

Correlation of Morris and Macruz indices with the ae/ao ratio in dogs with myxomatous mitral valve disease

Correlação dos índices de Morris e Macruz com a razão ae/a0 em cães com doença mixomatosa da válvula mitral

Correlación de los índices de Morris y Macruz con la relación ae/ao en perros con enfermedad mixomatosa de la válvula mitral

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ABSTRACT: Macruz and Morris indices are electrocardiographic measures used in medicine that suggest the presence of left atrial remodeling. In dogs, the main cause of left atrial remodeling is mitral valve myxomatous degeneration (MVMD), with electrocardiography being part of the cardiology evaluation of patients. Thus, the objective of this study is to measure and correlate the Macruz and Morris indices with left atrial remodeling in dogs with MVMD. For this, 19 male and female dogs, aged between 1 and 6 years, weighing less than 20kg, healthy, without heart diseases that make up the control group (CG) were evaluated; together with 46 dogs with MVMD, of small breed, elderly, subdivided according to the classification of CHF (Congestive Heart Failure) ACVIM (2018) - B1 (n=15), B2 (n=15) and C (n=16). It should be noted that all dogs underwent complete cardiological evaluation to obtain the values of the Macruz Index, Morris Index, P Wave duration on electrocardiography and the LA/Ao ratio on echocardiography, in both groups. The results showed that the Macruz Index and the Morris Index did not show significant difference ($p>0.05$) between the CG and the groups with MVMD, regardless of the CHF classes studied; as well as the values of the methods did not show a significant correlation with the values of the echocardiographic variable LA/OA

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ratio. Thus, it was possible to determine that the Macruz and Moris Indices methods are not effectively applied in the clinical routine in recommending left atrial remodeling in dogs with MVMD according to CHF classes.

Keywords: electrocardiographic measurements; left atrium; mitral; canine.

1 INTRODUCTION

Myxomatous mitral valve degeneration (MVMD) is the most frequently diagnosed heart disease in elderly and small dogs and can progress to congestive heart failure (CHF) (Veiga *et al.*, 2018). The test of choice for its diagnosis is echocardiography, as it allows, in a non-invasive way, the detection of degenerative lesions of the atrioventricular valves, valve insufficiencies and remodeling of the cardiac chambers (Junior *et al.*, 2009; Mazini & Prada, 2020). Left atrial remodeling is progressive due to regurgitating blood flow from the left ventricle to the left atrium during ventricular systole, resulting from the loss of coaptation of the valve apparatus. This process promotes a progressive increase in pressure and left atrial volume and is considered an important unfavorable prognostic indicator in MVMD and other canine heart diseases (Santilli *et al.*, 2020; Mazini & Prada, 2020; Soto-Bustos *et al.*, 2017).

Electrocardiographic examination is a widely available and low-cost diagnostic tool, recommended for heart rhythm assessment, identification of arrhythmias, and suggestion of cardiac chamber remodeling through the analysis of different electrocardiographic variables (Tilley, 1992; Petrus & Larsson, 2015). However, it has low sensitivity and moderate specificity in the detection of left atrial enlargement (Pahlow *et al.*, 1989). Atrial depolarization is represented by the P wave, a positive deflection that precedes the QRS complex in the DII lead. The increase in its duration (ms), associated or not with bifid morphology, suggests left atrial overload or remodeling, an alteration frequently observed in dogs with MVMD as CHF classes progressed (Keene *et al.*, 2019). Despite the limited sensitivity of conventional electrocardiography, methods such as the Macruz and Morris indices have been described and used with the aim of suggesting left atrial enlargement in human medicine and, more recently, in veterinary medicine (Savarino *et al.*, 2012; Martuchi *et al.*, 2022).

