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Studies on Pulsed-wave Doppler Echocardiography in Small Breed Dogs

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ABSTRACT

The study aims to evaluate and find the correlation of age and body weight of pulse wave Doppler echocardiographic indices of mitral velocity, tricuspid velocity, pulmonary and aortic velocity in 13 apparently healthy small breed dogs aged 1 to 9 years and weighing 6.5 to 15 kg were subjected to pulsed-wave Doppler echocardiography examination. Except for a positive correlation with age by Mitral peak A velocity and a positive correlation with body weight by Mitral E/A ratio, all other parameters are negatively correlated with age and body weight. The findings can be used to further determine the pathophysiological affections in future studies on small breed dogs.

HIGHLIGHTS

- Blood flow across the mitral valve, tricuspid valve, aortic velocity and pulmonary artery velocity were determined.
- Pulse wave Doppler proves to be useful in recording flow velocities in a non-invasive fashion.
- This diagnostic aid a less cumbersome and more reliable technique.

Keywords: Aortic flow velocity, mitral flow velocity, tricuspid flow velocity, pulmonary flow velocity

Doppler mode gives a physiological assessment of blood flow within cardiac chambers, across valve orifices, and in the great vessels (Smith *et al.,* 1986). It also provides information about cardiac morphology, its function and helps in establishing normal values with factors affecting them to diagnose a variety of pathological cardiac conditions, including abnormal trans-valvular flow and velocities (Kirberger *et al*., 1992a; Kumar *et al.*, 2018). In addition to weight, the breed is an important factor in the determination of normal echocardiographic measurements as do body size and somatotype (Della *et al.*, 2000) for dogs. The athletic ability and susceptibility to heart disease are influenced by dog breed and body conformation (Jacobson *et al.,* 2013). Therefore, echocardiographic reference ranges derived from some dog breeds may be misleading for others.

The presence of valvular incompetence leading to heart failure was higher in certain small and medium-sized breeds including Spitz (Thirunavukkarsu, 2014), Poodle, Schnauzer, Chihuahua, Doberman Pinscher, Boston terrier and Cocker spaniel. The incidence and risk related to cardiac diseases were found to be higher in the Pomeranian breed than that in the other breeds of dog (Kumar *et al*., 2014). The present study was designed to determine the reference ranges of pulsed-wave Doppler echocardiographic parameters of blood flow across the mitral valve, tricuspid valve and aortic velocity and pulmonary artery velocity and the possible effect of age and body weight in apparently healthy small breed dogs.

MATERIALS AND METHODS

The present study was conducted on 13 clinically healthy small breed dogs (2 Beagle, 11 Spitz breed) with an average age of 5.7 years (1-9 years) and an average bodyweight of 10.37 kg (6.5-15 kg). The dogs were considered healthy

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for echocardiographic examination based on history and absence of abnormalities on physical examination, cardiac auscultation, normal thoracic radiographs and electrocardiography. All examinations were performed with manual restraint of the animals without sedation. Echocardiographic examination was performed using the MyLab40vet ultrasound machine (ESAOTE INDIA) and a 3.3-5.5 MHz phased array probe (P.A. 122). The ultrasound beam was directed as parallel as possible to blood flow for optimal Doppler studies. From the cranial position, the base of the heart and the great vessels were examined while from the caudal (apical) position, the two-chamber, four-chamber and five-chamber views of the heart were assessed.

Mean, standard error and ranges were calculated for each measurement. Bivariate Pearson's correlation test was used to establish the correlation of various Doppler echocardiographic parameters with age and body weight of animals(Snedecor and Cochran, 1994). The level of statistical significance was set at P<0.05 and P<0.01.

RESULTS AND DISCUSSION

Mitral valve velocity and Tricuspid valve velocity

The Mean ± SE values of the MVE_{peak}, MVA_{peak} and the ratio of E wave to A wave of the mitral valve (MVE/A) were 0.48 ± 0.03 (range 0.34-0.69) m/sec, 0.32 ± 0.03 (range 0.22-0.58) m/sec and 1.49 ± 0.06, respectively range 1.26-2.00 (Fig. 1a). There was a non-significant negative correlation in E-wave peak velocity with age and body weight. Similarly, A-wave peak velocity had a non-significant negative correlation with body weight and a non-significant positive correlation with age. However, the mitral E/A ratio had a significant (P≤0.05; 0.05) positive correlation with body weight and negative correlation with age. The Mean ± SE values of TVE_{peak}, TVA_{peak}, and the ratio of E wave to A wave of the mitral valve (TVE/A) were 0.39 ± 0.02 (range 0.25-0.48) m/sec, 0.26 ± 0.02 (range 0.22-0.48) m/sec and 1.51 ± 0.07 (range 1.2-2.18), respectively (Fig. 1b). The TVA_{peak}, TVA_{peak} and ratio of E wave to A wave had a non-significant negative correlation with age and a nonsignificant correlation with the body weight.

