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Evaluation of right ventricle echocardiographic variables in apparently healthy domestic shorthair cats

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Abstract

Right ventricular structural and functional changes result from many cardiovascular disorders in cats. Accordingly, echocardiographic evaluation of the size and function of the right ventricle (RV) provides important prognostic information in many conditions affecting the right heart. Therefore, detection of these changes is clinically important and needs reference values to ease the diagnosis. The present study was designed to calculate structural and functional right ventricular variables in 10 apparently healthy cats (six males and four females, average age 1 year old and body weight 2.70 - 4.80 kg) with no sedation. For this purpose, The minimum, maximum, mean ± standard error of the mean of right ventricle internal dimension in systole and diastole (cm), right ventricle free wall thickness in systole and diastole (cm), fractional shortening (%), right ventricle volume in systole and diastole (mL), right ventricle area in systole and diastole (cm^2), ejection fraction (%) and fractional area change (%) were measured and reported. Descriptive statistics were provided for all calculated variables. Statistical correlation of the collected variables with body weight, gender and heart rate were analyzed. Results showed that there is a significant correlation between heart rate with body weight and between systolic and diastolic RV volumes with gender. The results of the present study would help clinicians in the diagnosis of the right heart changes in DSH cats.

Introduction

The evaluating structure and function of right ventricle (RV) in patients with cardiopulmonary disorders is an essential component of clinical management. The RV can be studied with various imaging and functional modalities. In clinical practice, echocardiography is the mainstay of evaluation of RV structure and function.[1]

The RV is formerly thought to be an optional cardiac chamber that offers a little contribution to overall cardiac function. Recently, more and more investigators focused on the evaluation of the RV and demonstrated that right ventricular function is essential in the management of patients with a variety of cardiovascular diseases.[2]

Currently, the presence of right ventricular functional abnormalities in cats with hypertrophic cardiomyopathy (HCM) remains unresolved. This uncertainty arises due to the predominant emphasis on evaluating the left atrium and ventricle in echocardiographic studies of cats with HCM, with limited attention given to the right ventricle.

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One recent study documented increased RV wall thickness in cats with HCM and found that RV hypertrophy was related to the severity of left ventricle (LV) hypertrophy and clinical severity.[3] Studies evaluating right ventricular structural and functional in healthy cats and cats with cardiac diseases are limited. Thus, it is necessary to establish echocardiographic normal reference ranges for both the structure and function of right ventricular (RV) variables. These reference values are crucial for interpreting echocardiographic assessments of the RV and for making comparisons with abnormal conditions.

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However, the larger sample size would be of value in these studies, inclusion of larger number of cats was limited in the present study due to ethical reasons. Accordingly, the present study was designed to determine a range of RV echocardiographic variables in apparently healthy domestic short-haired (DSH) cats without sedation.

Materials and Methods

Sample selection. The DSH breed cats were presented for routine check up to the Teaching Small Animal Hospital, University of Tehran, after notifying the owners about participation in the study. The apparently healthy DSH cats were selected based on the medical history, general examination, auscultation of the heart and lung, electrocardiography (ECG) in standard leads, routine hematological test, lateral and dorsoventral radiographs views from chest and echocardiographic assessment of left and RV by Two-dimensional (2D) and Motion mode (M-mode) echocardiography. Study design and ethical approval were obtained from the Faculty of Veterinary Medicine, University of Semnan, Semnan, Iran (No. E-12/93) and the final study was performed in the Faculty of Veterinary Medicine, University of Tehran. Finally, 10 apparently healthy cats (six males and four females, average age 1 year old and body weight 2.70 - 4.80 kg) were studied.

Preparing and training cases. To avoid the use of sedatives drugs, the healthy cats were positioned in the lateral recumbency for echocardiography for 20 min every day for 10 days and echocardiography was performed in a dark and quiet room. The final echocardiographic examination was performed on day 11. The 2D and M-mode echocardiography with simultaneous ECG monitoring were carried out using a Vivid 7 echo-cardiograph (GE Vingmed Ultrasound AS, Horten, Norway), with a 10 sec transducer. The recorded images were sent to the picture archiving and communications system (PACS) and the numbers obtained were extracted from the images.