Macruz *et al.* (1958) and Morris *et al.* (1964) studied electrocardiographic variables in human medicine with the objective of establishing auxiliary indices in the detection of left atrial enlargement, later called the Macruz Index and the Morris Index, respectively. The Morris Index, also known as the terminal force of the P wave, corresponds to the product between the

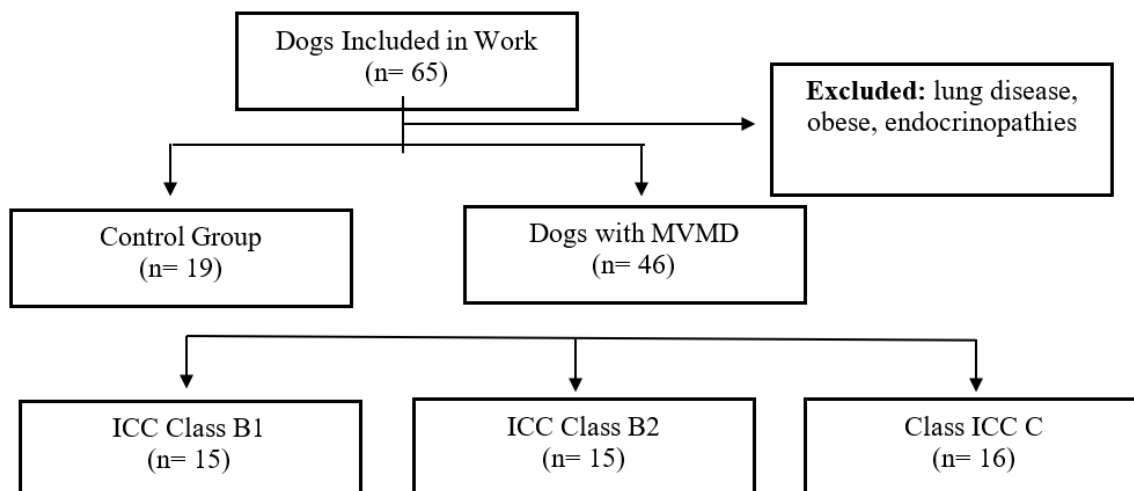
duration (ms) and the amplitude (mV) of the terminal portion of the P wave (Calderón-Olaguivel *et al.*, 2021). To determine it, lead V1 is used, and the presence of negative terminal deflection suggests left atrial enlargement (Morris *et al.*, 1964; Meek & Morris, 2002). In turn, the Macruz Index is calculated by the ratio between the duration of the P wave and the PR segment in the DII lead (Macruz *et al.*, 1958). Increased values of this index are considered indicative of left atrial remodeling in human medicine. Thus, the present study aimed to determine the values of the Morris and Macruz Indices in healthy dogs and in dogs with MVMD, correlating them with the echocardiographic variable left atrium/aorta ratio (LA/AO).

2 METHODS

The research was approved by the ethics committee under protocol 20/2022. For this purpose, sixty-five adult dogs (n=65), males and females of small to medium breed size, weighing less than 20kg, from the clinical-surgical care service of the veterinary hospital of the University of Marília and the Specialli Veterinary Institute – Marília/SP, were used. Thus, nineteen (n=19) healthy, adult dogs, aged between one and six years comprised the control group (CG) and forty-six (n=46) dogs with MVMD the sick groups (DG), being subdivided according to CHF classes (Keene *et al.*, 2019)

The dogs in the CG selected had no clinical history in the last three months, body weight and clinical parameters were within normal standards for the canine species, absent of clinical alterations compatible with respiratory, infectious and endocrine diseases. All dogs underwent complete cardiological evaluation, aiming to exclude evolving heart diseases. In the case of diagnosed conditions, the dogs were removed from the study and referred for further clinical care. The DG dogs underwent complete cardiological evaluation with clinical examination, measurement of systemic blood pressure, electrocardiogram, echocardiogram, CHF staging and, when necessary, therapy was prescribed for follow-up.

Figure 1. Flowchart for selection and exclusion of dogs with MVMD in the present study.

