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Original Article
Small Animal Diseases

Risk of arrhythmias in dogs with structural heart disease[1]

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ABSTRACT.- Mendonça D.A., Paiva J.P., Knackfuss F., Bendas A. & Alberigi B. 2022. **Risk of arrhythmias in dogs with structural heart disease.** *Pesquisa Veterinária Brasileira 42:e07153, 2022.* Instituto de Veterinária, Universidade Federal Rural do Rio de Janeiro, BR-465 Km 7, Seropédica, RJ 23890-970, Brazil. E-mail: dianamendonca.vet@gmail.com

Presently, pet life expectancy is becoming longer and several diseases inherent to age have been diagnosed, with heart disease being a frequent finding. Although various heart diseases have different pathophysiologies, many morphological and hemodynamic changes can predispose patients to arrhythmias. The presence of arrhythmias can worsen the underlying heart disease and predispose patients to develop new alterations, making arrhythmia detection important for establishing adequate therapeutic protocols and a better prognosis. The present study aimed to determine the arrhythmias most frequently found in dogs treated at the Cardiology and Respiratory Diseases Service (SCDR) of the Small Animals Sector of the Veterinary Hospital of the Federal Rural University of Rio de Janeiro (UFRRJ), during the period from January to 2014 to December 2017, relating them to sex, age group, size, and the presence or absence of heart disease. A total of 586 medical records of dogs treated with SCDR-UFRRJ were retrospectively evaluated. Of these, 15.4% had arrhythmias, 95.6% had diagnoses of heart disease, 61.1% (55/90) were diagnosed with *mitral valve disease*, and 27.8% (25/90) had dilated cardiomyopathies. The most frequent rhythm disturbances were premature ventricular complexes associated with chronic degenerative mitral valve disease or dilated cardiomyopathy. Statistical analysis confirmed the risk of a cardiac patient developing rhythm or conduction alterations (OR, 4.46; p = 0.0003). In conclusion, the pathophysiology of heart failure can lead to the development of rhythm and conduction disorders.

INDEX TERMS: Arrhythmias, dogs, heart.

RESUMO.- [**Potencial arrítmico de cardiopatias em cães.**] Com a maior expectativa de vida dos animais de estimação, diversas enfermidades inerentes a idade têm sido diagnosticadas, sendo as cardiopatias um achado frequente. Apesar das diferentes cardiopatias terem fisiopatologias distintas, diversas alterações morfológicas e hemodinâmicas podem ocorrer predispondo ao aparecimento de arritmias. A presença de arritmias pode agravar a doença cardíaca de base e predispor ao desenvolvimento de novas alterações, tornando-se importante a sua detecção para instituição de protocolos terapêuticos adequados e melhor prognóstico da doença. O presente estudo teve como objetivo determinar as arritmias mais frequentemente encontradas em cães atendidos no Serviço de Cardiologia e Doenças Respiratórias (SCDR) do Setor de Pequenos Animais do Hospital Veterinário da Universidade Federal Rural do Rio de Janeiro (UFRRJ), no período de janeiro de 2014 a dezembro de 2017, relacionando-as com sexo, faixa etária, porte e presença ou não de cardiopatias. De maneira retrospectiva, foram avaliados 586 prontuários de cães atendidos no SCDR-UFRRJ. Destes, 15.4% apresentavam alguma arritmia e 95,6% apresentavam diagnostico de alguma cardiopatia, sendo 61.1% (55/90) diagnosticados com endocardiose de mitral

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e 27.8% (25/90) com cardiomiopatia dilatada. O distúrbio de ritmo mais frequente foram os complexos ventriculares prematuros associados a doença valvar degenerativa crônica de mitral ou a cardiomiopatia dilatada. Na análise estatística, o risco de um paciente cardiopata desenvolver alterações de ritmo ou de condução foi confirmado (OR: 4,46; *p*=0,0003). Conclui-se que a fisiopatologia da insuficiência cardíaca pode levar ao desenvolvimento de distúrbios de ritmo e também distúrbios de condução.

TERMOS DE INDEXAÇÃO: Arritmias, cães, coração.

