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Increased normalized pulmonary transit times and pulmonary blood volumes in cardiomyopathic cats with or without congestive heart failure

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Abstract *Objectives:* To estimate heart rate-normalized pulmonary transit times (nPTTs) in cardiomyopathic cats with or without congestive heart failure (CHF). To assess potential associations of echocardiographic variables and nPTT and to evaluate nPTT as a test for the presence of CHF.
Animals: Forty-eight privately owned cats.
Methods: nPTT was measured using echocardiography and the ultrasound contrast media SonoVue® in 3 groups of cats: healthy cats (group 1), cats with cardiomyopathy (CM) but without CHF (group 2), and cats with CM and CHF (group 3). Interrelations between pulmonary blood volume (PBV), nPTT, stroke volume (SV), and echocardiographic variables were investigated by means of linear univariate and multivariate analysis.
Results: Median nPTT values in group 1, group 2, and group 3 were 3.63 (interquartile range [IQR], 3.20—4.22), 6.09 (IQR, 5.0—7.02), and 8.49 (IQR, 7.58—11.04), respectively. Values were significantly different between all 3 groups. Median PBVs in group 1, group 2, and group 3 were 27.94 mL (IQR, 21.02—33.17 mL), 42.83 mL (IQR, 38.46—50.36 mL) and 49.48 mL (IQR, 38.84—64.39 mL). SV, PBV, and shortening fraction $<30\%$ were significant predictors of nPTT. nPTT and left atrial to aortic root (LA:AO) ratio, not SV, were the main predictors of PBV.

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Conclusion: nPTT may be useful as a test for the presence of CHF in cats with CM and as a measure of cardiac performance. nPTT and LA:AO ratios predict CHF with equal accuracy. Increased PBV is significantly associated with higher nPTT and LA:AO ratios.

Abbreviations

AUC	area under the curve
CHF	congestive heart failure
CM	cardiomyopathy
ECG	electrocardiography
FATE	feline arterial thromboembolism
FERNA	first-pass radionuclide angiocardiography
FS	fractional shortening
HCM	hypertrophic cardiomyopathy
HR	heart rate
IQR	interquartile range
IVSd	interventricular septum diastole
IVSs	interventricular septum systole
LA	left atrium
LAD	left atrial diameter
LA:AO	left atrial to aortic root ratio
LVDd	left ventricular diameter diastole
LVDs	left ventricular diameter diastole
LVWs	left ventricular diameter systole
mRR	mean R—R interval
MMVD	myxomatous mitral valve disease
nPTT	heart rate—normalized pulmonary transit time
PBV	pulmonary blood volume
PTT	pulmonary transit time
PV area	pulmonary valve annular cross-sectional
ROC	receiver operating characteristics
SV	stroke volume
TP	time when the contrast media passes the pulmonary valve
TA	time when the contrast media enters the left atrium
TT4	total thyroxine
VTIpv	velocity—time integral pulmonary valve

Introduction

Heart rate (HR)-normalized pulmonary transit time (nPTT) is a measure of cardiac performance and describes the ratio between pulmonary blood volume (PBV) and stroke volume (SV). It is calculated by normalizing the pulmonary transit time (PTT) to the mean heart rate (mean R—R interval [mRR]) and it equals the number of SVs that are required to push one sample of blood from the pulmonary valve to the left atrium (LA).[1–5] PBV is the product of cardiac output (CO) and PTT (PVB = CO × PTT) and equals nPTT times SV.

Most studies on nPTT in dogs have used first-pass radionuclide angiocardiography.[1,3] The authors are aware of only one published study on measuring nPTT in dogs by using transthoracic echocardiography and a second-generation ultrasound contrast medium.[6] Recently, the measurement of nPTT in healthy cats using echocardiography with the contrast medium SonoVue®[d] was validated and shown to be consistently repeatable without documented adverse effects.[4] That study had also shown that body weight and age were not influencing factors.

The evaluation of cardiac function as well as risk assessment and monitoring in cats with cardiomyopathy (CM) is currently based on standard clinical methods, such as electrocardiography (ECG), thoracic radiographs, echocardiography, and biomarkers. Arrhythmias have been shown to be associated with an increased mortality in cats with hypertrophic CM (HCM).[7] A published study has also shown that the P-wave duration and lateral thoracic radiographs are specific predictors of LA enlargement in cardiomyopathic cats but lack sensitivity.[8] Left ventricular systolic and diastolic functions are often estimated by means of ultrasonographic 2-dimensional measurements and by Doppler-based assessment of cardiac blood flow.[9] Recently, a left atrial diameter (LAD) >16.5 mm has been shown to predict congestive heart failure (CHF) with a sensitivity and specificity of 87%; a left atrial to aortic root ratio (LA:AO) of >1.5 predicted CHF with a sensitivity of 81% and a specificity of 79%.[10] More recently, LA dysfunction, low left ventricular systolic function, and extreme left ventricular hypertrophy were shown to be independent predictors of decreased survival time in cats with HCM.[7] New methods like myocardial deformation measurement and tissue Doppler

[d] SonoVue®, Bracco Diagnostics, Milano, Italy.