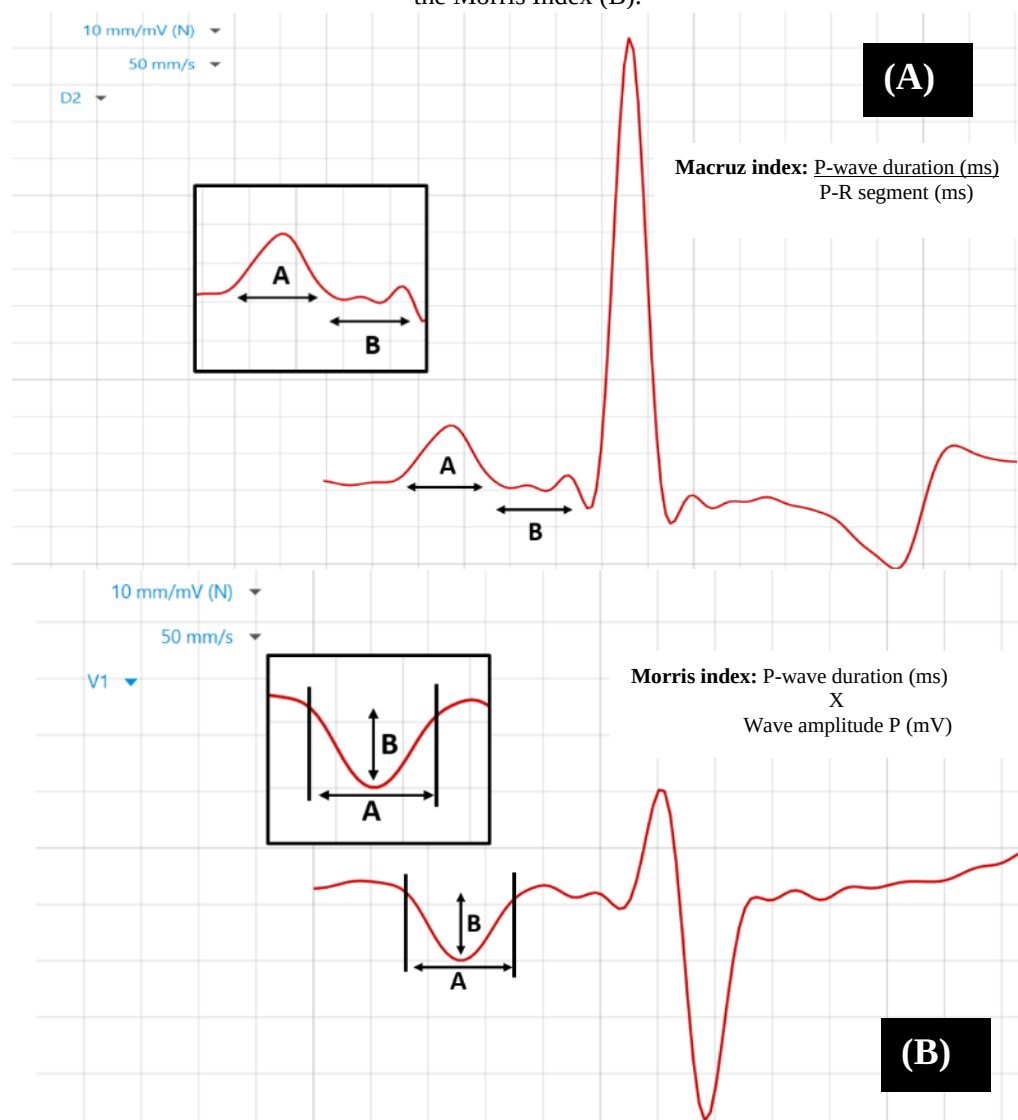


Source: personal archive, 2026.