Aortic velocity and pulmonary artery velocity

The Mean ± SE value of aortic velocity and pulmonary velocity were 0.74 ± 0.06 m/sec (range 0.34-1.15) (Fig. 1c) and 0.58 ± 0.04 m/sec (range 0.37-0.85) (Fig. 1d) respectively. Both aortic and pulmonary velocity showed a non-significant (P>0.05) negative correlation with age and body weight.

The mitral flow is positive and laminar with two main phases, E and A waves, each having a spiked triangular appearance (Bodh *et al.,* 2020). The mitral E velocity can be used as an index of left ventricular relaxation (Nagueh *et al.,* 1997). The MVE_{peak}, MVA_{peak} wave velocity and MVE/A ratio can be taken as markers of diastolic function. In healthy individuals, numerous factors may have an impact on trans-mitral flow pattern, including age, heart rate (Parker *et al*., 1987), loading conditions (Choong *et al*., 1987) and filling pressures (Vlahovic and Popovic, 1999). However, the effect of respiration on mitral flow velocities appeared minimal (Kirberger *et al*., 1992a) unlike tricuspid flow velocity. Therefore, the recording of both the mitral and the tricuspid flow velocities in association with respiration, can diagnose conditions with increased ventricular interactions.

The value of MVE_{peak} velocity recorded in the present study is lower than the reported small breed values i.e. 0.76 ± 0.09 (Reetu *et al.,* 2020) and 0.69 ± 0.09 (Bodh, 2014) in Spitz 0.64 ± 0.11 (Jacobson *et al.,* 2013) in Border Collie; 0.76 ± 0.13 (Schober and Fuentes, 2002) and 0.81 ± 0.18 (Cavalcanti *et al.,* 2007) in Boxers and 0.76 ± 0.14 (O'Sullivan, 2007) and 0.82 ± 0.11 (Kobal and Patrick, 2007) in Doberman Pinscher whereas, the MVA_{peak} velocity in the present study is in accordance with the range of Border Collie (0.53 ± 0.14, 0.35-0.76) (Jacobson *et al.,* 2013) and smaller than those for Spitz 0.52 ± 0.05 (Reetu *et al.,* 2020), 0.43 ± 0.12 (Bodh, 2014), Boxers 0.52 ± 0.12 (Schober and Fuentes, 2002) and 0.51 ± 0.11 (Cavalcanti *et al.,* 2007) and Doberman Pinscher 0.66 ± 0.11;0.55 ± 0.10 (Kobal and Patric, 2007; O'Sullivan, 2007). In addition, there was a non-significant effect of age on these parameters, as observed during regression analysis by Reetu *et al*. (2020).

The mitral E/A ratio was found to be greater than 1 in this study. In healthy dogs, the rapid ventricular filling peak (E-wave) is higher while the atrial contraction peak