INTRODUCTION

Heart disease is commonly diagnosed in animals during the senile phase. Although each disease has its specific pathophysiology, in general, it can progress with dilation or hypertrophy of chambers and heart failure (Hasenfuss & Mann 2018). With the evolution of the disease, there are changes in the morphology and hemodynamics of the cardiovascular system and, mainly, in the heart, leading to an electrical imbalance that predisposes the patient to arrhythmias (Dennis 2010). When present, arrhythmias can worsen the changes caused by the disease and, therefore, are important for determining the prognosis of the disease and the institution of adequate treatment (Falk et al. 2010).

Cardiac arrhythmias are defined as alterations in the generation or conduction of the cardiac impulse, generating an abnormality in the depolarization sequence of the atria and ventricles (Côté & Ettinger 2005) Although it is still difficult to determine the exact mechanism by which arrhythmias occur, it is known that they have a multifactorial origin, such as electrical imbalance triggered by heart diseases as they progress with chamber overload, hypoxia, and myocardial ischemia, electrolyte imbalance, and electrophysiological changes of myocardial fibers. Arrhythmias can also be triggered by an imbalance in the autonomic nervous system (Tomaselli et al. 2018).

The classification can be divided into disturbances in conduction or impulse formation. When formation disorders occur, there is a change in the automatism of the cells, while in conduction, there is a change in dromotropism (Opie 2004). Disturbances in impulse formation include alterations in the automatism of normal heart pacemaker cells, the development of automaticity in cells that do not normally have them, or activity provoked by oscillations of the resting membrane potential. Impulse conduction abnormalities may occur because of changes in autonomic tone or anatomical structures, such as myocardial ischemia and areas of fibrosis (Leach 2014).

In addition, they can be characterized according to the heart rate in bradyarrhythmias or tachyarrhythmias, and the latter can be subdivided according to the anatomical substrate involved in its origin: supraventricular or ventricular. Thus, they can be described as tachyarrhythmias with a wide or narrow QRS complex (Santilli et al. 2020).

The objective of this study was to establish the most frequent arrhythmias in dogs with heart disease through a retrospective, and nosological study of the medical records of patients treated at the "Serviço de Cardiologia e Doenças Respiratórias" (Cardiology and Respiratory Diseases Service – SCDR) of the "Setor de Pequenos Animais" (Small Animal Sector) of the Veterinary Hospital (HVPA) of the "Universidade Federal Rural do Rio de Janeiro" (UFRRJ).

MATERIALS AND METHODS

Study local and contextualization. The medical records of dogs treated at the SCDR of the HVPA-UFRRJ were evaluated from January 2014 to December 2017, where records were made of animals with diagnosed heart diseases and were monitored in the routine of the service through evaluation periodicals and electrocardiographic examination. The assessment of medical records consisted of identifying the presence of heart disease and its association with arrhythmias. Cases were included on the following criteria: confirmation and diagnosis of heart disease through clinical examination and complementary radiography and echocardiography examinations. Animals that presented with any concomitant heart disease were excluded from the analysis. Of these animals with heart disease, the diagnosis of arrhythmias (when present) was performed at the time of the examination through electrocardiographic tracing, which included the assessment of rhythm and heart rate.

Epidemiological and clinical data. Risk factors, such as size, age, sex, and heart disease, were evaluated individually in animals with arrhythmia. Ages were grouped as animals younger than ten years or older than ten years. The animals were grouped into small, medium, and large animals. Changes in rhythm and conduction disturbance were grouped as described by Santilli et al. (2019) into wide QRS, narrow QRS, or conduction disturbance to perform a more refined analysis of the risk factors of these changes.

Samples collection. Electrocardiographic examinations were performed with a TEB® brand C10+ digital electrocardiograph after clinical consultation for a minimum of 10 to 20 minutes in the room. The procedure was performed in a quiet environment with the help of a tutor to restrain the animal and with him in the right lateral decubitus position. The electrodes were fixed at specific locations, according to Tilley (1992). After positioning the electrodes, alcohol was used to moisten the skin and electrode to facilitate electrical conduction. The electrodes had a toothless alligator clip to reduce discomfort.