The computerized electrocardiogram was used using the Incardio/Impulse® 12-lead device. To measure the values of the duration of the P wave, Macruz Index and Morris index, the patients were gently placed in the right decubitus position with the capture of the four leads in the frontal plane (bipolar); three unipolar leads in the left upper limb, right upper limb and left lower limb; and six precordial leads, in the third right intercostal space below the sternochondral junction (V1), in the sixth left intercostal space at the level of the sternochondral junction (V2), in the sixth left intercostal space in a skiodistant space between V2 and V4 (V3), in the sixth left intercostal space at the level of the costochondrial junction (V4), in the sixth left intercostal space in a space equidistant from leads V4 and V6 (V5), and in the sixth left intercostal space in an equidistant space of the other derivations (V6).

The P wave was identified by the positive deflection of the D2 lead and later, the values of the Macruz Index were obtained using the value of the duration of the P wave (ms) and the P-R segment (ms) in the D2 lead. The Morris Index was obtained with the value of the duration (ms) and amplitude of the P Wave through the precordial derivation V1, with subsequent calculation resulting from the division of the Duration of the P Wave by the P-R Segment, as shown in Figure 2. All measurements were performed in three random cardiac cycles, aiming at the accuracy of the values.

Figure 2. Measurement of the duration of the P Wave (arrow A) and of the P-R Segment (arrow B) in the D2 derivation, with subsequent obtaining of the Macruz index (A). Measurement of the duration of the P wave (arrow A) and the amplitude of the P wave (arrow B) in the precordial lead V1, with subsequent acquisition of the Morris Index (B).



Source: personal archive, 2026.

To perform the echocardiographic examination, the Sonosite Micro MAXX model equipment, year 2014 – adult and pediatric sectoral probe with frequencies from 1 to 9 mhz – was used. The patients were gently placed on a mattress appropriate for the echocardiographic examination, in the right lateral decubitus position to obtain the echocardiographic sections of the right parasternal window (DPP) and left lateral decubitus with the echocardiographic sections obtained through the left parasternal window (PEP). For both windows, the transducer was framed between the 2nd and 5th EIC, aiming at the formation of echocardiographic images with subsequent measurement of ventricular systolic and diastolic function variables and other cardiac morphological evaluations through the long-axis four-chamber planes and papillary,

mitral, aortic and pulmonary plane short axis; and apical four- and five-chamber cuts (Boon, 2011; Chetboul *et al.*, 2016). To evaluate the left atrial remodeling, the measurements of the left atrial diameter and the aortic artery were obtained through the right parasternal window – cross-section – Aortic Plane, with subsequent measurement of the LA/Ao ratio, proposed by Hansson *et al.* (2002) in all dogs in the groups studied. The results were later correlated with the values obtained in the Macruz and Morris indices in the sick dogs (Figure 3).

The data obtained from the Macruz, Morris and P Wave duration indices, derived from the mean in the measurement of three cardiac cycles in both groups studied, were statistically analyzed in order to compare the values between the CG and GD, as well as the statistical correlation of the results with the echocardiographic variable LA/Ao ratio, related to the enlargement of the left atrium. The values were analyzed by the Kruskal-Wallis method and correlation analysis by the Spearman method at 5% probability, using the Jamovi software, 2019. The data obtained in relation to age, sex and race (casuistry) were expressed as percentages.