Two-dimensional echocardiography. Using 2D echocardiography, in the left parasternal four-chamber view and the size and volume of the RV in systole and diastole were measured and images were recorded (Fig. 1). The right ventricle volume in systole (RVVs) and diastole (RVVd) was automatically measured by echocardiography using planimetric method (area-length method) and according to:

$$V = 0.85\ A2 \times L^{-1}$$

where, V = volume, A = level, and L =length.[4,5]

The ejection fraction (EF) was calculated based on the measuring of RVVd and RVVs in a 2D method, according to:[4,5]

$$EF\% = (RVVd - RVVs) \times RVVd^{-1}$$

The fractional area change (FAC) was determined based on the right ventricle area in diastole (RVAd) and systole (RVAs) in a 2D method and according to:[4,5]

$$FAC\% = (RVAd - RVAs) \times RVAd^{-1}$$

M-mode echocardiography. Using M-mode 2D echo-cardiography, in the parasternal view of the longitudinal axis, right ventricle wall thickness in systole (RVFWs) and in diastole (RVFWd) and internal dimensions in systole (RVIDs) and diastole (RVIDd) were measured and images were recorded (Figs. 1E and 1F). The fractional shortening (FS) was calculated based on the RVIDd and RVIDs in the M-mode method and according to:[4,5]

$$FS\% = (RVIDd - RVIDs) \times RVIDs^{-1}$$

Statistical analysis. Statistical analysis was performed using SPSS Software (version 23.0; IBM Corp., Armonk, USA). Kolmogorov-Smirnov test was used to assess the normality of the data. Independent *t*-test was used to analyze quantitative data if it was normal and the Mann-Whitney U test was used if it was abnormal. Statistical correlation between variables was evaluated by the Pearson test. The $p \leq 0.05$ was considered significant.

Results

The minimum, maximum, mean ± SEM (standard error of the mean) of RVIDs, RVIDd, RVFWd, RVFWs (cm), FS (%), RVVd, RVVs (mL), RVAd, RVAs (cm^2), EF (%) and FAC (%) were displayed in Table 1. The statistical difference of the obtained variables with weight and gender, as well as the statistical correlation between the variables with body weight and heart rate were reported in Table 2.

There was no statistical significant difference in the RVIDs (p = 0.711), RVIDd (p = 0.278), RVFWs (p = 0.314), RVFWd (p = 0.794), RVVd (p = 0.363), RVVs (p = 0.990), RVAd (p = 0.848), FS% (p = 0.224), EF% (p = 0.740) and FAC% (p = 0.808) in cats with body weight lower and higher than 3.50 kg, while heart rate was significantly different in cats with body weight lower and higher than 3.50 kg (p = 0.002). These results was displayed in Table 2.

The heart rate (p = 0.276), RVIDs (p = 0.623), RVIDd (p = 0.980), RVFWs (p = 0.570), RVFWd (p = 0.614), RVAs (p = 0.466), RVAd (p = 0.680), FS% (p = 0.208), EF% (p = 0.284) and FAC% (p = 0.369) were not significantly difference between female and male cats, although there was a statistical significant difference in the RVVd (p = 0.043) between female and male cats (Table 2).

There was no statistically significant difference in the RVVs (p = 0.421) in cats lower and higher than 3.50 kg, but the RVVs in female and male cats differ significantly (p = 0.041).

There was not a statistically significant correlation between body weight and heart rate with RVIDs, RVIDd, RVFWs, RVFWd, RVVs, RVVd, RVAs, RVAd, FS, EF, and FAC.

