Slov Vet Res 2007; 44 (1/2): 31-40
UDC 636.7.09:612.173-073

Original Research Paper

# ECHOCARDIOGRAPHIC DIASTOLIC INDICES OF THE LEFT VENTRICLE IN NORMAL DOBERMAN PINSCHERS AND RETRIEVERS

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**Summary:** The aim of our study was to evaluate diastolic function of the left ventricle assessed by Doppler echocardiography in normal Doberman pinschers (DPs; n=39) and to study the effects of gender, age, body weight and heart rate on diastolic values. Diastolic echocardiographic values obtained in DPs were compared to the diastolic values in a group of Retrievers (n=20). The following correlations were found in DPs: a negative correlation between heart rate and mitral E/A ratio, a negative correlation between E-wave velocity and s/d ratio of pulmonary vein flow and a positive correlation between E-wave velocity and deceleration time of mitral E wave (DTE) and a negative correlation between left ventricular posterior wall in diastole (LVPWd) and DTE. Age, body weight and sex had no influence on the left ventricular diastolic indices in DPs. In Retrievers the following correlations were found: a negative correlation between heart rate and IVRT, a positive correlation between age and s/d ratio, a positive correlation between left ventricular dimension in diastole (LVDd) and mitral E/A ratio, a positive correlation between interventricular septal thickness in systole (IVSs) and DTE, a positive correlation between LVPWd and DTE and a positive correlation between LAD and s/d ratio. Body weight had no influence on the left ventricular diastolic indices in Retrievers. There was no gender influence on diastolic parameters in either group of dogs.
We found statistical significant difference in several of the obtained diastolic indices in DP comparing to the Retrievers: d - wave (P = 0,0316), s – wave (P = 0,0035), Ar – wave (P < 0,001) and mitral A – wave (P =0,0179) were significantly higher and DTE (P < 0,001) was significantly longer in DP. Differences were also found in comparison to a group of dogs of different breed and boxers from the literature.
Results show that Doberman pinschers have some differences in diastolic parameters present that may be inherent for the breed, but may be also influenced by physiologic conditions such as heart rate or due to variability in sampling.

**Key words:** veterinary medicine; cardiology-veterinary; ventricular function, left – physiology; diastole – physiology; echocardiography; dogs

## Introduction

Within the last few decades there has been a growing realization that heart failure can occur in the presence of normal systolic function. (1) More studies defining indices of diastolic function were performed by development of sophisticated echocardiographic techniques. (2,3) We know that some indices of left ventricular systolic function can differ in various breeds. (4,5) For example in Doberman Pinschers it was found that systolic echocardiographic parameters were different from dogs of other breeds. (5) We were interested if also diastolic indices can vary in Doberman Pinschers. An influence of several factors such as body weight, heart rate and gender on echocardiographic diastolic indices was found in other breeds. (6, 7, 8) We assumed that age, body weight, heart rate and gender of examined dogs have some influence on the left ventricular echocardiographic diastolic indices, similar as in other author's studies.(6,7,8) The influ-

Received: 29 May 2007
Accepted for publication: 24 July 2007

ence of age, body weight and heart rate on diastolic indices can explain up to 51% of the differences in Doppler echocardiographic values. (8)

The aim of our study was to evaluate diastolic function of the left ventricle assessed by Doppler echocardiography in normal Doberman pinschers and to study the effects of gender, age, body weight and heart rate on diastolic values in comparison to a group of large breed dogs. For the comparison of measured diastolic values in the same time period and by the same observer, a group of 23 Retrievers was also examined.

## Material and methods

A physical examination, electrocardiography and echocardiography were performed in 47 Doberman pinschers of various body weights and age, both male and female animals and in a group of 23 various Retrievers (14 Labrador retrievers - LR, 6 Golden retrievers - GR, 2 Flat-coated retrievers - FCR and one LRxGR mixed), also of various body weights, age and both sexes. All dogs were healthy according to the owner's report and randomly selected from the population (either of Doberman pinschers or Retrievers) in Slovenia. Inclusion criteria for dogs to be included were normal history, normal physical examination, normal electrocardiogram (ECG) (only applicable for DP) (9) and normal echocardiographic dimensions (4) (left ventricular systolic and diastolic dimension, interventricular septum dimension in systole and diastole, left ventricular posterior wall thickness in systole and diastole, dimension of the left atrium, dimension of aorta, fractional shortening, ejection fraction, end systolic and end diastolic volume of left ventricle calculated by Teicholz formula.

