with regular P-R intervals.[7] Sinus arrhythmia is always present with incomplete AV block and dropped beats; however, simultaneous pneumograms and electrocardiograms failed to show a correlation of these two mechanisms with the respiratory cycle in 10 horses studied.[9]

The frequency of occurrence of incomplete AV block without dropped beats in horses is difficult to define since the P-R interval in this species is related to the heart rate, and a significant difference has been demonstrated between the average values of Thoroughbred and crossbred horses in contrast to draft horses.[15] As a result, various authors have established upper limits for P-R intervals ranging from 0.40 second to 0.47 second.

Types and Frequency of Occurrence of Arrhythmias and Conduction Disturbances in Various Species

Prevalence data from large random population samples are not available in animals. Most published series of cases are based on electrocardiographic findings in animals selected for study on the basis of abnormal rhythms detected by clinical examination, or because of histories suggesting cardiovacular disease. In dogs, however, prevalence data are available on a consecutive series of 3,000 animals brought to a large veterinary clinic for examination (TABLE 1).[16] This Table does not include sinus tachycardia or sinus arrhythmia, since the circumstances of the study usually did not permit examination of the animals in a quiet resting state. Electrocardiographic abnormalities other than arrhythmias and conduction disturbances are also not included. In this series of 3,000 dogs, 124 abnormal arrhythmias or conduction disturbances were found in 95 animals. The prevalence ratio, therefore, of dogs having one or more of these findings was 32/1,000 in a veterinary clinic population. In a series of 323 dogs suspected of having circulatory

TABLE 1
TYPES AND FREQUENCY OF OCCURRENCE OF SPONTANEOUS ABNORMAL ARRHYTHMIAS AND CONDUCTION DISTURBANCES IN 95 DOGS FROM A SAMPLE OF 3,000 DOGS (PATTERSON *ET AL.* 1961)

Ventricular premature beats	43
Atrial premature beats	14
Atrial fibrillation	13
Incomplete atrioventricular block	12
Incomplete atrioventricular block with dropped beats	12
Paroxysmal ventricular tachycardia	8
Ventricular parasystole	4
Paroxysmal atrial tachycardia	3
Atrioventricular nodal premature beats	3
Atrioventricular dissociation	3
Atrial flutter	2
Complete heart block	2
Left bundle branch block	2
Right bundle branch block	2
Wolff-Parkinson-White syndrome	1
Total	124

disturbances, 98 were found to have heart rates exceeding 160 beats per minute (TABLE 2).[17] As would be expected, the majority of these cases had sinus tachycardia.

In addition to the arrhythmias and conduction disturbances listed in TABLES 1 and 2 others which have occurred spontaneously in dogs include SA block, sinus extrasystoles, sinus bradycardia, paroxysmal atrial tachycardia with block, AV nodal escape beats with and without retrograde conduction, all varieties of ectopic ventricular beats (unifocal, multifocal,

TABLE 2
DIAGNOSES IN 95 DOGS WITH HEART RATES ABOVE 160 BEATS PER MINUTE OUT OF 323 ANIMALS EXAMINED (GRATZL, 1960)

Continuous sinus tachycardia	85
Atrial fibrillation	5
Paroxysmal ventricular tachycardia	3
Atrial fibrillo-flutter	2
Continuous AV nodal tachycardia	2
Paroxysmal AV nodal tachycardia	2
Paroxysmal sinus tachycardia	1
Atrial flutter	1
Ventricular flutter	1
Continuous ventricular tachycardia	1

interpolated, coupled, noncoupled, bigeminy, trigeminy, escape beats without retrograde conduction, fusion beats), intermittent right and left bundle branch block, and phasic dissociation between sinuatrial node and a rapid ventircular pacemaker in sinus arrhythmia.