Statistical analysis. Chi-square or Fisher's exact tests were used to compare the frequencies within each discrete variable and establish the presence or absence of associations between the variables. To assess the possible risk factors for the development of arrhythmias, variables such as size, sex, age, and heart disease were evaluated using univariate logistic regression analysis. A significance level of 5% was used to establish statistical significance. All statistical analyses were performed using SPSS® 20.2 program, with a significance level of 5%.

RESULTS

A total of 586 medical records of dogs treated at the SCDR-UFRRJ were evaluated, of which 62.5% (366/586) were females, and 37.5% (220/586) were males. The ages ranged from four to 20 years, and the mean age of these animals was 11.1±2.7 years old. When the age group of these animals was evaluated, 43.9% (257/586) were aged up to 10 years, and 56.1% (329/586) were older than ten years. When observing the size of these animals, 66.4% (389/586) were small, 26.1% (153/586) were medium-sized, and 7.5% (44/586) were large. Among the animals in this sample, 84.6% (496/586) did not have arrhythmias or conduction disorders, and 15.4% (90/586) had some rhythm or conduction alterations. When assessing the

presence of heart disease, 95.6% (560/586) had a diagnosis of heart disease, and 4.4% (26/586) had no diagnosis of heart disease. Among patients with heart disease, 90% (529/586) had mitral valve disease (MVD), 5.3% (31/586) had dilated cardiomyopathy, and 0.7% (4/586) were diagnosed with arrhythmogenic right ventricular cardiomyopathy (RVAC).

Of the total patient records, 15.4% (90/586) had at least one rhythm or conduction disorder. When evaluating the medical records of dogs with rhythm or conduction disorders, 42.2% (38/90) were male, and 57.8% (52/90) were female. These animals were aged between 5 and 20 years, with a mean of 11.1 ± 2.7 years. When the age group of these animals was evaluated, 5.6% (5/90) were between 1-6 years old, 35.5% (32/90) were between 6-10 years of age, and 58.9% (53/90) were older than ten years. The majority were small dogs (42.2% (38/90) of small dogs; 26.7% (24/90) medium, and 31% (28/90).

Table 1. Absolute (N) and relative (%) frequencies of arrhythmias diagnosed in animals with heart disease according to the type of arrhythmia

Conduction disorders	N	%
First-degree atrioventricular block	16	17.8
Second-degree atrioventricular block	9	10.0
Third-degree atrioventricular block	4	4.4
Right bundle branch block	5	5.6
Left bundle branch block	1	1.1
Rhythm disturbances	**N**	**%**
Ventricular bigeminism	3	3.3
Atrial premature complex	10	11.1
Ventricular premature complex	32	35.6
Junctional escape	1	1.1
Atrial fibrillation	2	2.2
Atrial flutter	1	1.1
Supraventricular tachycardia	5	5.6
Ventricular tachycardia	7	7.8
Ventricular trigeminism	1	1.1

There was no association between the presence of rhythm or conduction disorders and age group variables (F=2.742; p=0.246) or sex (x^2=0.993; p=0.319). However, it is interesting to observe that there was an association between the size of the animals and the presence of rhythm alteration or conduction disorder (x^2=88.252; p<0.001) and the presence of heart disease with rhythm alteration or conduction disorder (x^2=15.200 p< 0.001). The frequencies of rhythmic and conduction alterations found in this study are described in Table 1. Notably, the total number of alterations was greater than the number of dogs (90); since five patients were diagnosed with two heart diseases simultaneously, 8.9% (8/90) of the animals had a combination of two or more alterations.

When evaluating the frequency of the most frequent heart diseases in the 90 dogs with electrocardiographic alterations, 61.1% (55/90) had mitral valve disease, 27.8% (25/90) had dilated cardiomyopathy, 4.4% (4/90) had arrhythmogenic right ventricular cardiomyopathy, and 12.2% (11/90) had no diagnosis of heart disease. It is noteworthy that the total number of animals with or without heart disease was greater than 90, as five patients were simultaneously diagnosed with two heart diseases. The distribution of arrhythmias observed according to the respective heart disease is described in Table 2, and the frequency of arrhythmias in dogs without heart disease is shown in Table 3.

