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Modified Simpson's method of disc in the diagnosis of dilated cardiomyopathy in dogs

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Abstract

Dilated cardiomyopathy, the second most common canine acquired heart disease, is one of the leading cause morbidity and mortality in middle to old aged large breed dogs. The cases presented with signs suggestive of cardiac diseases were screened for DCM with the aid of standard B mode and one dimentional M-mode echocardiography. Totally eight confirmed cases of DCM were selected for the present study and subjected to modified Simpson's method of discs for LV volume measurement and biplanar EF. All the parameters under study were repeated in six healthy control dogs also. The data was analysed statistically by paired t-test. The results showed a statistically significant increase in LV EDVI and ESVI and significant reduction in EF BP, compared to control. This study demonstrated that the two-dimensional modified Simpson's method of discs as a superior alternative to M-mode measurements for assessing left ventricular (LV) volume. Since, M-mode relied on a one-dimensional approach based on LV geometry, which might lead to inaccuracies, especially in cases of LV dyssynchrony in diseased heart. In contrast, the Simpson's method accurately captures the complex three-dimensional shape of the LV by summing elliptical discs, providing a more precise assessment of LV volume. This improved accuracy is essential for diagnosing the chamber enlargement and volume and managing conditions like DCM, making the 2D modified Simpson's method the preferred choice in veterinary cardiology.

Keywords: *Dilated cardiomyopathy, Simpson's method of discs, Simpson's rule, echocardiography, end-diastolic volume, end systolic volume*

Cardiac disease in dogs is a significant concern, as it represents one of the leading causes of morbidity and mortality in companion animals now a days. Dilated cardiomyopathy (DCM), the second most prevalent acquired cardiac disease in dogs, characterised by progressive ventricular dilation and reduced myocardial contractility. The most common form of this condition is idiopathic dilated cardiomyopathy (Tidholm *et al.,* 2001).

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Echocardiography is the confirmatory diagnostic tool in the diagnosis of DCM. In which, M-mode echocardiography is most widely used for measuring the left ventricular (LV) dimensions and function; however, it has certain limitations. As a one-dimensional technique, it relies on geometric assumptions that may not accurately reflect the complex anatomical variations present in diseased states. In this context, the Simpson method of discs (SMOD) emerges as a sophisticated and reliable alternative for assessing LV volumes and function. By utilising a two-dimensional framework, this method transcends the limitations of M-mode by offering a comprehensive volumetric analysis that embraces the complex geometry of the heart. This method estimates heart volume by summing a series of parallel cylindrical sections, with the diameters derived from tracing the endocardial borders in one or two orthogonal left ventricular (LV) apical views. This method is currently endorsed as a preferred approach by the American Society of Echocardiography (ASE). The principle behind this method involves calculating the total LV volume by adding a stack of elliptical disks, with the height of each disk determined as a fraction (typically 1/20) of the LV long axis, based on the longer of the two lengths measured from the two- and four-chamber views.

Materials and methods

Study population

The present study was conducted at the Department of Veterinary Clinical Medicine, Ethics and Jurisprudence, College of Veterinary and Animal Sciences, Mannuthy, Thrissur during April 2023 to June 2024. The dogs presented, with signs suggestive of cardiac disease were screened for DCM with the aid of echocardiography. Eight confirmed cases of DCM (Group II) underwent modified Simpson's method of disc (SMOD) measurement for left ventricle. Six adult healthy dogs were selected as control (Group I). Body weight and body surface area Group I and II animals were recorded for indexing the EDV and ESV. All the parameters under study were repeated in control animals also.

Echocardiographic procedure

Echocardiographic examinations were performed using Esoate MyLabX8 exp ultrasound scanner with phased array probe (1-5 MHz). The animal was positioned on **left** lateral recumbency over a cut-out section in the table, allowed the probe to be placed from below through a window in the table (Koch *et al*., 1996). Dilated cardiomyopathy cases were confirmed with standard echocardiographic parameters viz. LA/Ao ratio and EF (Teichholz) and FS from M-mode echocardiography. The confirmed cases were selected for the modified Simpson's method of disc (SMOD) measurements. This biplane method of disc measurements was done on left apical four chamber (Fig. 1a) and two chamber views (Fig. 1b) with selection of end diastolic frames (at the time of mitral valve closure) and end systolic frames (corresponding to the last frame before mitral valve opening). Two-dimensional echocardiographic image acquisition should aim to maximize LV areas, while avoiding foreshortening of the left ventricle. The LV area was measured by tracing the endocardial border on each selected image; maximal LV length was measured from the middle of a line connecting the two mitral annuli to the endocardial border of the LV apex. Left ventricle volumes were recorded as per values of the ultrasound machine. Ejection Fraction (EF) was calculated from SMOD derived end-diastolic and end-systolic LV volumes (Fig. 2) by the software automatically (Boon, 2011 and Lang *et al*., 2015). The EDV and ESV were indexed to body surface area for obtaining end diastolic volume index (EDVI) and end systolic volume index (ESVI).