In horses, frequency data are available on 306 Thoroughbreds of average age 3.5 years.[10] In the majority of these animals, electrocardiograms were recorded as part of a survey. Arrhythmias or conduction disturbances which were found in either initial or subsequent tracings are shown in TABLE 3. These data are probably more representative of the order of frequency with which some of the arrhythmias and conduction disturbances occur than are

TABLE 3
ARRHYTHMIAS AND CONDUCTION DISTURBANCES IN 306 THOROUGHBRED HORSES (STEEL, 1963)

Incomplete atrioventricular block (first degree) (P-R 0.40 to 0.44 in 23; P-R 0.44 to .57. in 4)	27
Incomplete atrioventricular block with dropped beats (P-R 0.40 to 0.44 in 9; P-R > 0.44 in 13)	25
Atrial premature beats	11
Ventricular premature beats	8
Atrial fibrillation	4
Intraventricular block	4
Intra-atrial block	1
Paroxysmal ventricular tachycardia	1

Wandering pacemaker was reported as "common"

Sinuatrial block was reported in "several horses"

collections of abnormal electrocardiograms from clinically preselected cases at veterinary institutions. An example of the latter is shown in TABLE 4.[7] The relatively easily recognized clinical characteristics of atrial fibrillation lead to frequent recording of this arrhythmia: over 125 cases have been reported in horses.

In cattle, the only data available are from preselected cases. In one institution a total of 43 arrhythmias in this species had the following distribution: atrial fibrillation—36; ventricular extrasystoles—5; complete atrioventricular block—1; atrial automatic beats—1.[7]

A large spectrum of arrhythmias and conduction disturbances has been observed in cattle and swine with experimental foot and mouth disease.[18]

Another investigator studying experimental foot and mouth disease in swine reported that ventricular premature beats occurred more frequently in this species than in cattle, where conduction disturbances predominated.[19]

A cardiovascular screening survey has been done on 388 domestic cats, which included at least a one-lead electrocardiogram. In this series no arrhythmias or conduction disturbances were detected.[20]

Although abnormalities have been reported in other domestic mammals, the data are inadequate to determine the frequency of occurrence of various arrhythmias and conduction disturbances.

TABLE 4
ARRHYTHMIAS AND CONDUCTION DISTURBANCES
IN CLINICALLY SELECTED HORSES (BROOIJMANS, 1957)

Atrial fibrillation	89
Wandering pacemaker	53
Incomplete atrioventricular block	7
Incomplete atrioventricular block with dropped beats	46
Complete atrioventricular block	1
Atrial extrasystoles	8
Ventricular extrasystoles	8
Paroxysmal ventricular tachycardia	5
Sinuatrial block	2
Paroxysmal sinus tachycardia	2
Wolff-Parkinson-White syndrome	1
Right bundle branch block	1
Sinus premature beats (probable)	1

Specific Arrhythmias and Conduction Disturbances

Atrial Premature Beats

In dogs, atrial premature beats indicate atrial myocardial disease.[16] In most cases this is associated with chronic mitral valve disease with insufficiency. Other evidence of heart disease has been found in some horses with this arrhythmia; however, the data are not adequate to state conclusively that atrial premature beats alone are definite indications of heart disease in this and other species.

Paroxysmal Atrial Tachycardia

This arrhythmia occurs less commonly in dogs than atrial premature beats. In addition to atrial myocardial disease associated with mitral insufficiency, it has also been observed in a dog with a malignant aortic body tumor infiltrating the atrium, and during treatment of a dog with atrial fibrillation.

It was observed in two other dogs and progressed over a period of several months from atrial premature beats to paroxysmal atrial tachycardia and finally into atrial fibrillation. Thus it is regarded as having more significance than isolated atrial premature beats. In human electrocardiograms, atrial premature beats or paroxysmal atrial tachycardia are differentiated from sinus premature beats and paroxysmal sinus tachycardia by the presence of abnormal *P* waves. This distinction is difficult to apply in animals because of the varying form of *P* waves in many normal individuals. In many dogs, these two arrhythmias are indicated by suddenly changed *P* waves. In some cases, however, these suddenly changed *P* waves resemble those which gradually occur with inspiration in sinus arrhythmia. It therefore is questionable in some cases whether one is dealing with a sinus focus or an ectopic atrial focus. From a clinical standpoint this differentiation does not appear to be significant in dogs, since atrial myocardial disease is almost always present in either case. The significance of paroxysmal atrial tachycardia in species other than the dog cannot be reliably stated.

