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Echocardiographic assessment of right ventricular blood flow and tricuspid annular plane systolic excursion in apparently healthy domestic short-haired cats

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Abstract

Right ventricular parameters change in many cardiovascular diseases; so, the presence of normal right ventricular parameters is necessary to diagnose these diseases. Ten clinically healthy adult domestic short-haired cats including six males and four females in the range of 2.70 to 4.80 kg were studied using echocardiography without sedation. The speed and pressure of blood flow through the tricuspid and pulmonary valves, speed of the movement of tricuspid valve and tricuspid annular plane systolic excursion (TAPSE) were recorded using conventional pulsed-wave (PW) Doppler, tissue Doppler imaging (TDI) and M-mode, respectively. No significant statistical differences were observed between the measured values and sex, heart rate and body weight. A positive correlation was observed between the maximum velocity of the right ventricular outflow tract and heart rate and also between TAPSE slope and body weight. With determining the normal values of PW-TDI of the right ventricle in apparently healthy domestic short-haired cats, it is expected that with providing normal reference values, the diagnosis of heart diseases especially asymptomatic heart disease be achieved as soon as possible to provide the best appropriate therapeutic management and monitoring decision about them.

Introduction

Echocardiography is a powerful diagnostic tool in non-invasive assessing of the size, structure, function and dynamics of blood flow to the heart being known in dogs and cats.[1] The right ventricle (RV) was not considered in the past few years due to the complicated geometric structure; but today, right ventricular structure and function are considered as an important factor in the diagnosis of different kinds of cardiovascular and lung diseases in veterinary medicine. Tissue Doppler imaging technique (TDI) is a powerful technique being used to assess RV myocardial function.[2] Tricuspid annular plane systolic excursion (TAPSE) is an echocardiographic parameter of RV systolic function.[3] It is considered among the most reliable tools to measure or estimate the ejection fraction of the RV as well as cardiac output and diastolic function. But, the value of this tool may get influenced due to the co-occurrence of any other diseases such as chronic obstructive pulmonary disease. The normal values related to the pulsed-wave (PW) tissue Doppler echocardiography of the right heart have not already been presented in cats in previous studies. The RV function can be impaired due to primary right-sided heart disease or secondary to left-sided cardiomyopathy or valvular heart disease.[2] The TDI is a special Doppler technique consisting of measuring the myocardial motion velocities throughout the entire cardiac cycle. However, the motion analyzed by TDI is myocardial motion and not red blood cell motion.[4] Spectral PW-TDI is a technique measuring momentary peak myocardial velocity as it moves through a preselected sample volume. There are many conditions that can change the tricuspid valve velocity like tricuspid valve dysplasia which is a congenital malformation that can lead to volume overload of the right heart chambers and subsequent dilation.[5]

To the best of the authors' knowledge, the reference data presenting tricuspid valve motion velocities of the right heart are missing in the normal domestic short-haired (DSH) cats, which may help the practitioner in early diagnosis of the myocardial dysfunction.

The aim of this study was to present normal values regarding the tricuspid valve movement in systole and

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diastole using TDI and measuring TAPSE in apparently healthy DSH cats and to assess the correlation between these values with the blood flow parameters.

Materials and Methods

Sample selection. The clinically healthy adult DSH cats presented to Small Animal Teaching Hospital, University of Tehran, Tehran, Iran, were selected based on the medical history, general examination, auscultation of the heart and lung, electrocardiography (ECG) in standard leads, routine hematological tests and radiographs from lateral and dorso-ventral views and echocardiography. Study design and ethical approval were obtained from the Faculty of Veterinary Medicine, University of Semnan, Semnan, Iran (No. E-12/93). Finally, 10 apparently healthy DSH cats (average age: one year old, body weight: 2.70 - 5.10 kg and gender: six males and four females) were studied.

Preparing and training of cases. To prepare and train the cats for avoiding emotional behaviors during the study (without sedation), cats were located in the required position of echocardiography 20 min every day for 10 days and echocardiography was performed. After ensuring animal health and passing 10 days of training, echocardiography began on the 11th day. Echocardiography was performed in a dark and quiet room and all cats were examined in a lateral recumbency. Echocardiographic examination with simultaneous ECG was performed using a Vivid 7 echocardiography (GE Vingmed Ultrasound AS, Horten, Norway) with a 10 sec transducer.