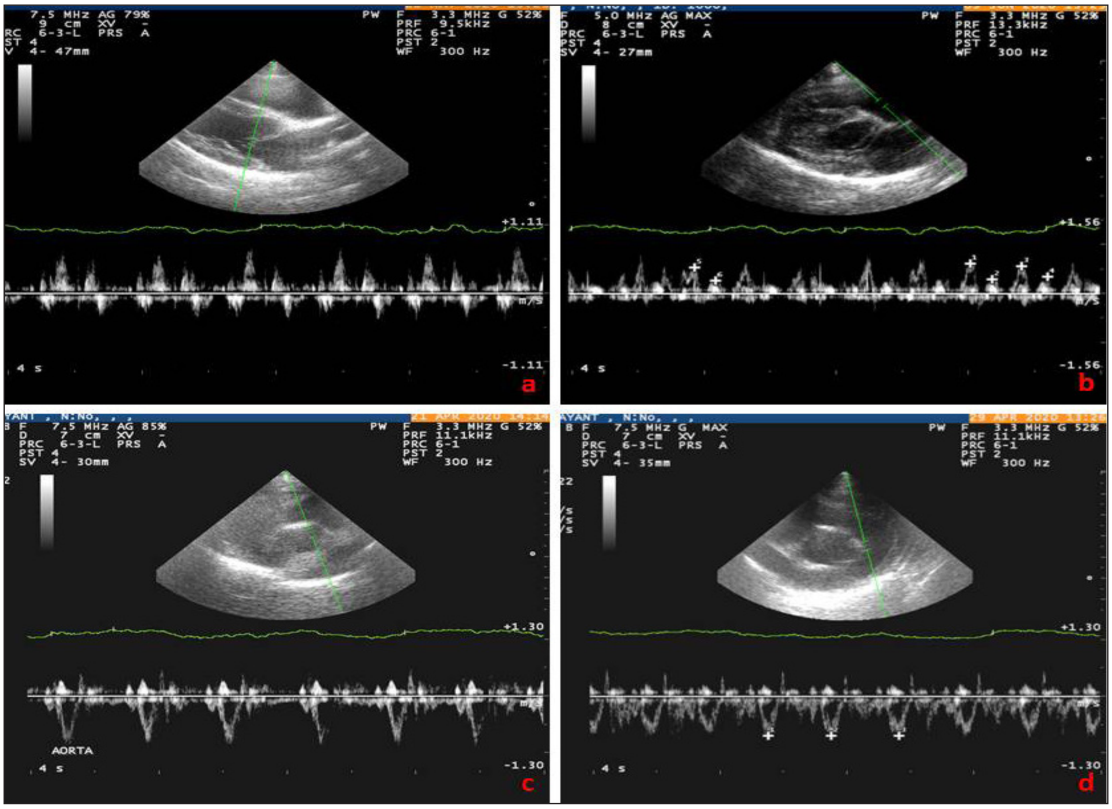

Fig. 1: Doppler echocardiogram. **(a)** Mitral flow velocity, **(b)** tricuspid flow velocity, **(c)** aortic flow velocity, **(d)** pulmonary flow velocity

(A-wave) is lower, making the E/A ratio always greater than 1 (Appleton *et al.,* 1988a). The mitral E/A ratio for small dog breeds in the present study was similar to the values reported for Boxers (1.47 ± 0.34) (Schober and Fuentes, 2002) and lower than values reported in small breed i.e. Spitz (1.6 ± 0.45) (Bodh, 2014), Boxers (1.58 ± 0.19) (Cavalcanti *et al.,* 2007) and Doberman Pinscher 1.26 ± 0.19; 1.40 ± 0.30 (Kobal and Patric, 2007; O'Sullivan *et al*., 2007). The lower MVA_{peak} and MVE_{peak} may be attributed to less number of dogs involved in the present study. Non-significant effects of body weight on mitral E and A velocities were in accordance with the findings in Doberman Pinschers (Kobal and Patric, 2007) and E/A value with Spitz (Bodh, 2014) and Doberman Pinschers breeds (Kobal and Patric, 2007).

The tricuspid flow velocity curve is a valuable adjunct to the interpretation of the mitral flow velocities because it reflects the filling characteristics of the right side of the heart. The diastolic velocities are slightly lower than those of the mitral valve. The tricuspid inflow profile was similar to the mitral inflow profile. The peak velocity changes during the respiratory cycle, with an increase during inspiration and a decrease during expiration (Nishimura *et al.,* 1989). The values of TVE_{peak} wave velocity and TVA_{peak} wave velocity of Spitz (0.57 ± 0.11, 0.38 ± 0.08) (Reetu *et al*., 2020) and Boxers (0.71 ± 0.13, 0.45 ± 0.12) (Bodh, 2014) were higher than the findings of the present study. A lesser number of animals involved in the study may be stated as a reason for lower values as in the case of mitral flow velocity. TVE_{peak} was lower than the MVE_{peak} because higher left atrial pressures cause a higher pressure difference between the left atrium and ventricle during early diastole resulting in higher velocities (Bodh *et al*., 2020; Fuji *et al.,* 1985). The E and A peaks of tricuspid flow showed a non-significant correlation with body weight, similar to the findings in normal dogs (Fuji *et al*., 1985). Increased tricuspid peak velocity may be secondary to the increased right atrial pressure or volume secondary to the tricuspid insufficiency that results in increased velocities therefore must be considered while evaluating diastolic