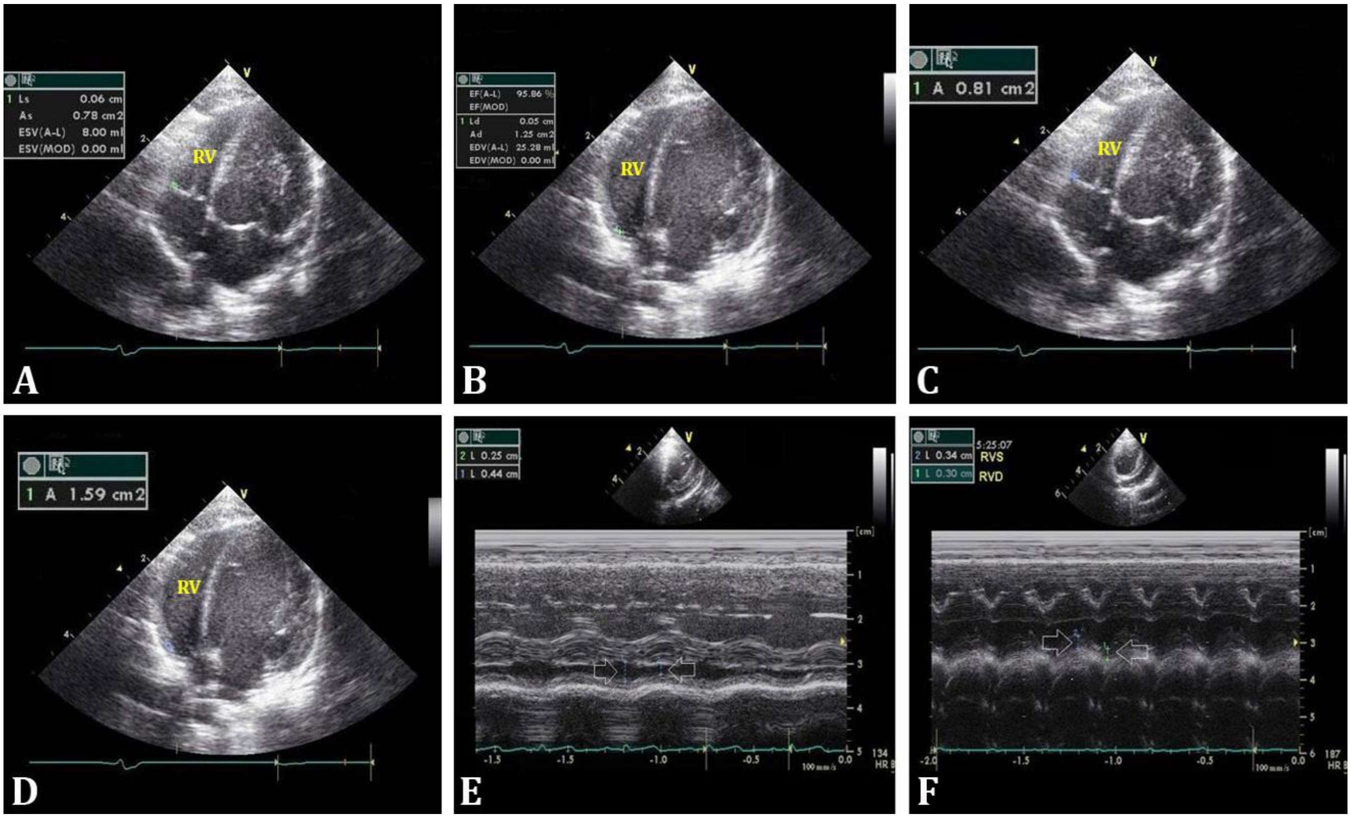

Fig. 1. The 2D-echocariogram, left-sided 4-chamber parasternal apical view. **A)** Right ventricle volume in systole, **B)** Right ventricle volume in diastole, **C)** Right ventricle area in systole, and **D)** Right ventricle area in the diastole (RV: right ventricle). The M-mode echocardiogram with 2D echocardiography guided, right-sided parasternal longitudinal axis view. **E)** Right ventricular internal dimension in diastole (1) and in systole (2) (arrows), and **F)** Right ventricular free wall thickness in diastole (1) and in systole (2), (arrows).

Table 1. Minimum, maximum and mean ± SEM of echocardiographic variables of right ventricle obtained from 2D and M-mode echocardiography in apparently healthy DSH cats.

Variable	Minimum	Maximum	Mean ± SEM
RVIDs (cm)	0.13	0.38	0.25 ± 0.30
RVIDd (cm)	0.20	0.64	0.40 ± 0.40
RVFWs (cm)	0.14	0.35	0.27 ± 0.20
RVFWd (cm)	0.10	0.30	0.21 ± 0.20
FS (%)	24.00	56.00	36.00 ± 3.34
RVVs (mL)	0.02	8.00	1.40 ± 0.80
RVVd (mL)	0.23	25.00	7.30 ± 2.00
RVAs (cm^2)	0.15	0.70	0.37 ± 0.07
RVAd (cm^2)	0.71	1.25	0.95 ± 0.05
EF (%)	68.00	99.00	84.00 ± 3.67
FAC (%)	34.90	82.70	62.00 ± 5.61

RVIDs: right ventricular internal dimension in systole. RVIDd: right ventricular internal dimension in diastole. RVFWs: right ventricular free wall thickness in systole. RWFWd: right ventricular free wall thickness in diastole. FS: fractional Shortening. RVVs: right ventricular volume in systole. RVVd: right ventricular volume in diastole. RVAs: right ventricular area in systole. RVAd: right ventricular area in diastole. EF: Ejection fraction. FAC: fractional area change.