Electrocardiographic measurements were performed only in DP as we wanted to exclude any possible arrhythmias, which the DPs are known for. Standard nine-lead electrocardiogram was recorded in right lateral position in all DP. All dogs had simultaneous ECG recordings during the echocardiographic study.

The echocardiographic measurements were performed in the right and left parasternal and left apical window (10). Left ventricular wall and cavity dimensions were measured in diastole and systole in M-mode and aorta with left atrial diastolic dimension were measured in two-dimensional right short axis view.

Color Doppler echocardiography was used to examine all the valve areas from the right parasternal and left apical view. Pulsed wave Doppler was used to measure the following parameters from the left apical view: pulmonary vein flow velocity from the left or right pulmonic vein (systolic, diastolic and atrial reverse flow), mitral inflow maximum velocity (E and A wave, E wave deceleration time, the isovolumic relaxation time). Mitral flow was measured at the tips of open mitral leaflets in the left ventricle. To measure pulmonary vein flow velocities the sample volume was placed approximately 2 to 5 mm distal to the entrance of the pulmonary vein into the left atrium. The sample volume size used had an axial dimension of 4 mm. Velocities were measured in at least three cardiac cycles. Values of three cardiac cycles were averaged for quantitative data analysis, irrespective of respiratory phase.

### *Statistics*

Descriptive statistics was calculated and the correlation coefficients between age, body weight, heart rate and systolic and diastolic indices in both groups were calculated. Data were reported as average value ± 1 standard deviation. Analysis of variance (ANOVA) was used to evaluate differences in Doppler-derived indices between females and males in both groups. Pearson's correlation coefficients were calculated to determine correlation between age, body weight, and heart rate and individual systolic and diastolic parameters in DPs and Retrievers. For comparison of the values of diastolic indices in DPs and the values of diastolic indices in Retrievers from our study and other dog breeds from the literature Student's T-test was used. Differences with $P< 0,05$ were considered to be significant and differences with $P< 0,01$ were considered to be highly significant.

## Results

Data were obtained from 47 clinically normal Doberman Pinschers. Eight Doberman Pinschers were excluded from the study for the following reasons: dilated cardiomyopathy (2 dogs), ductus arteriosus persistens (1 dog), ventricular premature complexes (1 dog); three dogs had the end systolic and/or end diastolic dimensions of the left ventricle deviating more then two standard deviations from normal values (4); one dog was excluded from the study because he died two years after the examination without known cause. Among 39 dogs included in the study 22 were females and 17 were males, age from 1 to 11 years (4,31 ± 2,38 years), body weight ranged from 26 to 53 kg. The 39 Doberman Pinschers represented approximately 6,5% of the Slovene population of Doberman Pinschers.

There were 23 dogs of various Retrievers examined in the study for comparison to DP. One dog (LR) was excluded from the study because of the systolic murmur due to mitral regurgitation and two other dogs were excluded due to left ventricle deviating more then two standard deviations from normal values. (4) Among 20 Retrievers included in the study there were 13 females and 7 males, age from 1 to 9 years (3,93 ± 2,11 years) and body weight ranged from 26 to 37 kg.

### *Physical examination and Electrocardiography*

The results of physical examination and electrocardiography in DP were the following: heart rate (114±19 beats per minute), normal sinus rhythm (64,1% dogs), sinus arrhythmia (35,9% dogs) and normal heart sounds. Electrocardiographic parameters of all DP were normal. Sixteen dogs (42%) had mean electrical axis < 40° which is considered specific and normal for the breed. (11)

The results in Retrievers: heart rate (107,32 ± 16,8 beats per minute), normal sinus rhythm or sinus arrhythmia and normal heart sounds.

### *Echocardiography*

The indices of systolic function of the left ventricle in DP and in Retrievers from our study are presented in Table 1.