Statistical analysis

The obtained data were subjected to statistical analysis in IBM SPSS Statistics v24 for windows. The group wise comparison of data was carried out by paired t-test. Parameters includes LA/Ao, EF (Teichholz), FS, EDV, ESV and EF (Simpson's) were compared between Group I and Group II by paired t-test. The level of significance fixed at 5 per cent.

Results and discussion

During the study period, 56 dogs were confirmed with DCM. Among which, eight dogs were randomly selected for the present study. The body weight of DCM affected dogs varied between 24 to 40 kg with mean value of 30.74 ± 1.76 kg, while, mean body surface area of diseased animal was 0.99 ± 0.04 m^2. The corresponding values in control animals were 29.25 ± 1.69 kg and 0.96 ± 0.04 m^2. On M- mode, a hypokinetic dilated left ventricle with atrio-ventricular valve insufficiency, and left atrial enlargement were observed in diseased dogs. Results of all echocardiographic parameters under study are represented in the table 1.

On echocardiography, mean value of EF (Teichholz) in group II animals was found to be 29.75 ± 3.03 per cent, which was remarkably low compared to control (60.00 ± 1.65 per cent), with statistically significant difference ($p < 0.001$). Similarly, significantly low FS was observed in diseased animal ($p < 0.001$), which is in line with findings of Singh *et al*. (2014). While, EF calculated by biplanar Simpson's method of disc was found to be 31.63 ± 3.06 per cent. Tidholm and Jonsson (1997) and Dukes-McEwan *et al*. (2003) reported EF < 40% measured by 2D echocardiographic images (modified Simpson's rule) as abnormally low, indicating systolic dysfunction and reduced inotropy. This variation in EF between M-mode and Simpson method, might be due to the dyssynchrony in interventricular wall motion in diseased

animals, which led to less accurate measurement of EF from the one-dimensional image (Nishijima *et al*., 2005). Delayed ventricular conduction, whether caused by myocardial disease or left bundle branch block, could lead to inter- and intra-ventricular dyssynchrony, which posed a practical challenge in the measurement of M-mode echocardiography parameters. In cases of dilated cardiomyopathy (DCM), dyssynchronous contraction in the LV was observed even during normal sinus rhythm (Stephenson *et al*., 2012 ; Wess *et al*., 2017). The mean values of EDV in group I (control) and group II (diseased) were obtained as 54.73 ± 7.07 and 93.94 ± 6.39 mL, respectively. A statistically significantly elevated EDV was observed in diseased dogs compared to control ($p < 0.01$). Also, the mean value of ESV in group I and group II were 22.03 ± 3.03 and 63.53 ± 4.09, with statistically significant difference ($p < 0.01$).

The error in volume measurement due to variation in body weight minimised by indexing EDV and ESV with body surface area (EDVI and ESVI). In diseased dogs, the mean EDVI was found to be 96.39 ± 7.70 mL/m^2, which was markedly high compared to control (57.61 ± 8.46 mL/m^2), with statistically significant difference ($p < 0.01$). Likewise, the mean value of ESVI in group I and group II were obtained as 23.27 ± 8.91and 64.88 ± 4.48 mL/m^2, respectively. The mean ESVI in diseased was notably high compared to control, with statistically significant difference ($p < 0.01$). The proposed guidelines for diagnosing canine DCM by the ESVC proposed that an ESVI value of < 30mL/m^2 considered as normal, while, a cut-off value of ESV-I > 80 mL/m^2 was suggested as clear evidence of systolic dysfunction (Dukes-McEwan *et al*., 2003). While, Wess *et al.* (2010) and Smets *et al*. (2014) established a cut off value for ESVI, up to 50-55 mL/m^2 was considered normal, while systolic dysfunction was diagnosed when the ESVI > 55 mL/m^2. An EDVI value of > 95 mL/m^2 and ESVI value of > 55 mL/m^2 were considered as cut-off values in SMOD measurements found to be superior to conventional M-mode measurements to detect early echocardiographic changes in Doberman Pinschers with DCM as suggested by Wess *et al.* (2010). In this study, mean values of EDVI and ESVI were significantly high in diseased animals compared to control animals ($p < 0.01$), with statistically significant difference, which is in accordance with aforementioned findings. The ESVI was regarded as a better indicator of systolic function because it solely depends on afterload as suggested by Borgarelli *et al*. (2006).