Pulsed wave Doppler echocardiography. Spectral PW Doppler of the trans-tricuspid flow was obtained from the left parasternal view while the sample volume of 3.00 × 1.00 mm cursor was placed in the tip of the tricuspid valve leaflets. The measured parameters for the tricuspid valve were as follows: Tricuspid valve Vmax (E peak velocity), trans-tricuspid flow velocity at A point, E/A ratio and maximal (peak) pressure gradient (PG) of trans-tricuspid flow (Fig. 1). The right ventricular outflow tract (RVOT) Vmax was measured from the right parasternal short-axis view at the level of the aorta and pulmonary artery and RVOT Vmax and RVOT maxPG were evaluated (Fig. 2).

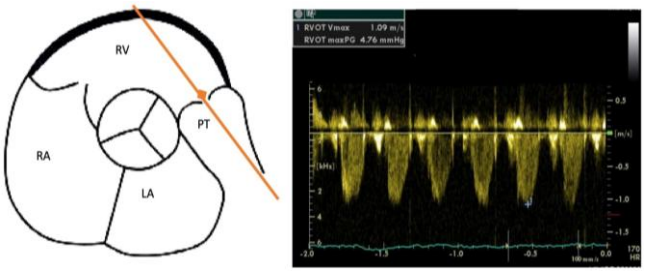

Fig. 2. Right parasternal short axis view at the level of the aorta and pulmonary artery. The right ventricular out flow velocity (RVOT Vmax) was measured. The schematic drawing on the left side shows the position of the curser. RA: Right atrium; RV: Right ventricle; LA: Left atrium; LV: Left ventricle; PT: Pulmonary trunk.

Tissue Doppler imaging. Measuring the speed and direction of the tricuspid valve movement was done by PW-TDI and two-dimensional color TDI from apical four-chamber view; so that, the sample volume cursor was placed at the level of tricuspid valve leaflets and the systolic peak velocity (Sa), early diastolic peak velocity (Ea) and late diastolic peak velocity (Aa) were calculated (Fig. 3).

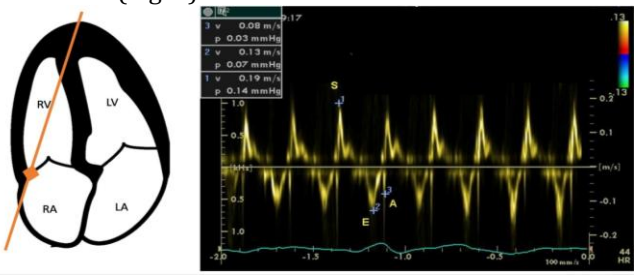

Fig. 3. Pulsed-wave tissue Doppler imaging at the level of tricuspid valve leaflets from apical four-chamber view. The schematic drawing on the left side shows the position of the curser. 1: Systolic peak velocity; 2: Early diastolic peak velocity; 3: Late diastolic peak velocity; RA: Right atrium; RV: Right ventricle; LA: Left atrium; LV: Left ventricle.

M-mode echocardiography. Tricuspid annular plane systolic excursion was measured from an M-mode recording of the lateral aspect of the tricuspid valve annulus; then, the height and slope of TAPSE were measured (Fig. 4).

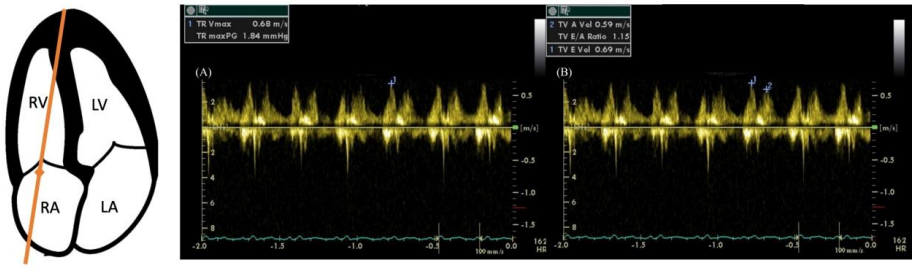

Fig. 1. Left parasternal long axis at the level of tricuspid valve. Tricuspid valve (TR) Vmax and maximal (peak) pressure gradient (peak PG) of a trans-tricuspid flow have been measured. Left parasternal long axis view at the level of tricuspid valve. Tricuspid valve (TV) Vmax (E peak velocity), trans-tricuspid flow velocity at A point and E/A ratio have been measured. The schematic drawing on the left side shows the position of the curser. RA: Right atrium; RV: Right ventricle; LA: Left atrium; LV: Left ventricle.

