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Echocardiographic Assessment of Right Heart Indices in Dogs with Mitral Valve Disease

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ABSTRACT

The most commonly encountered cardiac disease in veterinary practice is valvular disease, which accounts for 70 to 75 per cent of cardiac diseases. Small dog breeds, over 5 years of age, such as Cavalier King Charles Spaniels, Cocker Spaniels, Pomeranians, Daschunds, Chihuahuas, and mixed breeds, are predisposed to mitral valve disease. The current study aimed to assess right-heart echocardiographic indices in dogs with mitral valve diseases. The right heart indices like right atrial and right ventricular dimensions, fractional area change, tricuspid annular plane systolic excursion, transtricuspid velocities, Tei index, etc. were measured in 12 clinically healthy and 17 dogs with mitral valve disease. SPSS software was used to perform statistical analysis on the collected data.2-D and M-mode echocardiography showed a significant increase in right atrial dimensions in diastole (RA-min_d) and TAPSE. Continuous wave Doppler revealed a substantial increase in systolic pulmonary artery and mean pulmonary artery pressure in 16.64 percent of cases. No significant changes were reported in other parameters. Although TDI was superior to conventional Doppler in grading systolic dysfunction, both techniques were ambiguous in identifying systolic dysfunction due to a hyperdynamic ventricular wall in mitral valve disease, and conventional Doppler was unable to grade mild and moderate failure due to the pseudonormalization phenomenon in diastolic dysfunction.

HIGHLIGHTS

- Mitral valve disease (MVD), constitutes 70-75% of cardiac diseases in veterinary practice, with a predisposition in small dog breeds over 5 years old.
- Thoracic radiography revealed a significant difference in the VHS between normal and MVD dogs, indicating cardiac enlargement.

Keywords: Mitral valve disease, Right heart, TAPSE, RV FAC, Tei index, etc.

Degenerative mitral valve disease is a common cause of congestive heart failure in dogs, and it is marked by persistent degenerative alterations in the valve, as well as gradual valve thickening that leads to valvular insufficiency (Petric, 2015). Sometimes, thickening may extend into the proximal segments of the primary chordae tendineae, which results in lengthening and rupture of the chordae tendineae in advanced cases of MVD (Borgarelli *et al.*, 2012). Valvular disease frequently noticed in middle-aged to older, small sized breeds like Cavalier King Charles Spaniels, Dachshunds, Toy Poodles, Chihuahuas, and Cocker spaniels (Leach, 2017). Considering the close association between the two ventricles and the possibility that abnormalities in the LV may affect the RV, functional assessment of both ventricles should be undertaken during regular clinical assessment, regardless of the underlying clinical condition (Visser, 2017).

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In veterinary field, clinical studies on RV dysfunction are less, and they are primarily based on overt symptoms of right-sided congestive heart failure. Right ventricular indices that assess RV systolic and diastolic function in dogs with MVD may be clinically beneficial in diagnosing the presence and progression of RV dysfunction. Due to the complicated geometry of the RV, endocardial trabeculae, ventricular interdependence, and load dependency of RV functional indices, evaluating RV function is challenging (Visser, 2015). In clinical practice, echocardiography is the primary method of evaluating RV structure and function since it is noninvasive, widely available, and inexpensive when compared to other modalities (Haddad *et al.,* 2008).

MATERIALS AND METHODS

Animals

The present study was carried out at the Small Animal Medicine Out-patient Unit of the Madras Veterinary College Teaching Hospital, Tamil Nadu Veterinary and Animal Sciences University, Chennai, from March 2022 to November 2022. In this study, dogs were divided into two groups: apparently healthy dogs (Group I) and clinical cases of mitral valve disease (Group II). Healthy client-owned, dogs brought for routine check-ups and vaccinations were included in the healthy group (n = 12) for the generation of referral values for selected parameters. Healthy dogs and dogs with clinical signs suggestive of heart failure underwent a thorough clinical examination, laboratory investigation, Doppler blood pressure measurement, radiography, electrocardiography, and echocardiography (2-dimensional mode, M mode, spectral Doppler, and tissue Doppler imaging). Seventeen dogs with mitral valve disease were confirmed by echocardiography. Laboratory investigations (hematology and serum biochemistry) were carried out using an auto analyzer in accordance with standard protocol. Radiographs were taken of all the animals to record changes, and VHS was calculated (Buchanan and Bucheler, 1995). Electrocardiography (Tilley *et al.,* 2008) and systolic blood pressure (Rondeau *et al.,* 2013) were recorded as per standard protocol.