**Table 1:** The indices of systolic function of the left ventricle, heart rate, body weight, dimension of aorta, left atrial dimension and LV mass in normal DP and normal Retrievers and comparison of these parameters between both groups of dogs

| | DP | DP | Ret | Ret | DP : Ret |
|---|---|---|---|---|---|
| Parameter | N | $\bar{x}$ ± SD | N | $\bar{x}$ ± SD | P |
| Heart rate | 39 | 114 ± 19 | 19 | 107,32 ± 16,79 | 0,181 |
| BW | 39 | 35,1 ± 5,41 | 20 | 29,95 ± 2,89 | 0,000 |
| LVDd (mm | 39 | 48.2 ± 5.4 | 19 | 46,34 ± 3,36 | 0,112 |
| LVDs (mm) | 39 | 33.3 ± 4.2 | 19 | 30,38 ± 3,82 | 0,011 |
| IVSd (mm) | 39 | 8.3 ± 1.9 | 19 | 9,29±1,89 | 0,069 |
| IVSs (mm) | 39 | 12.6 ± 2.2 | 19 | 13,61±2,34 | 0,125 |
| LVPWd (mm) | 39 | 8.4 ± 1.1 | 19 | 8,95 ±1,49 | 0,163 |
| LVPWs (mm) | 39 | 11.7 ± 1.6 | 19 | 13,03 ±2,39 | 0,0370 |
| LAD (mm) | 36 | 37.8 ± 5.0 | 19 | 37,59 ±3,87 | 0,861 |
| Ao (mm) | 37 | 25.2 ± 2.7 | 19 | 25,15±3,12 | 0,952 |
| FS (%) | 39 | 30.7 ± 5.1 | 19 | 34,54±5,65 | 0,017 |
| EF tz | 39 | 0.57 ± 0.07 | 19 | 0,63±0,07 | 0,004 |
| EDV tz (ml) | 39 | 110.6 ± 29.5 | 19 | 99,84±17,07 | 0,085 |
| ESV tz (ml) | 39 | 46.5 ± 14 | 19 | 37,03±10,96 | 0,007 |
| LV Mass (g) | 39 | 160.15 ± 48.6 | 19 | 165,75±49,07 | 0,684 |

Legend: DP – Doberman Pinschers , Ret – Retrievers, N – the number of examined dogs, SD – standard deviation, $\bar{x}$– mean value, BW – body weight, LV – left ventricle, LVDd – left ventricular diastolic dimension, LVDs – left ventricular systolic dimension, IVSd – interventricular septum dimension in diastole, IVSs – interventricular septum dimension in systole, LVPWd – left ventricular posterior wall thickness in diastole, LVPWs – left ventricular posterior wall thickness in systole, LAD – dimension of the left atrium, Ao – dimension of aorta, FS – fractional shortening, EFtz – ejection fraction caculated by Teicholz formula, EDVtz – end diastolic volume of left ventricle calculated by Teicholz formula, ESVtz – end systolic volume of left ventricle calculated by Teicholz formula,

### *Diastolic echocardiographic parameters*

Pulmonary venous flow. Pulmonary venous flow was possible to record in 19 DP, in the rest image quality was too low due to restlessness of dogs, panting or low signal. In 15 (79%) DP pulmonary venous systolic flow was visible as monophasic. In 4 (21%) DP pulmonary venous systolic flow was biphasic (early and late systolic flow, s1- and s2-wave). In 18 DP the systolic pulmonary vein velocity was lower than diastolic velocity. In one DP the systolic pulmonary vein flow velocity was higher than diastolic pulmonary vein flow velocity (s-wave: 0,67 ms-1, d-wave: 0,63 ms-1).

Pulmonary vein systolic to diastolic velocity ratio (s/d) in 18 DP was 0,58 to 0,92. In one DP the s/d ratio was 1,2. The velocity of pulmonary vein reversal flow (Ar-wave) was -0,35 ± 0,12 ms-1.

A good quality signal of pulmonary venous flow was obtained from 17 dogs from the group of Retrievers. In 14 Retrievers (82,3 %) the obtained pulmonary venous systolic flow was monophasic and in 3 (17,7 %) Retrievers pulmonary venous systolic flow was visibly biphasic. Systolic pulmonary vein flow velocity was lower than diastolic velocity in all Retrievers. Pulmonary vein systolic to diastolic velocity ratio (s/d) in Retrievers ranged from 0,6 to 0,97.