3 RESULTS

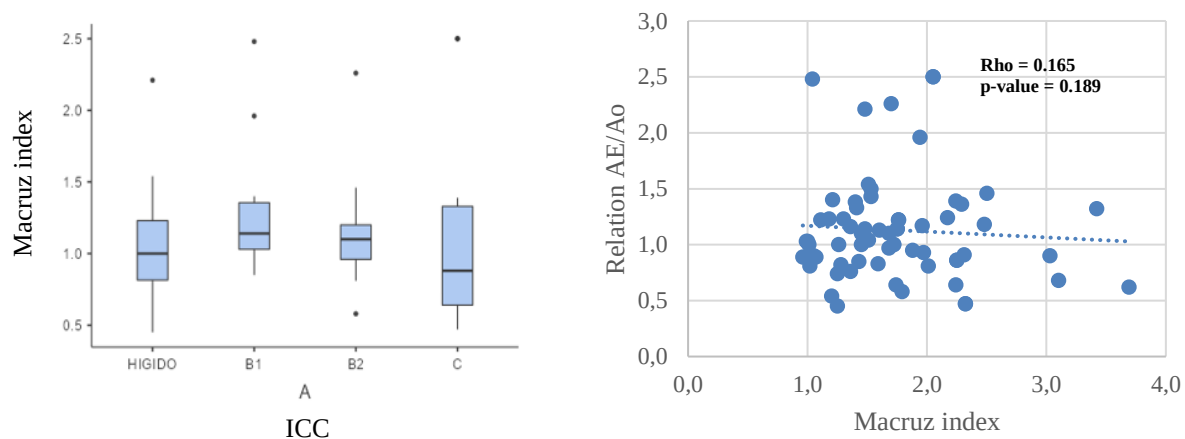
A total of 65 dogs were evaluated, with CG consisting of 19 dogs and DG of 46 dogs with MVMD. The dogs were analyzed from January to October 2023. Regarding the sample of the dogs in the present study, 37% of the CG (n= 7) were males and 63% (n= 12) were females. As for the breeds, 42% (n=8) were Shih-tzu, 14% (n=3) Pinscher, 10% (n=2) Chihuahua (n=2), 10% (n=2) mixed breed, 6% (n= 1) Spitz, 6% (n= 1) Schnauzer, 6% (n= 1) Pug and 6% (n= 1) Poodle; with a mean body weight of 6.0 ± 3.0 kg and a mean age of 3.5 ± 1.9 years.

Dogs with MVMD were characterized by 33% (n=15) males and 67% (n=31) females. Regarding the breeds, 36% (n=17) are mixed-breed, 11% (n= 5) are Maltese, 13% (n= 6) are Pinscher, 13% (n= 6) are Shih Tzu, 13% (n= 6) are Poodle, 8% (n= 4) are Lhasa Apso, 2% (n= 1) are Jack Russell, 2% and 2% (n= 1) are Yorkshire. Regarding age and average body weight, the DG Class B1 dogs were 10.6 ± 3.0 years old and had a body weight of 7.4 ± 2.9 kg. The DG Class B2 dogs with an age of 11.6 ± 2.4 years and body weight of 8.3 ± 3.3 kg and those in class C the weight was 6.6 ± 3.2 kg and age of 12.3 ± 2.7 years.

Regarding the Macruz Index, the values obtained in the groups studied are described in Table 1 and, when comparing the values obtained in the CG and DG groups, no significant differences were observed. When the data were analyzed only among DGs according to CHF classes, no significant differences were found either (Figure 3). The values obtained were

correlated with the echocardiographic variable LA/OA ratio, in which there was no significant correlation.

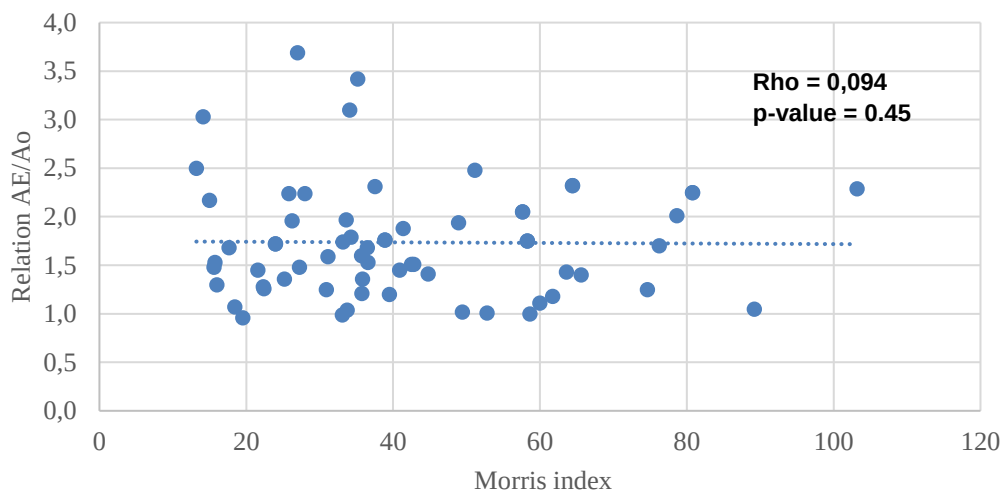
Figure 3. Values obtained for the Macruz Index in healthy dogs, compared to patients with MVMD according to their CHF classes **(A)**. Correlation between the Macruz Index and the LA/Ao Ratio in dogs with MVMD **(B)**.