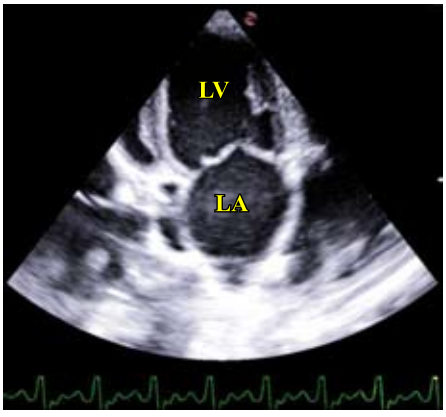

Fig. (1a) Left apical
2- chamber view

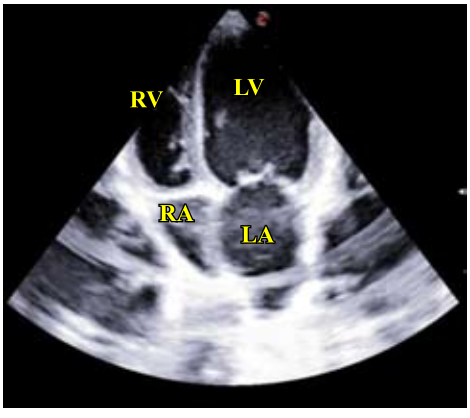

Fig. (1b) Left apical
4- chamber view

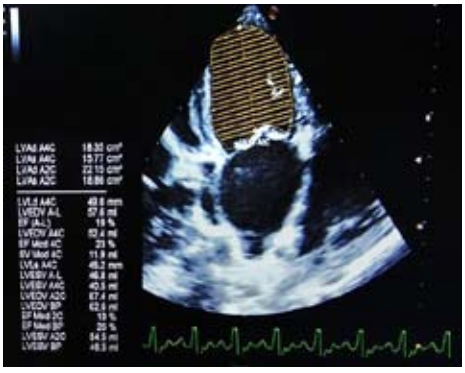

Fig. (2) Left apical
2- chamber view- SMOD measurement

Kluser *et al*. (2016) investigated the predictors of sudden cardiac death in Doberman Pinschers with DCM and found that an increase in the EDVI to 50 mL/m^2 raised the risk of mortality by eight-fold. In this study, the mean values of EDVI and ESVI in control group were also in accordance with the findings of Smets *et al.* (2014), who proposed a reference interval of 49–93 mL/m^2 for EDVI, and 22–50 mL/m^2 for ESVI in a study of healthy Boxers. The SMOD demonstrated the strongest correlation with actual left ventricular volume in diseased hearts and appeared to be relatively unaffected by changes in ventricular geometry as reported by Borgarelli *et al*. (2006). Therefore, based on the findings of this study, which demonstrated significantly elevated EDV, ESV, EDVI, and ESVI, along with a reduced EF (Simpson's), a more precise planimetric characterisation of DCM can be achieved.

Table 1. Mean values of echocardiographic parameters under study in group I and II animals

Parameters	Group I (n=8) (Mean ± SE)	**Group II (n=6)** (Mean ± SE)	**t-value**	p-value
EF (Teichholz) (per cent)	60.00 ± 1.65	29.75±3.03	7.938**	< 0.001
FS (per cent)	30.33 ± 1.05	14.38 ± 1.60[a]	7.689**	< 0.001
LA/Ao ratio	1.34 ± 0.14	2.31 ± 0.04	6.834**	< 0.001
EDV (BP) (mL)	54.73 ± 7.07	93.94 ± 6.39	4.084**	0.002
ESV (BP) (mL)	22.03 ± 3.03	63.53 ± 4.09	7.645**	< 0.001
BSA (m^2)	0.96 ± 0.04	0.98 ± 0.04	0.549	0.593
EDVI (mL/m^2)	57.61 ± 8.46	96.39 ± 7.70	3.365**	0.006
ESVI (mL/m^2)	23.27 ± 8.91	64.88 ± 4.48	6.838**	< 0.001
EF (Simpson's) (per cent)	60.00 ± 2.11	31.63 ± 3.06	0.85**	< 0.001

Conclusion

In conclusion, the current study demonstrated more accurate planimetric LV volumes with the SMOD method for accurate identification of echocardiographic changes in DCM. The study also indicated that M-mode measurements might underestimate ventricular volumes due to their reliance on geometric assumptions, often leading to misinterpretation of cardiac function.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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