Echocardiography

An ultrasound system (Aeroscan CD25) with Colour and spectral Doppler modes and a 2.5–5 MHz phased array transducer was used for echocardiography.

Patient preparation and positioning

For the echocardiographic assessment, the area between the third and seventh ribs was shaved 1-2 cm lateral

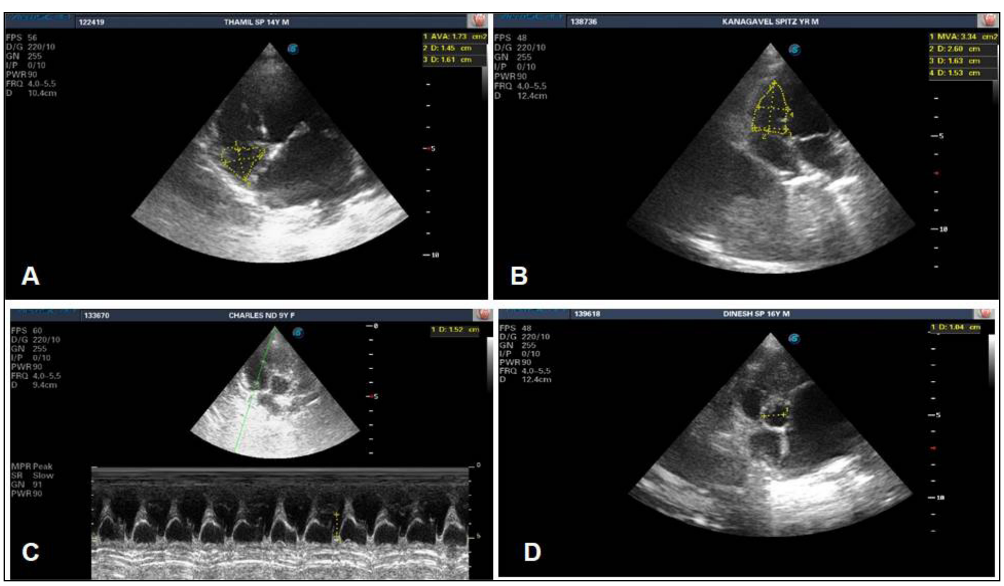

Fig. 1: B and M-mode right heart echocardiography in dogs with MVD. **(A)** Measurement of right atrial dimensions; **(B)** Measurement of right ventricular dimensions and area in systole in MVD; **(C)** TAPSE (Tricuspid annular plane systolic excursion) in MVD dogs; **(D)** Measurement of aortic dimeter in MVD dogs

to the sternum on both sides of the thoracic wall. The echocardiography was performed in right lateral recumbency according to standard procedure (Boon 1998).

Measurements

A right ventricle-focused left parasternal apical four-chamber view was used for obtaining the right atrial measurements. The right atrial minor dimension (RA-min) was taken parallel to the tricuspid annulus plane, and the major dimension (RA-maj) was perpendicular to it; planimetry was used to trace the right atrial area (RAA). The three linear dimensions of the right ventricular cavity were RV-maj, RV-min, and TVA. The major dimensions of the right ventricle were measured from the apex to the plane of the tricuspid annulus, the minor dimensions were measured at the mid-ventricular level along a line perpendicular to this, and the tricuspid valve annulus was measured from hinge point to hinge point. The right ventricle area (RVA) was traced by planimetry.

The tricuspid annular plane systolic excursion (TAPSE), an M-mode-derived parameter, was obtained with the cursor parallel to the right ventricular free wall. A two-dimensional cranial left parasternal view was used to measure the diameter of the subvalvular right ventricular outflow tract (RVOT) in diastole (Visser *et al.,* 2015). The right parasternal short axis view was utilized to calculate linear aortic dimensions during the start of diastole, shortly after the aortic valve was closed (Caivano *et al.,* 2018).

The transtricuspid flow velocity (E and A velocities) and tricuspid regurgitation velocity were measured using standard methods (Boon, 1998). Using pulsed wave Doppler, the lateral tricuspid annulus velocity (S), early diastolic (E), and late diastolic (A) velocities were calculated from the left parasternal apical four-chamber view (Baron *et al.,* 2014). The isovolumic contraction time (IVCT) was recorded between the end of A and the beginning of S, and the ejection time is the length of the S wave. The isovolumic relaxation time (IVRT) was measured between the end of S and the beginning of E (Teshima *et al.,* 2006).