Discussion

In previous studies with a focus on the LV, additional information has been presented on some RV variables, however, a complete evaluation of the RV echocardiography in DSH cats is lacking in the literature.[4,5]

Until recently, reference values reported for cats have been somewhat more uniform, probably related to the smaller dispersion in body sizes; however, LV internal dimension does demonstrate a statistical correlation to body size and also might be influenced by breed. Some of these data for selected 2D and M-mode echocardiographic measurements of LV variables were published and therefore the prediction was estimated for reference values.[4,6,7]

Numerous studies have been done in multi-breed and single-breed apparently healthy cats for presenting normal echocardiographic parameters of the LV by 2D and M-mode echocardiography as a reliable and practical method for the evaluation of function and structure of the LV.[4] Therefore, in the present study, the same method has been used to evaluate the function and structure of the RV, and the results can be complementary to previous research and variables of the RV.

Table 2. The statistical difference of echocardiographic variables with weight and gender.

Variable	Weight (kg)		Gender	
	< 3.50	> 3.50	Female	Male
HR (per min)	230.00 ± 7.55*	174.00 ± 9.80*	217.00±19.30	195.00 ± 12.70
RVIDs (cm)	0.25 ± 0.05	0.28 ± 0.04	0.28 ± 0.05	0.24 ± 0.04
RVIDd (cm)	0.35 ± 0.05	0.45 ± 0.07	0.43 ± 0.08	0.40 ± 0.06
RVFWs (cm)	0.35 ± 0.03	0.30 ± 0.03	0.25 ± 0.05	0.30 ± 0.03
RVFWd (cm)	0.21 ± 0.02	0.23 ± 0.04	0.20 ± 0.05	0.23 ± 0.03
RVVd (mL)	10.00 ± 4.59	4.58 ± 2.60	13.70 ± 4.20	3.26 ± 2.30
RVAs (cm^2)	0.27 ± 0.12	0.37 ± 0.08	0.44 ± 0.13	0.33 ± 0.08
RVAd (cm^2)	0.67 ± 0.08	0.64 ± 0.08	0.92 ± 0.10*	0.94 ± 0.05*
FS (%)	31.80 ± 4.00	40.04 ± 5.03	30.70 ± 2.65	39.60 ± 4.96
EF (%)	83.62 ± 5.63	85.68 ± 5.09	79.40 ± 6.40	87.80 ± 4.08
FAC (%)	63.50 ± 9.03	60.50 ± 7.08	55.50 ± 7.63	66.40 ± 7.90

HR: heart rate. RVIDs: right ventricular internal dimension in systole. RVIDd: right ventricular internal dimension in diastole. RVFWs: right ventricular free wall thickness in systole. RWFWd: right ventricular free wall thickness in diastole. RVVd: right ventricular volume in diastole. RVAs: right ventricular area in systole. RVAd: right ventricular area in diastole. FS: fractional shortening. EF: ejection fraction. FAC: fractional area change. * indicate significant differences at $p < 0.05$.

Body weight, heart rate, and 19 M-mode echocardiographic variables were measured in 41 non-anesthetized healthy cats by Jacobs *et al.* Normal values of RVIDd and RVFWs were reported only in 30 cases as 6.00 ± 2.00 mm and not determined, respectively.[8] In their findings, they observed a significant positive correlation between body weight and RVIDs as well as RVIDd. However, these results contradict the findings of our present study. It is important to note that these results could have been influenced by the sample size. Additionally, our study aligns with their observation that there is no significant correlation between heart rate, body weight, and RVIDs.

Sisson *et al*. investigated the effect of taurine on echocardiography parameters of healthy cats and cats affected with dilated cardiomyopathy. There was no significant correlation between plasma taurine concentration and M-mode echocardiographic variables in healthy cats. The ranges, mean values, and standard deviations of RVIDd derived from the M-mode echocardiographic studies of 79 normal cats were reported 0.00 - 0.83, 0.46, and 0.17 cm, respectively.[9] The RVIDd in our study was 0.40 ± 0.04 cm, which was near to this measurement in our study. Also in this study, there was no significant correlation between RVIDd and body weight which agrees with our result. However, by obtaining normal echocardiographic variables, we were able to evaluate the effects of the drug and monitor patients with cardiac disease or other conditions that may impact their health.

