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AN ASSESSMENT OF LEFT VENTRICULAR SYSTOLIC FUNCTION WITH THE USE OF A CONTINUOUS DOPPLER IMAGING IN DOGS WITH SPONTANEOUS MITRAL REGURGITATION. A PRELIMINARY STUDY

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Abstract

The aim of this study was to evaluate systolic function of left ventricle in dogs with spontaneous mitral regurgitation by estimating the rate of pressure rise in the left ventricle (dP/dt). Ninety-three dogs of different breed and sex, with chronic degenerative valvular disease were examined. All dogs had echocardiography examination with dP/dt estimation assessed from mitral regurgitant jet using continuous Doppler-echocardiography. The dogs were divided into four classes of heart failure according to NYHA class. Results: dogs in NYHA I dP/dt = 2,142 ±1,309, SF=33.6±10.5, EF=66.58± 14; NYHA II dP/dt = 3,062 ±1,798, SF=42 ±10, EF=76.5 ±11.5; NYHA III dP/dt = 3,483 ±2,136, SF=44.2 ±21, EF=75.7 ±13; NYHA IV dP/dt = 4,496 ±1,797, SF=40.6 ±6, EF=70.4 ±16. Dogs with chronic cardiac insufficiency and mitral insufficiency due to chronic degenerative valvular disease had no echocardiograhic evidence of left ventricular systolic dysfunction assessed from mitral regurgitant jet dP/dt.

Key words: dog, heart, cardiac ultrasound, bicuspidal insufficiency.

Mitral regurgitation due to non-inflammatory valvular degeneration (chronic degenerative valvular disease) is a frequent problem in elderly dogs. In mitral regurgitation, a great part of stroke volume flows back to the left atrium, and leads to left atrial volume overload followed by left ventricular volume overload. The left ventricular chamber progressively increases. This pathological process leading to systolic dysfunction and heart failure manifests symptoms due to low output and pulmonary congestion. Several indices have been proposed to assess left ventricular systolic dysfunction in patients with chronic mitral regurgitation. Two markers are used most frequently, assessing 2D and M-Mode echocardiography: shortening fraction and ejection fraction, calculated by the geometric method based on Teicholz formula, or planimetric method based on Simpson formula. Both methods are considered acceptable with good repeatability and reproducibility. The geometric method over-estimates systolic volume index in nonlinear way at the late stages of the disease (17). A rate of pressure rise in the left ventricle (dP/dt) assessed from mitral regurgitant jet using continuous Doppler-echocardiography is a sensitive method for estimating left ventricular systolic performance, and in contrast to other methods, reveals early systolic dysfunction in patients with mitral insufficiency (11). This method has a good correlation with the catheter-measured peak dP/dt and is clinically useful and feasible as a non-invasive method of estimation of cardiac systolic function in dogs (1).

The goal of this study was to evaluate systolic function of left ventricle in dogs with spontaneous mitral regurgitation by estimating the rate of pressure rise in the left ventricle, assessed from mitral regurgitant jet using continuous Doppler-echocardiography.

Material and Methods

The study comprised 93 dogs with spontaneous mitral regurgitation due to chronic degenerative valvular disease. The dogs were of different sex (66 male, 27 female) and different breeds: 29 dachshunds, 29 mix breed, eight miniature schnauzers, three German shorthaired pointers, three miniature poodles, three Doberman pinchers, three Yorkshire terriers, two Airedale terriers, and one representative of the following breeds: basset hound, beagle, boxer, bullterrier, cairn terrier, Chihuahua, Dalmatian, Labrador retriever, medium pincher, Pekingese, Polish Lowland sheepdog, West Highland White terrier, and whippet.

Dogs with congenital heart disease and concomitant severe disease (neoplastic, inflammatory, endocrinological *etc.*) were excluded. All dogs were

subjected to clinical examination, haematological and biochemical tests (RBC, WBC, Ht, Hb, PLT,ALT, AST, AP, total protein, urea, creatinine, K^+, Na^+, Ca^{++}, Cl^-), ECG, and echocardiography. Some dogs additionally had endocrinological test, chest radiography, or abdominal ultrasound examination.