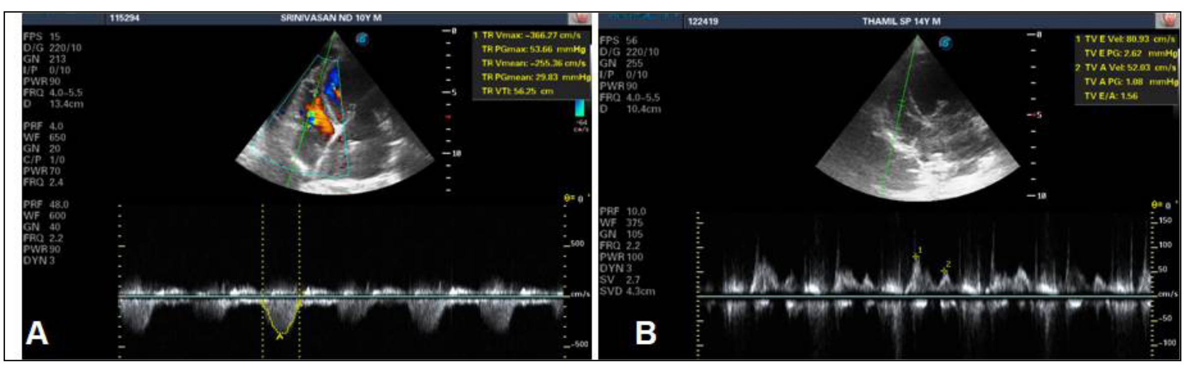

Fig. 2: Spectral Doppler right heart echocardiography in MVD dogs. **(A)** Measurement of Tricuspid E velocity and A velocity in MVD dogs; **(B)** Measurement of Tricuspid regurgitation (TR) velocity in MVD dogs

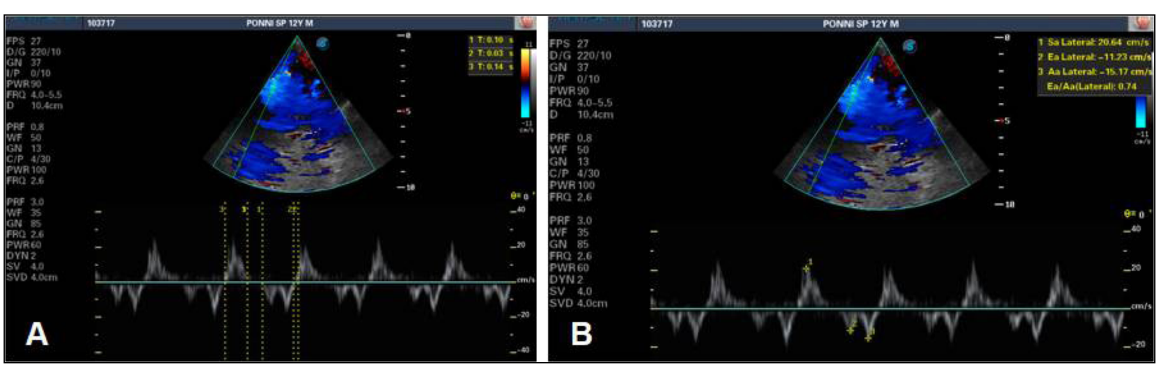

Fig. 3: Pulsed wave tissue Doppler right heart echocardiography in MVD dogs. **(A)** measurement of S', E' and A' velocity; **(B)** Measurement of IVCT, IVRT and ET

Calculations

Right ventricular fractional area change (RV FAC) = [(RVAd – RVAs/RVAd) × 100].

TAPSE: Ao = TAPSE/Ao

Systemic pulmonary artery pressure (sPAP) = 4 peak TR^2 mmHg

Mean pulmonary artery pressure (mPAP) = 0.61 × sPAP mmHg

Right ventricular myocardial performance index (RV MIP) = IVCT + IVRT/ET.

STATISTICAL ANALYSIS

The data was evaluated in IBM® SPSS software using an independent t-test to determine if there was a statistically significant difference between all of the parameters.

RESULTS AND DISCUSSION

In the current study, the mean ± S.E. of age of the dog affected with MVD was 11.25 ± 0.73 years, ranging from 5 years to 15 years. Sex-wise incidence was reported to be highest in male dogs, at 58.82 per cent (10/17) while it was 41.17 per cent (7/17) in female. The highest incidence of MVD was reported in the spitz breed, at 47.05 per cent, followed by non-descript breed at 29.41 per cent. In Daschund, Lhasa Apso, Miniature Pinscher and Labrador Retriever incidence rates were found to be 5.88 per cent each. According to Thirunavukkarasu (2019), the Spitz breed of dog was the most frequently documented breed, while older dogs between the ages of 8 and 10 years were most likely to develop mitral valve disease.