Echocardiographic diastolic parameters of pulmonary venous flow in both groups of dogs (DP and Retrievers) are presented in table 2.

Transmitral flow. Good quality signal of transmitral flow was obtained in 38 DP. All dogs had biphasic mitral flow with visible early (E) and atrial (A) wave. The E-wave peak velocity in 35 DP was higher than A-wave peak velocity, hence the E/A ratio was more than 1. Four (10,5%) DP had E-wave peak velocity lower than A-wave velocity, hence the E/A ratio in these dogs was below 1 (0,87 – 0,95).

The value of mitral E wave deceleration time in 38 DP was 142 ± 27 ms.

Transmitral flow was recorded in 20 Retrievers. All Retrievers had biphasic mitral flow (E – and A – wave). Mitral E – wave peak velocity in all Retrievers was higher than A –wave peak velocity and the the E/A ratio more than 1.

Echocardiographic diastolic parameters of transmitral flow in both groups of dogs (DP and Retrievers) are presented in table 2.

**Table 2:** Echocardiographic diastolic parameters of pulmonary venous and transmitral flow in normal DPs and normal Retrievers and comparison of these parameters between both groups of dogs

| | DP | DP | Ret | Ret | DP:Ret |
|---|---|---|---|---|---|
| Parameter | N | $\bar{x}$ ± SD | N | $\bar{x}$ ± SD | P |
| BW | 39 | 35,1 ± 5,41 | 20 | 29,95 ± 2,89 | 0,000 |
| HR | 39 | 114 ± 19 | 19 | 107,32 ± 16,79 | 0,181 |
| s (m/s) | 19 | 0,48 ± 0,08 | 17 | 0,39 ± 0,09 | 0,0035 |
| d (m/s) | 19 | 0,63 ± 0,11 | 17 | 0,53 ± 0,15 | 0,0316 |
| Ar (m/s) | 19 | -0,35 ± 0,12 | 17 | 0,25 ± 0,06 | 0,000 |
| s/d | 19 | 0,78 ± 0,15 | 17 | 0,75 ± 0,10 | 0,349 |
| E (m/s) | 38 | 0,82 ± 0,11 | 20 | 0,77 ± 0,15 | 0,300 |
| A (m/s) | 38 | 0,66 ± 0,11 | 20 | 0,58 ± 0,12 | 0,0179 |
| E/A | 38 | 1,26 ± 0,19 | 20 | 1,34 ± 0,24 | 0,205 |
| DTE (ms) | 38 | 142 ± 27 | 20 | 94,1 ± 29,80 | 0,000 |
| IVRT (ms) | 38 | 58 ± 14 | 19 | 60,7 ± 16,76 | 0,549 |

Legend: DP – Doberman Pinschers , Ret – Retrievers, N – the number of examined dogs, SD – standard deviation, $\bar{x}$ – mean value, BW – body weight, HR – heart rate, s – systolic pulmonary venous flow velocity, d – diastolic pulmonary venous flow velocity, Ar – atrial reversal flow, s/d – ratio between systolic and diastolic pulmonary venous flow velocity, E – early ventricular filling velocity (E-wave), A – late ventricular filling velocity (A-wave), E/A – ratio between mitral A- and E-wave, DTE – mitral deceleration time, IVRT – isovolumic relaxation time,

### *Correlations between echocardiographic parameters and BW, HR and age in DP and Retrievers*

The correlation coefficients were calculated between age, body weight, heart rate and systolic and diastolic echocardiographic indices of examined DP and Retrievers. Among independent variables in DP a negative correlation between heart rate and mitral E-wave to A-wave ratio was found. In Retrievers a negative correlation between heart rate and IVRT and a positive correlation between age and s/d ratio was found. Heart rate, age and body weight did not affect any other diastolic parameter in DPs and Retrievers.

Among individual systolic and diastolic parameters the following correlations were found in DP: a positive correlation between mitral E-wave and mitral deceleration time, a negative correlation between mitral E-wave and pulmonary venous s/d ratio and a negative correlation between the LVPWd and DTE. The following correlations among individual systolic and diastolic parameters were found in Retrievers: a positive correlation between LVDd and mitral E/A ratio, a positive correlation between EDVtz and mitral E/A ratio, a positive correlation between IVSs and DTE, a positive correlation between LVPWd and DTE and a positive correlation between LAD and s/d ratio.