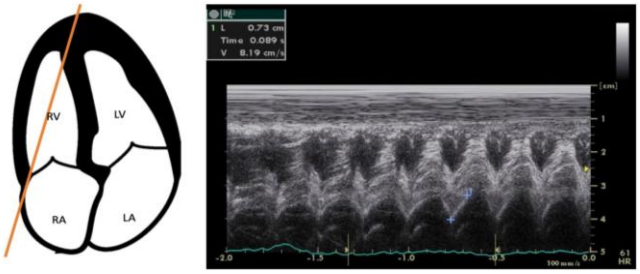

Fig. 4. Measuring tricuspid annular plane systolic excursion from apical view. The schematic drawing on the left side shows the position of the curser. RA: Right atrium; RV: Right ventricle; LA: Left atrium; LV: Left ventricle.

Statistical analysis. After recording the data and calculating indices in the corresponding tables, statistical analysis was performed using SPSS Software (version 22.0; IBM Corp., Armonk, USA) and the *p*-value less than 0.05 was considered significant. It should be mentioned that the confidence level for all analyses was considered 95.00%. For each of the parameters obtained from the spectral PW Doppler echocardiography, M-mode and PW-TDI, mean, standard error of the mean (SEM), minimum and maximum were measured. All data were evaluated in terms of normality by the Kolmogorov-Smirnov test. To assess echocardiographic amount difference between the male and female groups, in the case of parameters with normal distribution independent *t*-test and about those who did not have a normal distribution, Mann-Whitney U test was used. To determine the correlation between the measured values of the RV with body weight, sex and heart rate, the Pearson correlation test was used.

Results

This study was done on 10 clinically healthy DSH cats of both sexes. The descriptive analyses including mean, SEM, minimum and maximum values of the tricuspid and pulmonary valves are presented in Table 1. In assessing trans-tricuspid blood flow during diastole, trans-tricuspid flow was positive and linear and divided into the waves A and E. The E wave in all cases showed higher values than the A wave. The trans-tricuspid blood flow values showed no statistically significant difference between the two weight groups below 3.50 and above 3.50 kg as well as male and female groups ($p > 0.05$; Table 1). Additionally, there wasn't any correlation between the trans-tricuspid blood flow and weight, sex and heart rate (Table 1). The trans-pulmonic flow was observed as a negative (divergent) and linear flow during systole. The trans-pulmonic flow values showed no statistically significant difference between the two weight groups below 3.50 and above 3.50 kg as well as male and female groups ($p > 0.05$; Table 1). A positive incomplete and severe correlation was observed between RVOT Vmax and heart rate ($p < 0.001$ and r = 0.995; Table 1). The functional parameters of RV including the systolic, diastolic and late diastolic peak velocity of tricuspid valve leaflets and the TAPSE are observable in Table 1. For the values obtained from TDI and M-mode echocardiography in males and females, no statistically significant difference was observed (Table 1). In M-mode echocardiography, there was an incomplete positive and average correlation between the TAPSE slope and weight ($p = 0.045$ and r = 0.643) and between other functional parameters of the RV and weight, no significant correlation was observed ($p > 0.05$; Table 1).

Discussion

In this study, the trans-tricuspid and trans-pulmonic flows were respectively obtained from apical four-chamber and right parasternal short-axis views and the sample volume of 3.00 × 1.00 mm cursor was placed in the tip of tricuspid and pulmonary valves, respectively. In this study, the average maximum speed of trans-tricuspid flow and RVOT were respectively reported as 0.66 (range of 0.49 - 0.97) and 0.93 m sec^{-1} (range of 0.65 - 1.27), being corresponded to the Petrič *et al.* findings.[6] In the study of

Table 1. Descriptive analysis including mean, standard error of the mean (SEM), minimum (Min) and maximum (Max) and distribution of echocardiographic values based on weight and sex and the correlation of them with body weight (BW), gender and heart rate (HR).

Parameters	Male (n = 6)	Female (n = 4)	*p*-value	Mean ± SEM	Min	Max	BW	Sex	HR
TV Vmax (m sec^{-1})	0.60 ± 0.04	0.74 ± 0.08	0.12	ND	ND	ND	NS	NS	NS
TV A velocity (m sec^{-1})	0.36 ± 0.05	0.43 ± 0.04	0.39	ND	ND	ND	NS	NS	NS
E/A ratio	1.75 ± 0.17	1.73 ± 0.11	0.91	ND	ND	ND	NS	NS	NS
TV maxPG (mmHg)	1.51 ± 0.21	2.32 ± 0.51	0.13	ND	ND	ND	NS	NS	NS
RVOT Vmax (m sec^{-1})	0.85 ± 0.06 *	1.05 ± 0.09 *	0.11	ND	ND	ND	NS	NS	r = 0.99, $p < 0.001$
RVOT maxPG (mmHg)	3.02 ± 0.46	4.57 ± 0.77	0.10	ND	ND	ND	NS	NS	NS
Sa Vmax (m sec^{-1})	0.13 ± 0.02	0.11 ± 0.02	0.56	0.01 ± 0.12	0.05	0.20	NS	NS	NS
Ea Vmax (m sec^{-1})	0.12 ± 0.02	0.11 ± 0.02	0.76	0.01 ± 0.11	0.04	0.20	NS	NS	NS
Aa Vmax (m sec^{-1})	0.06 ± 0.01	0.05 ± 0.01	0.44	0 ± 0.63	0.03	0.12	NS	NS	NS
TAPSE (cm)	0.77 ± 0.04	0.64 ± 0.15	0.45	0.08 ± 0.79	0.50	1.26	NS	NS	NS
TAPSE slope (cm)	ND	ND	ND	0.06 ± 0.72	0.39	1.01	r = 0.64, $p = 0.04$	NS	NS