In dogs with MVD, the commonly reported clinical signs were inappetence in 64.70 per cent cases (11/17), followed by chronic cough in 41.17 per cent (7/17), lethargy in 29.41 per cent (5/17), ascites and limb edema in 23.52 per cent cases each (4/17), and anorexia in 17.64 per cent cases (3/17). These findings are in accordance with the study of 617 dogs with MVD by Serres *et al.* (2006). Cardiac auscultation of 17 dogs revealed, systolic murmurs as the most frequent findings, followed by chronic cough, ascites, and lethargy. This concurs with findings of Baisan *et al.* (2016). On thoracic radiography, a significant difference was noticed in the VHS of MVD dogs (11.5 ± 0.23) as compared to normal dogs (10.25 ± 0.28). These findings are pursuant to Oyama *et al.* (2008), and Gordon *et al.* (2017). In accordance with Diana *et al.* (2009) and Keene *et al*. (2019), pulmonary edema and venous congestion represent additional radiographic abnormalities associated with increased VHS.

Three of the 17 dogs with MVD showed atrial fibrillation; two dogs had reduced R wave amplitude; and one dog had occasional VPCs as alterations on the electrocardiogram. Borgarelli *et al*. (2004) reported comparable findings as well. The haematological and serum biochemistry parameters of MVD and healthy dogs were not significantly different, and values lie within the reference range. These support the results of Schober *et al.* (2010) and Prihirunkit *et al.* (2014). The recorded systolic blood pressure was 119.5 ±10.3 mmHg, which is in accordance with Schober *et al*. (2010).

Table 1 summarizes the Mean ± S.E. of various B and M-mode echocardiographic indicators of the right heart in dogs with MVD. No significant increase was noticed in RA-min_s (cm), RA-maj_d (cm), RAA_s (cm^2), RAA_d (cm^2), RVA_s (cm^2), RVA_d (cm^2), RV-maj_s (cm), TVA_s (cm), RV- min_d (cm), RV-maj_d (cm), and TVA_d (cm) of MVD dogs when compared to normal dogs, which represents chamber dilatation. Right ventricular systolic dysfunction was relatively common in dogs with left-sided congestive heart failure.

Table 1: Mean ± S. E. values comparing B and M- Mode Right heart echocardiographic parameters between normal dogs and dogs with MVD

Parameter	Normal group (n = 12)	MVD group (n = 17)	p-value
RA-min_s (cm)	1.16 ± 0.07 [a]	1.635 ± 0.14 [a]	0.17[NS]
RA-maj_s (cm)	1.59 ± 0.10 [a]	1.18 ± 0.15 [a]	0.80[NS]
RA-min_d (cm)	1.32 ± 0.066	1.89 ± 0.1[b]	0.03*
RA-maj_d (cm)	1.86 ± 0.077 [a]	2.40 ± 0.19 [a]	0.28[NS]
RAA_s (cm^2)	1.66 ± 0.18 [a]	2.69 ± .47 [a]	0.38 [NS]
RAA_d (cm^2)	1.98 ± 0.917 [a]	3.81 ± 0.45 [a]	0.10 [NS]
RVA_s (cm^2)	2.12 ± 0.231 [a]	2.30 ± 0.34 [a]	0.98 [NS]
RVA_d (cm^2)	3.13 ± 0.243 [a]	3.33 ± 0.46 [a]	0.99 [NS]
RV-min_s (cm)	1.10 ± 0.1 [a]	1.02 ± 0.08 [a]	0.95 [NS]
RV-maj_s (cm)	2.09 ± 0.11 [a]	2.13 ± 0.16 [a]	0.99 [NS]
TVA_s (cm)	1.13 ± 0.09 [a]	1.18 ± 0.10 [a]	0.99 [NS]

RV- min_d (cm)	1.27 ± 0.08 [a]	1.29 ± 0.11 [a]	0.99 [NS]
RV-maj_d (cm)	2.58 ± 0.12 [a]	2.62 ± 0.13 [a]	0.99 [NS]
TVA_d (cm)	1.31 ± 0.10 [a]	1.43 ± 0.11 [a]	0.90 [NS]
RVOT (cm)	1.12 ± 0.08 [a]	1.55 ± 0.10 [a]	0.05 [NS]
Ao (cm)	1.24 ± 0.75 [a]	1.49 ± 0.82 [a]	0.18 [NS]
TAPSE (cm)	1.12 ± 0.09 [a]	1.637 ± 0.11[b]	0.04*
RV FAC (%)	32.25 ± 5.30[a]	32.45 ± 2.88 [a]	0.99 [NS]
TAPSE: Ao	0.99 ± 0.14 [a]	1.12 ± 0.08 [a]	0.77 [NS]