ANOVA showed no differences in values of diastolic indices between females and males in DP as well as in Retrievers.

The results of positive or negative correlations between heart rate, age, body weight and individual systolic and diastolic parameters in DP and Retrievers are presented in Table 3 and Table 4.

**Table 3:** Correlations between heart rate as well as individual systolic and diastolic parameters in DP.

| Variable | P | r |
|---|---|---|
| Heart rate E/A | 0,036 | -0,360 |
| LVPWd DTE | 0,015 | -0,392 |
| E –wave DTE<br>s/d | 0,045<br>0,003 | 0,325<br>-0,657 |

Legend: E – w ave - early ventricular filling velocity , LVPWd - left ventricular posterior wall thickness in diastole, E/A – ratio between mitral A- and E-wave, DTE – mitral deceleration time, s/d – ratio between systolic and diastolic pulmonary venous flow velocity

**Table 4:** Correlations between heart rate, age as well as individual systolic and diastolic parameters in Retrievers

| Variable | P | r |
|---|---|---|
| Heart rate IVRT | 0,037 | - 0,496 |
| s/d<br>age<br>LAD | <br>0,002<br>0,019 | <br>0,704<br>0,517 |
| E/A<br>LVDd<br>EDVtz | <br>0,043<br>0,040 | <br>0,469<br>0,474 |
| DTE<br>IVSs<br>LVPWd | <br>0,010<br>0,012 | <br>0,577<br>0,566 |

Legend: IVRT – isovolumic relaxation time, s/d – ratio between systolic and diastolic pulmonary venous flow velocity, LAD – left atrial dimension, E/A – ratio between mitral A- and E-wave, LVDd – left ventricular dimesion in diastole, EDVtz – end diastolic volume calculated by Teicholz formula, DTE – mitral deceleration time, IVSs – interventricular septum thickness in systole, LVPWd – left ventricular posterior wall thickness in diastole

### *The comparison of diastolic indices in DP, Retrievers, and other dog breeds from the literature*

The results of comparison of the values of diastolic indices in DP and the values of diastolic indices in Retrievers and other dog breeds from the literature are presented in table 1, table 2 and table 5.

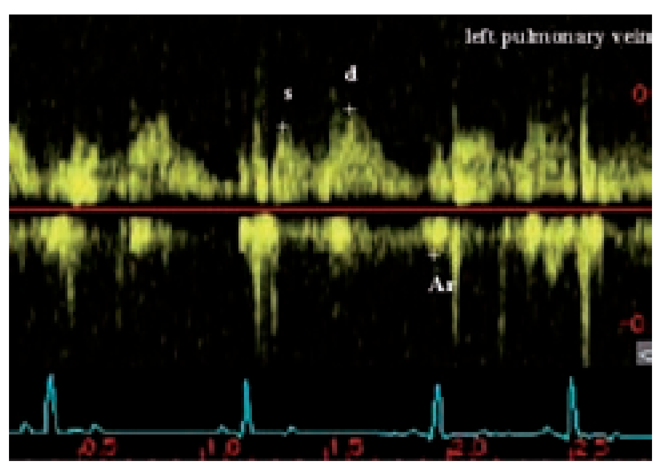


**Figure 1:** Pulmonary venous flow in the left pulmonary vein

Legend: s – systolic pulmonary venous flow (s-wave), d – diastolic pulmonary venous flow (d-wave), Ar – pulmonary venous reversal flow (Ar-wave)

**Table 5:** The reference values of the left ventricular systolic and diastolic achocardiographic parameters from the literature and comparison of our DP to referenced population