TV: Ttricuspid valve; PG: Pressure gradient; RVOT: Right ventricular outflow tract; Sa: Systolic peak velocity; Ea: Early diastolic peak velocity; Aa: Late diastolic peak velocity; TAPSE: Tricuspid annular plane systolic excursion. ND: Not determined, NS: Not significant. *: Significant difference at $p < 0.05$.

Petrič *et al*. there was a correlation between the maximum speed of trans-tricuspid E wave and heart rate; while, it was not observed in this study and there was only an incomplete severe positive correlation between RVOT Vmax and heart rate.[6] In the present study, the average blood pressure (BP) of trans-tricuspid and trans-pulmonic flows was respectively reported as 1.83 and 3.64 mmHg, using spectral PW Doppler. It is worth mentioning that no studies have been done in cats to determine the BP of the tricuspid valve inlet and the pulmonary valve outlet so far. Thus, our study is the first study that provides reference values for these parameters. The use of TDI, in comparison with the bi-dimensional echocardiography and conventional Doppler, provides a better evaluation of myocardial segmental function and allows an adequate evaluation of cardiac diastolic function as well,[7] besides revealing sudden changes in cardiac contractility with greater precision, being not detectable in conventional echocardiography.[8]

In the present study, for evaluation of the tricuspid valve movement using the PW-TDI technique from apical four-chamber view, the sample volume cursor was placed at the level of the tricuspid valve leaflets. The PW-TDI values of the tricuspid valve for the mean of parameters Sa, Ea and Aa were reported 12.70, 11.90, and 6.30 cm sec^{-1}, respectively. Koffas *et al*. studied 25 normal cats and 23 cats with hypertrophic cardiomyopathy (HCM) using the PW-TDI technique.[9] The PW-TDI of the tricuspid valve took place only in eight healthy cats and the breed of these cats was not mentioned clearly. This study is the only study until today that has reported tricuspid valve TDI values. Koffas's *et al.* have examined the PW-TDI of tricuspid valve as a part of their sick population characteristics and so far, no study has evaluated a wide range of TDI values of tricuspid valve systematically.[9] So, our study is the first study that provides reference values of TDI in apparently healthy cats.

Tricuspid annular plane systolic excursion is an echocardiographic parameter of right ventricular systolic function.[10] The slope of tricuspid valve motion along the longitudinal axis of the heart seems to be a reasonable indication of right ventricular systolic function.[11,12] Pariaut *et al.* have evaluated TAPSE in dogs to determine reference values and the impact of pulmonary hyper-tension.[10] The results of this study showed that there was a curvilinear correlation between TAPSE and body weight. So far, no studies have been conducted to determine the TAPSE parameter in cats. In the present study, TAPSE was acquired by placing the M-mode cursor through the lateral portion of the tricuspid valve annulus, and the systolic movement of tricuspid valve annulus was recorded from apical 4-chamber view. The TAPSE average was reported as 0.79 cm in this study. The average height and slope of TAPSE for 10 apparently healthy DSH cats were 0.79 and 0.72 cm, respectively. In the study of D'Oronzio *et al*., there were no significant differences in TAPSE between the two groups of males and females.[13] The results of our study showed an incomplete positive and medium correlation between body weight and TAPSE. So, our study provides a reference interval in a small population of apparently healthy cats. Spalla *et al.* have evaluated TAPSE in 64 cats with HCM and 27 normal cats. Their study showed that the TAPSE was lower in cats with HCM in comparison with the control group. Therefore, this issue emphasizes on the importance of the normal TAPSE ranges.[14] It should be mentioned that the obtained reference range from our study may not be appropriate in cats less than 2.70 and more than 4.80 kg, because cats with this range of weight didn't exist in this reference group.

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Conflict of interest

The authors declare no conflict of interest.

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