Source: personal archive, 2026.

Regarding the values of the Morris Index obtained in the CG and DG dogs, they are described in Table 1. When comparing the groups studied here, no significant differences were evidenced, as well as when the DG was compared according to the CHF classes. The correction of the values with the LA/Ao ratio in the DG did not demonstrate a positive and significant correlation between the data (Figure 4).

Figure 4. Correlation of the values obtained between the Morris Index and the AE/Ao ratio in dogs with DG and with MVMD.



Source: personal archive, 2026.

Regarding the duration of the P(ms) wave, the values studied are described in table 1 and when compared between the GC and GD groups, a significant difference was identified with classes B2 and C. When compared only between the ICC classes of the GD, a significant difference was also noted between class B1 in relation to class B2 and class C. However, no difference was observed between B2 and C. the values of Wave P correlated significantly and positively with the LA/Ao ratio ($r=0.64$). The values of the variables studied are shown in Table 1 and Figure 5.

Table 1. Values obtained in relation to the Macruz Index, Morris Index, P Wave Duration and AE/Ao Ratio in healthy dogs and patients with myxomatous mitral valve disease.

Table of Contents		Macruz	
	Min.	Average	Max.
Control	15,7	30.9th	74,7
B1	15,6	44.8th	89,2
B2	13,2	38.9th	78,7
C	14,1	36.4th	103
Table of Contents		Morris	
	Min.	Average	Max.
Control	15,7	30.9th	74,7
B1	15,6	44.8th	89,2
B2	13,2	38.9th	78,7
C	14,1	36.4th	103
Wave		P(ms)	
	Min.	Average	Max.
Control	38	45b	52
B1	33	42b	57
B2	41	52a	59
C	45	51a	72
Relationship		AE/Ao	
	Min.	Average	Max.
Control	0,96	1.30a	1,59
B1	0,99	1.40a	1,96
B2	1,68	1.76b	2,50
C	1,74	2.27c	3,69

Lowercase letters that are different from each other represent a statistical difference of $p < 0.001$.

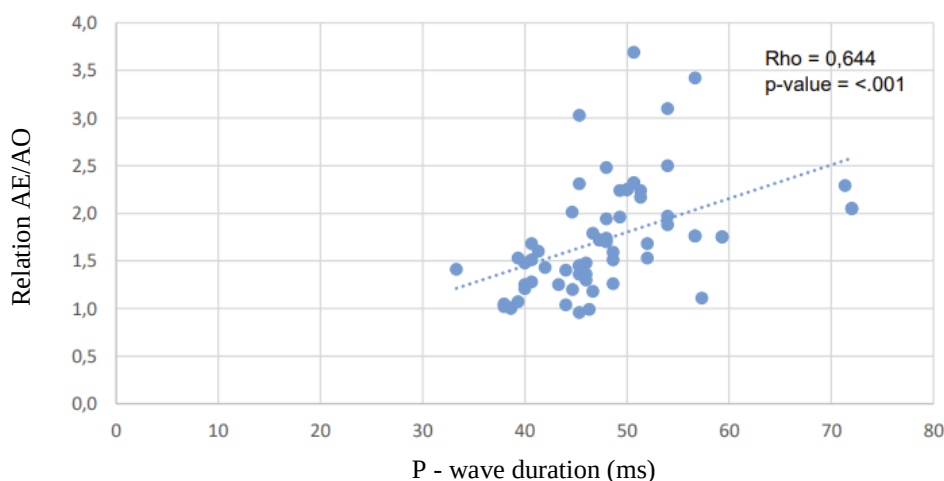
B1= Patient with MVMD class ICC B1

B2 = Patient with MVMD class ICC B2

C = Patient with ICC class C MVMD

Source: personal archive, 2026.