Atrial Flutter

This arrhythmia appears to be very rare in animals. It has definitely been observed in at least five dogs. Electrocardiograms taken on panting dogs may trap the unwary observer, and erroneous diagnoses of atrial flutter have been made in some cases. In some horses with atrial fibrillation, series of large, fairly regular waves may be seen intermittently which have been reported as atrial flutter. This pattern has also been designated as fibrillo-flutter. The irregular ventricular rate is not altered by these large waves. In addition they are not sufficiently regular in amplitude, contour, or duration to be classified as atrial flutter; therefore electrocardiograms with this pattern should be designated as coarse and fine atrial fibrillation. True atrial flutter with varying block can be demonstrated, as a rule, during quinidine treatment for atrial fibrillation in horses prior to conversion to normal sinus rhythm.

Atrial Fibrillation

This arrhythmia has been commonly reported in animals. Undoubtedly the high frequency of occurrence in collected series of electrocardiograms results from the striking auscultatory and pulse characteristics. In addition, dogs with this arrhythmia usually have signs of congestive heart failure, and horses often are noted to lack endurance, although signs of congestive heart failure are uncommon in this species. In 13 dogs with this arrhythmia (TABLE 2), atrial myocardial disease was found at necropsy in all cases, and in most it was associated with mitral insufficiency. It has also been seen in a few dogs with various congenital heart diseases. In man, a strikingly small incidence of atrial fibrillation is observed in pure mitral insufficiency in contrast to its fairly common occurrence in mitral stenosis.[21] In dogs,

however, mitral stenosis is practically nonexistent. Although two cases have been observed by others,[22,23] this condition has not been detected in over 6,500 dogs examined for the presence of cardiovascular disease. The diagnosis in one of the observed cases is equivocal.[23]

Clinical evidence relating to the onset, clinical signs, prognosis, and success of treatment indicates that atrial fibrillation occurs in large species such as the horse and cow with less underlying heart disease than the dog.[9] A difference also exists in the canine species between large and small breeds. Clinical evidence in support of this impression can be cited. Cattle have been reported with paroxysmal atrial fibrillation.[7] Some horses with atrial fibrillation may continue to do light work for years without overt signs of congestive heart failure and generally can be converted to normal sinus rhythm with quinidine therapy. After conversion, some horses have gone back to racing and performed well.[9] Spontaneous conversion to normal sinus rhythm in horses is very rare. Large dogs (e.g., over 75 lb. body weight) with atrial fibrillation occasionally live many months before showing congestive heart failure, while medium-sized dogs (e.g., 20 to 40 lb. body weight) usually are in congestive heart failure with the onset of the arrhythmia and seldom survive six months. Atrial fibrillation is rare in small dogs (e.g., under 10 lb.), even in the presence of severe myocardial disease and congestive heart failure. Conversion of atrial fibrillation to normal sinus rhythm with quinidine or digitalis therapy has rarely been successful in dogs, and spontaneous conversion to normal sinus rhythm has never been reported.[24] Spontaneous atrial fibrillation has never been satisfactorily documented in cats, although it can be induced experimentally. It has been suggested that differences in atrial mass may be a primary factor accounting for the clinical variations observed between species.[25] Experimental work in support of this hypothesis has shown that sustained atrial fibrillation can be induced by electrical stimulation in adult cattle, while in calves, goats, and sheep the same method produced only transient bouts of atrial fibrillation.[26] Additional experimental work in dogs has shown that atrial fibrillation will not persist in areas of atrial myocardium of less than a critical mass.[27] This study also emphasized the importance of vagal stimulation to shorten the mean refractory period of atrial myocardial cells in order to achieve sustained atrial fibrillation in experimental dogs. This aspect may also play a role in maintaining atrial fibrillation in horses where physiological high vagal tone exists. Since blood pressure has been shown to be elevated in horses with spontaneous and experimental atrial fibrillation,[28] it is possible that even higher than normal vagal tone is present in this arrhythmia. The ventricular rate in horses with atrial fibrillation has been found to be normal or even slower than normal in some animals, although in most cases it is somewhat elevated. This is in contrast to atrial fibrillation in man and dogs, where rapid

ventricular rates are almost always observed before treatment with digitalis. The instances of normal or slow ventricular rates in horses have been attributed to high vagal tone characteristic of this species.[28]

Atrial fibrillation in cattle reportedly developed during hospitalization in 11 out of 36 cases.[7] In 7 of these 11 cows, the arrhythmia appeared during treatment for "indigestion."