When assessing the risk factors for arrhythmias of wide QRS, narrow QRS, or conduction disturbance by odds ratio analysis, no significant risk factors were observed that predisposed the dogs to these alterations (Table 4). However, the risk of cardiac patients developing rhythm or conduction alterations was confirmed (OR, 4.46; p=0.0003).

Risk analysis for dogs with arrhythmogenic right ventricular cardiomyopathy was not performed because of the bias imposed by the pathophysiology of the disease, in which all affected animals' manifest rhythm disorders (Kumar et al. 2015). In addition, it is interesting to note that among the animals without a diagnosis of heart disease, all had conduction disorders (11), and one animal (Golden Retriever, male, ten years old) that, in addition to the conduction disorder, also had narrow QRS arrhythmias and wide QRS.

Table 2. Absolute (N) and relative (%) frequencies of arrhythmias related to the respective diagnosed heart diseases

Arrhythmias	MVD		DCM		ARVC	
	N	%	N	%	N	%
First-degree atrioventricular block	6	7%	3	3%	-	-
Second-degree atrioventricular block	7	8%	1	1%	-	-
Third-degree atrioventricular block	2	2%	2	2%	-	-
Right bundle branch block	2	2%	-	-	-	-
Left bundle branch block	1	1%	-	-	-	-
Ventricular bigeminism	2	2%	1	1%	-	-
Atrial premature complex	8	9%	2	2%	-	-
Ventricular premature complex	18	20%	13	15%	4	4%
Junctional escape	1	1%	-	-	-	-
Atrial fibrillation	-	-	-	-	-	-
Atrial flutter	1	1%	1	1%	-	-
Supraventricular tachycardia	4	4%	1	1%	-	-
Ventricular tachycardia	5	6%	3	3%	-	-
Ventricular trigeminism	1	1%	-	-	-	-

MVD = mitral valve disease, DCM = dilated cardiomyopathy, ARVC = arrhythmogenic right ventricular cardiomyopathy.

DISCUSSION

The highest expected frequency of cardiovascular changes in elderly animals (Parker & Kilroy-Glynn 2012) was observed, since the average age of the animals was 11 years. In addition, most of the care provided at SCDR-UFRRJ consists of preoperative assessments of adult and elderly animals to determine the presence or absence of cardiovascular alterations (Ferreira et al. 2006, Fernandes et al. 2010).

Due to the high number of preoperative evaluations, most of the animals treated were females, mostly elderly, and with mammary tumors, requiring surgical intervention and, consequently, pre-anesthetic cardiological evaluation (Fonseca & Daleck 2000, Caldas et al. 2016). In addition, most of the treated animals were diagnosed with mitral valve disease (90%), common in the elderly and small-to-medium-sized animals (Carneiro 2011, Borgarelli et al. 2012, Parker & Kilroy-Glynn 2012), which were the majority in the present study. Interestingly, although some tumors can cause arrhythmias (Keyes et al. 1993), a study evaluated 29 bitches with mammary tumors (malignant or benign) using electrocardiography, none of them had ventricular or atrial arrhythmias or even rhythm disorders other than respiratory sinus arrhythmia (Bahr Arias et al. 2021), suggesting that this type of tumor has less influence on arrhythmogenesis than other tumors with greater potential to cause arrhythmia, such as splenic tumors (Keyes et al. 1993) or pheochromocytoma.

Although only 15.4% of the animals had some type of arrhythmia, and these occurred at a lower frequency compared to another recent study (Noszczyk-Nowak et al. 2017), when related to heart disease, the presence of arrhythmia worsens the prognosis of the primary disease (Bonagura & Lehmkuhl 2013). Therefore, their occurrence is highly representative. In addition, the number of animals evaluated was lower than those reported in previous studies (Patterson et al. 1961, Aptekmann et al. 2010) and the electrocardiographic examination was performed in the clinic, with the animal at rest and for a short period, which may underestimate the diagnosis of arrhythmias (Côté & Ettinger 2005, Noszczyk-Nowak et al. 2017).