Aloka 4000+ ultrasound system was used for the echocardiographic measurements with 3-5-7.5 transducers. The longitudinal and transverse parasternal views and the apical 2-chamber and 4-chamber views were used. Heart rate was monitored during the study with an electrocardiographic lead. Left systolic function was quantified from parasternal views with the shortening fraction (SF%=[LVDD-LVDS/LVDD]x100) and the ejection fraction (EF%=[LVVolD-LVVolS/LVVolD]x100). Continuous-wave Doppler spectrum of the mitral regurgitation (MR) from 2-chamber or 4-chamber apical views was determined on the basis of the following measurements: firstly the maximum flow spectrum velocity (MR Vmax) was estimated, and then two points on the MR spectrum corresponding to 1 m/s and 3 m/s were identified (Fig. 1).

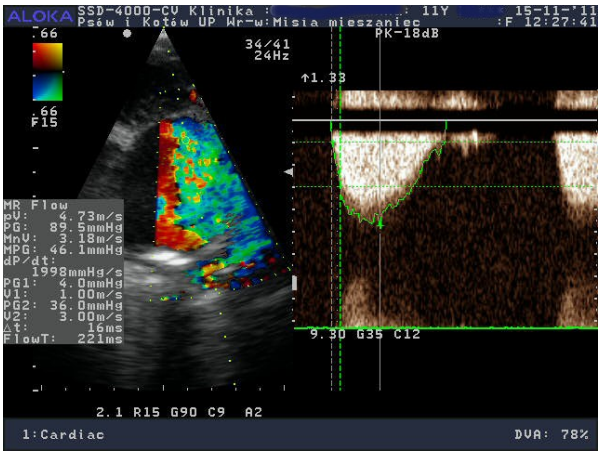

Fig 1. Echocardiographic estimation of dP/dt of mitral regurgitation.

These points corresponded to LV-left atrial pressure gradients of 4 mmHg an 36 mmHg using the modified Bernouli equation ($P=4v^2$). Doppler derived dP/dt was defined as $\Delta P/\Delta t=36\text{-}4/\Delta t=32$ mmHg/Δtx1000 Hg/sec. The dogs were divided into four classes of heart failure according to New York Heart Association (NYHA) class. Data were expressed as the mean ±standard deviation. Kruskal Wallis test was used to compare the parameters. Statistical significance was defined at $P<0.05$.

Table 1
Clinical and echocardiographic characteristics of the dogs in the study

	NYHA class			
	I	II	III	IV
	N =15	N = 38	N = 36	N =4
Symptoms	-	26	36	4
dyspnea with excitation or exercise cough	-	15	36	4
ascites	-	-	4	-
syncope	-	-	3	1
Age (years)	10± 3.1	11.2± 2.5	12.24± 2	11.25± 3.4
Body weight	16± 9.55	13.15± 8.86	12.87± 8.96	12.97± 8.2
Medical therapy				
ACEI		7	36	4
Diuretics		2	35	4
Digoxin		-	20	4
Pimobendan			26	2
Heart rate (beat per minute)	112.6± 18.4	126.4± 27.4	151± 32.4	185± 48.7
MR pV max m/s	5.29± 0.8	5.43± 0.9	5.17± 0.72	5.05± 0.51
SF %	33.6± 10.5	42.04±10	44.2± 21	40.63± 5.7
EF %	66.58± 14	76.5± 11.5	75.7± 13	70.4± 16
dP/dt mmHg/s	2,141.9± 1,309	3,062± 1,798	3,483± 2,136	4,496± 1,797

SF- left ventricular shortening fraction, EF- left ventricular ejection fraction, MRpV max –regurgitant jet maximal velocity, dP/dt – maximum flow spectrum velocity.

Results

The baseline of clinical and echocardiographic characteristics of the dogs are summarised in Table 1.

The main illness of all dogs was congestive cardiac insufficiency resulting from the chronic degenerative mitral valve disease. One mix breed dog suffered additionally from tracheocollaps, one miniature schnauzer was in remission from leukaemia, and one whippet had mitral and tricuspidal insufficiency. These dogs were not excluded because the other pathologies were mild and had no influence on cardiovascular status. Male dogs were over expressed, which was partially caused by a gender predisposition to this disease, but was also connected with owners' preferences.