The RVIDd was measured in four DSH cats (three healthy and one affected) 2.80 ± 1.36 and 1.70 ± 0.59 mm, respectively, to determine intra- and inter-observer variability of echocardiographic measurements in awake cats.[10] This result was near to our study (4.00 ± 0.40 mm).

Litster and Buchanan measured RVFW and RVID in 10 obese and 10 non-obese cats 2.20 ± 0.50 mm and 3.40 ± 0.50 mm, respectively.[11] These reported results were near to results approximately.

Chetboul *et al*. studied on 100 healthy cats of six different breeds which had recieved no medications and did not have a history of heart nor respiratory tract disease. In this study, the diameter of right ventricle during diastole (RVIDd) and thickness of the right myocardial wall during systole (RVFWs) were measured and reported 3.00 ± 1.40 mm and 2.70 ± 0.80 mm, respectively.[12] In our study, the measurement of RVIDd was near to this latter mentioned results and the measurement of RVFWs was in the reported range. Also, they reported statistical differences in RVIDd with the breed, body weight, and gender, which disagree with our results because they used different statistical analysis methods and studied more cases multi-breed in comparison with our study.

Chetboul *et al*. measured means ± SD, minimum and maximum values, and reference ranges of RVIDd and RVFWs (mm) echocardiographic variables in 53 healthy Sphynx cats older than 12 months as 3.00 ± 1.40, 0.50 - 6.60 and 0.30 - 5.80 and 3.40 ± 1.30, 1.50 - 6.60 and 0.90- 5.90 mm, respectivly.[13] The same measurements were performed in our study, which were near to results reported by Chetboul *et al*.. Additionally, they reported statistical differences in RVFWs with gender and a positive statistical correlation between left ventricle free wall thickness, interventricular septum thickness, and RVFWs.

RVIDd was measured in 30 healthy, 22 cats with pleural effusion and 12 cats with pulmonary edema and was reported as median and interquartile range 2.50 (2.25 - 3.50), 4.40 (2.90 - 6.25), and 2.80 (1.30 - 3.20) mm, respectively by Johns *et al*.[14] The RVIDd measurement in our study was as mean ± SEM 4.00 ± 0.20 mm. There was no significant difference in RV diameter between cats with pulmonary edema and healthy cats. There was a significant difference in RV diameters between cats with pleural effusion and healthy cats as well as between cats with pleural effusion and cats with pulmonary edema, with cats with pleural effusion exhibiting significantly increased RV diameters. Poorer LA function and increased

RV dimensions are associated with pleural effusion in cats with left-sided heart disease.[14] According to these results and changed measurements in affected cats, presenting normal echocardiographic variables in single-breed cats could improve medical intervention decisions in healthy and affected cats.

Visser *et al.* measured right heart echocardiographic variables in control cats (n = 26), cats with subclinical HCM (n = 31), and cats with HCM and congestive heart failure (CHF; n = 24). They were reported RVIDd , RVFWd , RVIDs , RV FS and FAC as mean ± SEM 6.70 ± 1.40 mm, 2.40 ± 0.40 mm, 1.40 ± 0.30 mm, 3.40 ± 1.10 %, 50.00 ± 8.80% and 63.90 ± 6.60%, respectively. The results obtained from our study were 4.00 ± 0.40, 2.10 ± 0.20, 2.50 ± 0.30 (mm), 36.03 ± 3.34, and 62.00 ± 5.60 (%), respectively. No statistically significant differences in body weight, age, gender, purebred status, heart rate, or sedation status were measured among all groups, these reported results supported in our results.[3]

In this study, left long axis 4-chamber parasternal in 2D and right long-axis in M-mode echocardiography was the best views for evaluation of RV echocardiography.

To date, echocardiographic assessment of RV size and function is underutilized in feline cardiology. Indices of RV size and function are notoriously difficult to acquire and measure due to the chamber's relatively complex shape.

In conclusion, in this study, we found differences between healthy DSH cats and other cat breeds and between certain 2D and M-mode echocardiographic variables and body weight and sex. We also determined values for RVIDs, RVFWd, and FS%, RVVs, RVVd, and FAC% that were not considered in detail in previous studies. The results of this study will help to interpret the echocardiographic findings and in the differentiation between healthy and unhealthy DSH cats.

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Conflict of interest

The authors declare no conflict of interest.

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