In contrast, the presence of rhythm or conduction abnormalities in animals without diagnosed heart diseases, as found in this study, may be related to the presence of other undiagnosed systemic or inflammatory diseases (Oron et al. 2015, Willis 2018, Santilli et al. 2019). In addition, conduction disorders are relatively common in dogs, even those without heart disease, due to the physiological predominance of parasympathetic over sympathetic tone, predisposing dogs to the appearance of bradyarrhythmias, such as the atrioventricular block (AVB) diagnosed in the study (Van Vliet et al. 1995). These findings corroborate the findings of previous studies that demonstrated the prevalence of these disorders in a large number of animals (Patterson et al. 1961), but more recent studies carried out by Carvalho et al. (2009) and Silveira et al. (2018) showed a lower frequency of these arrhythmias, which may be related to the absence of symptoms. Although first- and second-degree AVBs can be asymptomatic and therefore of no clinical importance,

Table 3. Absolute (N) and relative (%) frequencies of arrhythmias in animals without heart disease

Arrhythmias	Other diseases	
	N	%
First-degree atrioventricular block	7	50%
Second-degree atrioventricular block	1	7%
Right bundle branch block	3	21%
Ventricular premature complex	1	7%
Atrial fibrillation	1	7%
Ventricular tachycardia	1	7%

Table 4. Potential risk factors for arrhythmias in dogs treated at the Service of Cardiology and Respiratory Diseases of the Small Animal Sector of the Veterinary Hospital of the Federal Rural University of Rio de Janeiro from January 2014 to December 2017

	N	Narrow QRS			Wide QRS			Conductions disturbances		
		n (%)	*p*-value	OR (95% CI)	n (%)	*p*-value	OR (95% CI)	n (%)	*p*-value	OR (95% CI)
TOTAL	586	18 (3.1)			42 (7.2)			36		
Breed										
Small/Medium	542	14 (2.6)	<0.051	0.27	26 (4.8)	<0.0001	0.08	25 (4.6)	<0.0001	0.1
Large	44	4 (9.0)			16 (36.4)			11 (25.0)		
Sex										
Male	220	9 (4.1)	0.39	1.69	19 (8.6)	1.41	0.37	13 (5.9)	0.99	0.94
Female	366	9 (2.5)			23 (6.3)			23 (6.3)		
Age										
< 10	257	5 (1.9)	0.24	0.48	17 (6.6)	0.77	0.86	16 (6.2)	0.92	1.02
>10	329	13 (4.0)			25 (7.6)			20 (6.1)		
CD										
MVD	529	13 (2.5)	0.005	0.17	25 (4.7)	<0.0001	0.04	18 (3.4)	<0.0001	0.12
DCM	31	4 (13.0)			17 (54.8)			7 (22.6)		

CI = confidence interval, CD = cardiopathy, MVD = mitral valve disease, DCM = dilated cardiomyopathy.

Santilli et al. (2016) demonstrated the progression of AVB degrees in 21.8% of the animals evaluated, and these findings are clinically relevant. Premature ventricular complexes (PVC) may be present in several neoplastic, inflammatory, and systemic diseases (Santilli et al. 2020), corroborating the suspicion of concomitant diseases and may even be a common finding in dogs (Aptekmann et al. 2010, Filippi 2011). In the present study, it was not possible to determine the possible cause of these premature ventricular complexes since only the occurrence of concomitant heart diseases and not other diseases was evaluated.

The frequency of arrhythmias in heart diseases is not surprising since cardiac remodeling involves changes in the cardiac structure and cellular matrix, predisposing patients to arrhythmogenesis (Magalhães et al. 2016, Azevedo et al. 2016). Among the cardiovascular diseases diagnosed, the most frequent was mitral valve disease, which has been described as a possible cause of arrhythmias in dogs (Beltrán et al. 2016, Häggström et al. 2017). As the study was based on a retrospective analysis, it was not possible to perform the staging of patients with MVD based on the data filled in the medical records. Therefore, no analysis was performed regarding the staging of the disease with the predisposition to arrhythmias. The etiology of these arrhythmias is multifactorial, although the role of myocardial wall stress in response to changes mediated by heart failure is crucial for their development (Hamlin 1999). The presence of PVCs in dogs with MVD is not surprising. Increased myocardial stress resulting from increased preload leads to greater tension in the ventricular wall and consequent chamber dilation, thus providing substrates for the deflagration of arrhythmic foci due to cellular disorganization (Crosara et al. 2010). The presence of premature atrial complexes (PACs) in dogs with the mitral disease is due to microscopic and histopathological changes that occur in the mitral valve and the atrioventricular node, such as tissue fibrosis, vacuolization, disorganization of the collagen layer, and accumulation of mucopolysaccharides (Amoresano et al. 2000), which makes it difficult for the impulse to pass, predisposing to blockage and formation of ectopic foci (Smith Jr. et al. 2015). The presence of atrioventricular blocks, which are branch blocks observed in dogs with mitral disease, has already been described and is related to the consequent increase in cardiac chambers, leading to disorganization of the myocardial structure, local inflammation, chronic degenerative process, and fibrosis (Tilley 1992, Verheule et al. 2004).