Figure 5. Correlation of the values obtained between the Morris Index and P Wave (ms) in DG dogs with MVMD.



Source: personal archive, 2026.

4 DISCUSSION

In this study, the number of female dogs was higher than that of male dogs, a result that differs from previous studies, in which males are generally more affected or more severely affected by MVMD, as described by Petrus *et al.* (2020) and Pascon *et al.* (2021). The breeds included in the present study also had a distribution like the prevalence documented in previous studies (Kim *et al.*, 2017; Mattin *et al.*, 2019). It was observed that elderly mixed-breed dogs, aged between 5 and 19 years, constituted the main group affected by valvular heart disease studied, corroborating the findings of Pascon *et al.* (2021), who evaluated risk factors, prevalence, and survival time in dogs with MVMD in Rio Grande do Sul.

Age is considered an important risk factor in dogs with MVMD, since heart disease has a degenerative and chronic character, with a high prevalence associated with aging (Keene *et al.*, 2019; Pascon *et al.*, 2021). The average body weight of the dogs evaluated was less than 15 kg, corroborating the studies by Kim *et al.* (2017), Mattin *et al.* (2019) and, later, Pascon *et al.* (2021). However, there are reports of the occurrence of MVMD in large breed dogs (O'brien, Beijerink, Wade, 2021; Kim *et al.*, 2017).

In human medicine, the Macruz Index is used as an indicator variable of left atrial overload. However, in the present study, no significant differences were observed between the control group (CG) and the groups with MVMD (GD), suggesting low applicability of the method in the identification of left atrial remodeling in dogs, as previously discussed in the medical literature (Savarino *et al.*, 2012).

The values obtained were also correlated with the echocardiographic variable LA/OA ratio, with no evidence of significant correlation. These results differ from those reported by Martuchi *et al.* (2022), who evaluated 11 dogs with MVMD according to CHF class and observed significant differences in the values of the Macruz Index when compared to those of healthy dogs. This finding suggests that the greater number of dogs included in the present study may have influenced the results obtained, reinforcing that the electrocardiographic method does not replace the echocardiographic evaluation of left atrial remodeling. Previously, De Oliveira (2019), when studying electrocardiographic methods in dogs with MVMD, demonstrated that the P-wave area and the Macruz Index can be useful in the diagnosis of left atrial overload. However, it stressed the need to establish species-specific normality values to determine appropriate probability distributions. Even so, none of the electrocardiographic parameters evaluated showed good sensitivity and specificity in the detection of left atrial and ventricular overload, as also observed in the present study.

A possible explanation for the low correlation of the method in the detection of left atrial remodeling may be related to the variability of the duration of the PR segment, a period in which the atrioventricular node delays the electrical impulse, giving rise to the PR interval. This variable is closely related to heart rate (HR) and may be prolonged or shortened according to the reduction or increase in HR, respectively (Santilli *et al.*, 2020).

Atrial volumetric overload promotes asymmetric enlargement of the left atrium, prolonging the intra-atrial depolarization time and favoring anisotropic conduction, in which the speed of propagation of the electrical impulse varies according to the direction traveled in the atrial myocardium (Savarino *et al.*, 2007; Soto-Bustos *et al.*, 2017; Maestri & Camp, 2023). This mechanism may explain the absence of significant differences in the Morris Index values between the CG and DG groups, as well as the absence of correlation with the LA/Ao ratio observed in the present study. These findings corroborate previous results that evaluated methods based on P-wave analysis for the detection of left atrial remodeling by electrocardiography in dogs (Soto-Bustos *et al.*, 2017; Calderon-Olagueivel *et al.*, 2019; Maestri & Camp, 2023).