Table 1: Mean ± SE values of various pulse wave Doppler echocardiographic parameters

Case	MVE_{peak}	MVA_{peak}	MVE/A	TVE_{peak}	TVA_{peak}	TVE/A	PV	AoV
1	0.4	0.22	1.81	0.48	0.22	2.18	0.42	1
2	0.5	0.25	2	0.34	0.23	1.47	0.54	0.34
3	0.41	0.28	1.46	0.31	0.22	1.4	0.58	1.15
4	0.53	0.37	1.43	0.55	0.44	1.25	0.62	0.59
5	0.57	0.35	1.62	0.45	0.41	1.09	0.69	0.73
6	0.69	0.53	1.3	0.52	0.38	1.36	0.78	0.92
7	0.43	0.29	1.48	0.4	0.25	1.6	0.74	0.83
8	0.77	0.58	1.26	0.29	0.24	1.2	0.85	0.93
9	0.4	0.22	1.81	0.25	0.16	1.56	0.37	0.63
10	0.34	0.25	1.36	0.32	0.2	1.6	0.52	0.61
11	0.37	0.26	1.42	0.44	0.26	1.7	0.46	0.45
12	0.42	0.25	1.2	0.4	0.22	1.81	0.63	0.84
13	0.46	0.36	1.27	0.32	0.22	1.45	0.42	0.64
Mean ± SE	0.48 ± 0.03	0.32 ±0.03	1.49 ± 0.06	0.39 ± 0.02	0.26 ± 0.02	1.51± 0.07	0.58 ± 0.04	0.74 ± 0.06
Age	-0.153	0.070	-0.628	-0.311	-0.241	-0.050	-0.198	-0.246
BW	**-0.195**	**-0.263**	**0.553**	**0.277**	**0.073**	**0.278**	**-0.387**	**-0.100**

function and atrial pressure (Appleton *et al.*, 1988b). The TVE/A velocity was found to be similar to that of Spitz (1.56 ± 0.32) (Bodh *et al.,* 2020).

The pulmonary velocity in our study was less than that in Border Collie 0.96 ± 0.20 (Jacobson *et al.,* 2013) and Boxers 1.10 (0.69–1.63) m/s (Isobe *et al*., 1986). The pulmonary artery showed the high susceptibility to be affected by variables like breed, age, heart rate and respiration (higher values obtained during inspiration) (Cunningham *et al.,* 2008).

Peak and mean velocities of the pulmonary artery were observed to be lower than the aortic velocity (Nishimura *et al.*, 1989) which is consistent with the observations of our study.

Aortic velocity reflects the entire left ventricle and it may prove beneficial in patients with significant left ventricular motion abnormalities (Bodh, 2014). It is also useful in differentiating normal subjects from patients with poor left ventricular systolic function. The Aortic flow velocity profile was negative with a rapid laminar acceleration phase i.e., downstroke (Bodh *et al.,* 2020) giving an asymmetrical knife-like shape to the flow profile (Kirberger *et al.*, 1992a). Peak AoV was lower than reported in Spitz (0.87 ± 0.07) (Bodh, 2014), Boxers 1.77 (1.14–2.37) m/s (Cunningham *et al.*, 2008) and English bull terriers (1.9 ± 0.2 m/sec) (O'Leary *et al.,* 2003). However, it was greater than the range documented in Spitz of Group 2 (range 1.5-7 years, Ao mean = 0.591 ± 0.082, range 0.51-0.704) (Reetu *et al.*, 2020). The AoV showed no correlation with body weight (Kirberger *et al.*, 1999b).

This study was designed to simulate clinical settings where dogs are not sedated and angle correction was not used. However, certain limitations can influence recorded blood flow velocities; lesser sample size was used that could directly affect the width of the reference range (Morrison *et al.*, 1992), the study lacks concurrent Doppler-derived and direct hemodynamic measures, which would be important for corroborating abnormal diastolic filling patterns (Oh *et al.,* 1999) and only one view was used for most of the interrogation and measurements. It can be concluded that the pulse wave Doppler proves to be useful in recording flow velocities in a non-invasive fashion, which makes this diagnostic aid a less cumbersome and more reliable technique. The findings of the present study comprising referential values of Doppler echocardiographic measurements could apply for small breed dogs in future studies.

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