Narrow QRS arrhythmias present in animals with MVD are usually frequent in more advanced stages of the disease due to atrial dilatation (Saoudi et al 2001); however, in the present study, the frequency of supraventricular disorders in dogs with MVD corresponded to 13% of dogs with illness and rhythm disturbance. As this was a retrospective study of clinical records, the staging of the disease was not considered, as not all medical records had relevant information for staging, according to American College of Veterinary Internal Medicine (Keene et al. 2019). Therefore, we believe that most animals were in less severe stages of the disease.

Although narrow QRS arrhythmias occurred in only 5% of the patients evaluated with some heart disease, these arrhythmias may be present with the progression of the disease owing to the replacement of healthy tissue by fibrous tissue in the heart, predisposing to the appearance of blocks and reentry into the myocardium tissue that is remodeled (Magalhães et al. 2016). Although the stage of the disease and, consequently, the individual severity of each stage were not considered, these findings suggest and reinforce the silent and microscopic progression that occurs in heart diseases. Likewise, wide QRS arrhythmias were diagnosed in 6% of the animals, which may be due to atrioventricular volumetric overload that alters the sympathetic tone and predisposes to the manifestation of spontaneous diastolic depolarization consequent abnormal automaticity, sustaining individually triggered arrhythmias, such as PVCs (Crosara et al. 2010, Bui et al. 2017). In addition, it is important to emphasize that these tachyarrhythmias may have been underdiagnosed due to their malignancy caused by diastolic involvement due to high heart rate (Lima 2014); therefore, these animals died before diagnosis. However, sudden death records were not evaluated in the analyzed data.

In animals with DCM, the frequency of wide QRS arrhythmias corresponded to 17% of the total number of dogs with the disease and rhythm disturbance, which is the most frequent disturbance and a common finding in this heart disease (Dukes-McEwan et al. 2003). However, as it is a disease that leads to a reduction in contractile myocyte numbers, interstitial fibrosis, and focal myocyte necrosis, it is not surprising to find arrhythmias in these patients, as such alterations have already been reported as potent substrates for arrhythmic triggering (Tidholm & Jönsson 2005). In addition, five animals presented with tachyarrhythmia, which is justified by the alteration of cellular automatism in response to increased sympathetic tone and volumetric overload (Saoudi et al 2001, Crosara et al. 2010).

Conduction disorders were present in six animals with DCM. These findings are not surprising because of the mechanism involved in cardiac remodeling present in this disease, which promotes generalized areas of low voltage and electrical silence consistent with scarring, leading to a decrease in impulse conduction. And altering the myocardial cell, also predisposing to re-entry, similar to humans (Liu 1992, Sanders et al. 2003).

CONCLUSIONS

From this study, it can be concluded that the pathophysiology of heart failure can lead to the development of rhythm disorders, with premature ventricular complexes being the most commonly presented and conduction disorders, such as atrioventricular blocks seen in the study.

Mitral valve disease was the most frequent heart disease, and dilated cardiomyopathy was the heart disease that presented the highest frequency of rhythm disorders, with premature ventricular complexes being the most diagnosed arrhythmia.

It is also concluded that although rhythm and conduction disorders are frequent in animals with structural heart disease, these abnormalities may also be present in animals without heart disease, emphasizing the importance of electrocardiography evaluations.

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