Left atrial enlargement results in prolongation of left atrial depolarization, causing an increase in P wave duration secondary to pressure overload (Santilli *et al.*, 2020). Ogawa *et al.* (2022) and Sahoo *et al.* (2021) also investigated electrocardiographic changes in the P wave and QRS complex as indicators of atrial and ventricular remodeling in dogs with MVMD, reporting a positive correlation between electrocardiographic findings and heart disease, reinforcing the clinical relevance of the present study. In this context, Soto-Bustos *et al.* (2017) evaluated, in 109 dogs with MVMD, different electrocardiographic methods related to the P wave, including P-wave area, Macruz Index and mean electrical axis. The authors observed low sensitivity (52.3% to 77%; median of 60%) and low to moderate specificity (47.2% to 82.5%; median of 56.3%), in addition to a low correlation with the echocardiographic variable LA/AO ratio for predicting left atrial enlargement. These results contradict some studies that associate P-wave alterations with left atrial remodeling but corroborate the findings of the present study in relation to the Macruz and Morris Indices.

Studies in human medicine suggest that left atrial remodeling due to increased P-wave duration may occur early, mainly due to the difficulty in differentiating atrial remodeling from intra-atrial block (Bayés-de-Luna *et al.*, 2021). Currently, this interpretation has been incorporated into the electrocardiographic routine, justifying that, in elderly dogs, delayed atrial conduction can increase the duration of the P wave without necessarily indicating left atrial remodeling secondary to progressive heart disease, as described by Santilli *et al.* (2020). In the

present study, the dogs evaluated were elderly and had valvular heart disease capable of promoting left atrial remodeling throughout the progression of the disease. However, the methods studied did not show differences in the values of the Macruz and Morris Indices between healthy and sick dogs, nor between the different classes of CHF of dogs with MVMD. In addition, no significant correlation was observed with the LA/OA ratio. Thus, intra-atrial block may represent one of the factors responsible for the alteration of the duration of the P wave, directly interfering in the results of the methods studied. This aspect had already been discussed by Tsao *et al.* (2007), who suggested that P-wave-related electrocardiographic abnormalities should be classified as left atrial abnormalities, rather than left atrial remodeling.

The LA/Ao ratio used in the echocardiographic evaluation of the left atrium in dogs with MVMD represents one of the methods most used by veterinary echocardiographers worldwide. Kuo *et al.* (2024), when evaluating the left atrial measurement preferences of 670 veterinary cardiologists from 54 countries, reported that approximately 90% of the professionals use the linear method obtained through the right parasternal window in a short axis, mainly due to the ease of image acquisition and the wide use of the method in previously published studies. This was the echocardiographic method adopted in the present study, showing a progressive increase in the values of the LA/Ao ratio as CHF progressed in dogs with MVMD.

Among the limitations of the present study, the breed variability, the different thoracic conformations, the number of sick animals included, and the lack of monitoring of heart rate variability stand out, factors that may have influenced the results obtained. It is believed that greater uniformity regarding the size, body weight and age of the animals, in addition to the increase in the number of healthy and sick dogs distributed according to CHF classes, as well as the evaluation of the relationship between heart rate and PR segment, may partially modify the results regarding the clinical applicability of electrocardiographic methods. Thus, regardless of the variable used, echocardiography remains the main method for confirming left atrial remodeling in dogs with MVMD. The electrocardiographic methods studied here still need further investigations to prove their definitive applicability in the veterinary clinical routine.

5 FINAL CONSIDERATIONS

After data analysis, it was possible to determine the values of the Macruz and Morris Indices in healthy dogs and dogs with MVMD, according to the different classes of CHF. However, the electrocardiographic methods evaluated did not demonstrate effective

applicability in the identification of left atrial remodeling in dogs with MVMD, regardless of CHF class.

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