| Parameter | N | Boxers* | N | Dogs of various breeds ** | N | DPs from the literature*** | DP:Dogs of various breeds** | DP: Boxers* |
|---|---|---|---|---|---|---|---|---|
| | | X ± SD | | X ± SD | | X ± SD | P | P |
| BW | 66 | 30 ± 4 | | | 10 | 36,1 ± 4,4 | | 0,000 |
| HR | 66 | 100 ± 21 | 14 | 85 ± 16 | 10 | 113 ± 12 | 0,000 | 0,001 |
| LVDd (mm) | 66 | 43,5 ± 4,7 | | | 10 | 38,4 ± 2,3 | | 0,000 |
| LVDs (mm) | 66 | 29,7 ± 3,6 | | | 10 | 29,2 ± 3,7 | | 0,000 |
| IVSd (mm) | 66 | 9,7 ± 1,5 | | | | | | 0,000 |
| IVSs (mm) | 66 | 13,3 ± 2,0 | | | | | | 0,098 |
| LVPWd (mm) | 66 | 9,7 ± 1,5 | | | | | | 0,000 |
| LVPWs (mm) | 66 | 13,8 ± 2,2 | | | | | | 0,000 |
| LAD (mm) | 66 | 33,7 ± 5,4 | | | | | | 0,000 |
| Ao (mm) | 66 | 21,7 ± 2,6 | | | | | | 0,000 |
| FS (%) | 66 | 32 ± 6 | 14 | 31 ± 4 | 10 | 24,0 ± 7,2 | 0,843 | 0,260 |
| EF tz | | | 14 | 58 ± 7 | | | 0,649 | |
| s (m/s) | 57 | 0,42 ± 0,12 | 14 | 0,39 ± 0,14 | 10 | 0,50 ± 0,59 | 0,026 | 0,046 |
| d (m/s) | 57 | 0,62 ± 0,12 | 14 | 0,56 ± 0,14 | 10 | 0,49 ± 0,42 | 0,118 | 0,749 |
| Ar (m/s) | 57 | -0,23 ± 0,05 | 14 | -0,20 ± 0,08 | 10 | 0,27 ± 0,44 | 0,000 | 0,000 |
| s/d | 57 | 0,72 ± 0,28 | 14 | 0,70 ± 0,16 | 10 | 1,0 ± 0,1 | 0,151 | 0,376 |
| E (m/s) | 63 | 0,76 ± 0,13 | 14 | 0,73 ± 0,11 | 10 | 0,76 ± 0,13 | 0,012 | 0,019 |
| A (m/s) | 63 | 0,53 ± 0,12 | 14 | 0,48 ± 0,16 | 10 | 0,55 ± 0,10 | 0,000 | 0,000 |
| E/A | 63 | 1,49 ± 0,34 | 14 | 1,63 ± 0,47 | 10 | 1,4 ± 0,3 | 0,000 | 0,000 |
| DTE (ms) | 55 | 80 ± 14 | 14 | 81 ± 17 | 10 | 131 ± 24 | 0,000 | 0,000 |
| IVRT (ms) | 58 | 53 ± 8 | 14 | 60 ± 20 | 10 | 83 ± 14 | 0,687 | 0,028 |

Legend: * –; Schober, Fuentes, Baade, Oechtering, 2002; ** – Schober. Fuentes. McEwan, French, 1998; *** - O'Sullivan, O'Grady, Minors, 2007;
N – the number of examined dogs, Ret – Retrievers, SD – standard deviation, BW – body weight, HR – heart rate, LVDd – left ventricular diastolic dimension, LVDs – left ventricular systolic dimension, IVSd – interventricular septum thickness in diastole, IVSs – interventricular septum thickness in systole, LVPWd – left ventricular posterior wall thickness in diastole, LVPWs – left ventricular posterior wall thickness in systole, LAD – dimension of the left atrium, Ao – dimension of aorta, FS – fractional shortening, EFtz – ejection fraction caculated by Teicholz formula, s – systolic pulmonary venous flow velocity, d – diastolic pulmonary venous flow velocity, Ar – atrial reversal flow, s/d – ratio between systolic and diastolic pulmonary venous flow velocity, E – early ventricular filling velocity (E-wave), A – late ventricular filling velocity (A-wave), E/A – ratio between mitral A- and E-wave, DTE – mitral deceleration time, IVRT – isovolumic relaxation time.