There was a significant increase in RA-min_d and TAPSE in MVD dogs when compared to RA-min_d and TAPSE in normal dogs. Because the ventricle is ejecting blood into the low-pressure left atrium, the resistance to ventricle emptying is reduced in dogs with moderate-to-severe mitral regurgitation caused by mitral valve disease. The loading conditions imposed on the left ventricles alter, and the end diastolic ventricular stretch associated with MR increases contraction force and leads to hyperdynemic ventricular performance, which may be the possible reason for increased TAPSE in the MVD group compared to normal dogs (Petchdee *et al*., 2021).

There was no significant difference between E velocity (76.5 ± 4.06 cm/s), A velocity (49.46 ± 2.96 cm/s), and E/A (1.63 ± 0.11) of MVD dogs when compared to E velocity (67.14 ± 2.97 cm/s), A velocity (43.81 ± 3.10 cm/s), and E/A (1.56 ± 0.1) of normal dogs. The reported findings that the E velocity, A velocity, and E/A ratio remained unchanged could be attributed to hyperdynemic ventricular function.

The reported TR Vmax, PR Vmax, sPAP, and mPAP in MVD dogs were 2.79 ± 0.25 m/s, 1.52 ± 0.13 m/s, 34.02 ± 6.48 mmHg, and 11.07 ± 4.06 mmHg, respectively. In the MVD group, 16.64 per cent (3/17) of the dogs showed increased sPAP, and 14 dogs showed sPAP within the normal range. Similarly, 16.64 per cent (3/17) of the dogs showed increased mPAP, and 14 dogs showed mPAP within the normal range. Pulmonary hypertension (PH), characterised by an increase in pulmonary artery pressure with or without pulmonary vascular resistance, is a common comorbidity in dogs with myxomatous mitral valve disease (MMVD). Increased sPAP and mPAP in dogs with MVD may be related to post-capillary pulmonary hypertension caused by increased left atrial pressure induced by MVD (Yuchi *et al.,* 2021).

Table 2 summarizes the mean±S.E. of various Pulsed wave tissue Doppler echocardiographic parameters of the right heart in healthy dogs with MVD. There was no significant difference between IVCT, IVRT, ET, E', A' S', RV MIP, and E/E' of MVD dogs and normal dogs. And values of S' (16.87 ± 0.97 cm/s) and E/E' (6.10 ± 0.63) were within the normal range, which is suggestive of no systolic or diastolic dysfunction of right ventricle in dogs with MVD. Additionally, this is explained by a hyperdynemic ventricular wall set on by end-diastolic ventricular stretch and altered ventricle loading conditions in dogs with mitral valve disease (Tilley *et al.,* 2008).

Table 2: Mean ± S.E. values comparing pulsed wave tissue Doppler right heart echocardiographic parameters between normal dogs and dogs with MVD

Parameter	Normal group (n=12)	MVD group (n=17)	p-value
IVCT (ms)	0.056 ± 0.007 [a]	0.48 ± 0.006 [a]	0.956 [NS]
IVRT (ms)	0.048 ± 0.05 [a]	0.035 ± 0.003 [a]	0.999 [NS]
ET (ms)	0.152 ± 0.007 [a]	0.168 ± 0.007 [a]	0.852 [NS]
E' (cm/s)	11.952 ± 1.857 [a]	14.288 ± 1.227 [a]	0.546 [NS]
A' (cm/s)	9.332 ± 0.73 [a]	14.494 ± 1.139 [a]	0.076 [NS]
S' (cm/s)	13.359 ± 1.385 [a]	16.87 ± 0.977 [a]	0.275 [NS]
RV MIP	0.707 ± 0.087 [a]	0.55 ± 0.052 [a]	0.980 [NS]
E/E'	6.582 ± 0.99 [a]	6.107 ± 0.633 [a]	0.989 [NS]

CONCLUSION

Despite higher m-mode and pulsed-wave tissue Doppler-derived right heart systolic indices in MVD, there were no appreciable alterations in either the right atrial or right ventricular dimensions. The parameters obtained from pulsed-wave tissue Doppler imaging were within normal limits, showing that there was no right ventricle systolic or diastolic dysfunction in dogs with MVD. All of these MVD observations are related with hyperdynemic ventricular walls, and more advanced modalities such as strain and strain rate are necessary to offer accurate information.

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