Ventricular Premature Beats

Ventricular premature beats have been reported in dogs, horses, cattle, swine, and cats, and probably occur spontaneously in all mammals.

In dogs they are considered definite evidence of myocardial disease, since this has almost always been observed at necropsy in cases which displayed this arrhythmia.[4,16] In most instances, coupling with the previous beat has been observed. Unifocal beats are most common; however, multifocal instances have been seen. Generally, the latter are associated with extensive myocardial disease. In dogs used for experimental investigations, spontaneous ventricular beats were never observed in 1,000 animals studied.[29] In 270 horses examined at a veterinary clinic, ventricular premature beats were observed in four animals.[30] The significance of this arrhythmia in horses and cattle cannot be stated with assurance. In seven out of eight horses (TABLE 3), ventricular premature beats were isolated transient findings. In another series (TABLE 4), three out of eight horses with ventricular premature beats also had atrial fibrillation, as did three out of five cattle.[7] Several other reports in the literature mention the occurrence of ventricular premature beats; however, an inadequate number of autopsies has been done. Since other arrhythmias are sometimes present and signs of infectious disease are occasionally observed, it seems likely that ventricular premature beats are indications of myocardial disease in horses and cattle as well as in dogs.

Paroxysmal Ventricular Tachycardia

This is a much less frequent arrhythmia than ventricular premature beats. In dogs it is regarded as evidence of more severe myocardial disease.[16] In practically all cases in which this arrhythmia has been observed in animals, ectopic ventricular complexes have been unidirectional. In horses this arrhythmia was more often associated with septicemia, toxemia, or severe digestive disturbance. Primary heart disease has seldom been incriminated as a sole causative factor. According to one investigator, paroxysmal ventricular tachycardia in horses is the arrhythmia "par excellence" in serious digestive disturbances.[7] As in other arrhythmias in this species, the number of autopsied cases is not adequate enough to be conclusive regarding the presence or absence of myocardial disease.

More clinical, physiological, and pathological correlations are needed to fully evaluate the significance of many of the spontaneous arrhythmias and conduction disturbances in animals mentioned in this paper. One of the difficulties in clinicopathological correlations is seen in one clinician-pathologist relationship in which the clinician involved thinks myocardial changes of greater or lesser degree can be found in practically any heart with or without arrhythmias or conduction disturbances, whereas the pathologist involved regards an electrocardiograph as a "voodoo box." It would appear that the subject discussed in this paper is still wide open for a "clinico-electro-patho-physiologist," who can provide answers that will satisfy everyone.

Summary

Most cardiac arrhythmias and conduction disturbances which occur in man have also been observed in one or more of the common domestic mammalian species. Certain of them are regarded as normal findings in individual species; e.g., sinus arrhythmia in dogs, wandering pacemaker, SA block, and incomplete AV block with dropped beats in horses. Species differences are also found regarding the significance of some abnormal arrhythmias; e.g., in animals with atrial fibrillation, the onset, prognosis, and success of treatment correlate better with atrial muscle mass than with the severity of underlying heart disease.

Many reports in the literature concern electrocardiographic abnormalities in only one or a few cases. The prevalence rates of spontaneous arrhythmias in large, unselected population samples of animals have not been determined; however, some authors have reported the prevalence of these abnormalities in animals specifically selected for electrocardiographic study. The prevalence ratio of dogs having one or more spontaneous abnormal arrhythmias and conduction disturbances was 32/1,000 in a 3,000-dog veterinary clinic population sample.

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