All patients had sinus rhythm on the electrocardiogram. The heart rate rose with progression of heart insufficiency. The regurgitant jet (represented by MRpVmax) and ejection fraction were the greatest in the dogs of NYHA II class. The shortening fraction was almost equal.

Discussion

This study demonstrates a good left ventricular systolic function assessed by SF, EF, and continuous Doppler imaging (dP/dt) in dogs with spontaneous mitral regurgitation. Several indices have been proposed to quantify left systolic function, but most of them are influenced by preload, afterload, and tachycardia in patients with mitral regurgitation (16). Doppler-derived dP/dt is not influenced by afterload, wall motion abnormalities, or the variations in ventricular anatomy and morphology, in contrary to other methods (13, 15). This method also more accurately reflects LV function and is a good tool to predict survival in human patients with chronic CHF (8), postoperative ejection fraction (12), inotropic requirement in patients undergoing mitral valve surgery (3), and myocardial oedema in dogs (9). The continuous-wave Doppler mitral regurgitant velocity spectrum allows reconstruction of the ventriculoatrial pressure gradient from mitral valve closure to opening, including left ventricular isovolumic contraction, ejection, and isovolumic relaxation. Assuming that the left atrial pressure fluctuation is relatively minor in comparison with the corresponding changes in the LV pressure during systole, the first derivative of the Doppler-derived VA pressure gradient curve (Doppler dP/dt) might be used to estimate the LV dP/dt curve, previously measurable only at catheterisation (catheter dP/dt). Doppler-derived dP/dt correlates well with invasively derived peak of dP/dt (2, 4).

The continuous-wave Doppler trace of functional mitral regurgitation is suitable for studying the timing of overall mechanical events and normalised rates of the pressure changes in the left ventricle but seems to be less reliable for estimating the atrioventricular pressure drop (22). The value of dP/dt obtained in our study is similar to healthy mongrel dogs (4). There are great differences in mean dP/dt value measured invasively: in healthy beagle dogs - 897.2 mmHg (19), healthy mongrel dogs - 3,437 ±333 (5, 6), and after inotropic drug infusion – 3,580- 4,620 mm Hg/sec (21). Dogs with heart insufficiency induced by tachypacing have a low mean value of invasively measured dP/dt - 993 mmHg/sec (14). In humans, a value under 1,000 mmHg/sec also suggests systolic failure and under 600 mmHg/sec is connected with the high risk of cardiac death (8).

All examined dogs had a significant abnormality of blood flow and geometry of the heart due to chronic degenerative valvular disease and haemodynamic important mitral regurgitation. Mitral regurgitant jet leads to volume overload, circumferential LV midwall fibres, and activation of contraction *via* the Frank-Starling mechanism. These changes are clearly seen in echocardiography, especially as hyperdynamic movement of the septum. We still do not know the mechanism responsible for valvular-ventricular interaction. Several studies have provided evidence that the left ventricular and arterial circulations interact in such manner as to optimise cardiac energetics (18). Mitral insufficiency and especially chordal disruption of mitral apparatus resulted in deterioration of left ventricle systolic function (10, 23). These could lead to systolic dysfunction, but in our research we did not see evidence of systolic failure until NYHA IV class. All measured echocardiographic parameters in NYHA I-III class failure, exceeded minimum values and were rather closer to the maximum of physiological range. Several authors also found preserved systolic function in dogs with naturally occurring mitral insufficiency until the late stages of the disease (7, 17)

In conclusion, in dogs with spontaneous mitral regurgitation due to chronic degenerative valvular disease, NYHA I-III class failure has no echocardiograhic evidence of changes of left ventricular systolic function measured by estimating the rate of pressure rise in the left ventricle (dP/dt) assessed from mitral regurgitant jet. Systolic dysfunction appears in dogs with severe heart failure (NYHA IV).

Study limitation. A limitation of this study was the small number of severely affected (NYHA IV) patients. Further investigation on a larger number of dogs is warranted.

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