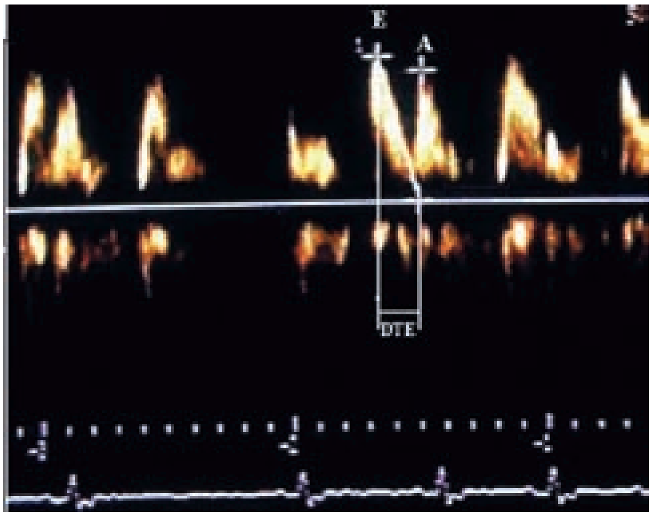


**Figure 2:** Transmitral flow (E – early mitral flow; A – mitral flow at the time of atrial contraction; DTE – mitral deceleration time

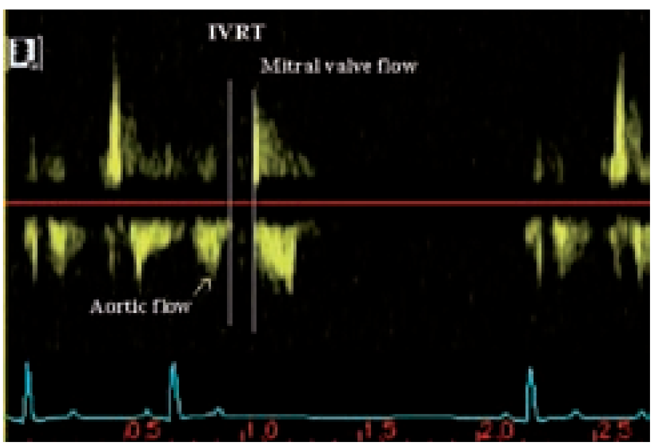


**Figure 3:** Isovolumic relaxation time (IVRT) measured between closure of aortic valve and before opening of mitral valve

## Discussion

Presently it is accepted that diastolic dysfunction can cause heart failure by itself, therefore knowing normal values of diastolic function can help to determine its function. However it is also known that echocardiographic parameters of systolic function can vary in different breeds of dogs. Especially some larger breeds of dogs like Doberman Pinschers are found to have lower fractional shortening than most of other dogs of the same size. (5) It was our hypothesis that if systolic variables can differ in this breed in comparison to other breeds than also diastolic parameters might have some differences. Our interest was to define any gender, age or heart rate influence on these parameters as well. Other authors have shown that diastolic abnormalities can be found in dogs with a normal systolic function and clinical signs can either accompany sole diastolic dysfunction or not. By the same authors good correlation was found between diastolic parameters and clinical signs of diseased dogs. (12).

Pulmonary venous flow was not perfectly laminar in all examined dogs (DP and Retrievers), but this was the case also in other study (13). A difficulty by obtaining pulmonary venous laminar flow was reported by other authors as well. (7)

Systolic pulmonary venous flow velocity values in DP were similar to values in DP from O'Sullivan et al's study (13) but were significantly different from systolic PV flow in Retrievers, (Table 2) and other dog breeds from the literature. (6,7) Pulmonary venous flow is dependent on intrinsic myocardial diastolic properties as well as external factors such as loading condition, left atrial and left ventricular systolic function, heart rate and rhythm. (8) We can speculate that differences in left ventricular systolic function have some influence on s flow velocity of PV between DPs and other breeds. We did not measure left atrial systolic function so we cannot discuss effect of possible influence of this on s flow velocity. Looking at heart rate (HR) in O'Sulivan et al's study where the HR were lower than in our study, we can assume that HR had no major effect on s wave. (13)

Clearly seen biphasic pulmonary venous systolic flow was evident in 4 (21%) DPs and in 3 (17,7 %) Retrievers. Other dogs showed monophasic pulmonary venous systolic flow. In one of the Schober's study the systolic flow was biphasic in 93% of healthy dogs without cardiovascular disease. (7) High heart rates can cause merging of pulmonary venous early (s1) and late (s2) systolic flow (heart rate in DPs was 114 ± 19 and in Retrievers 107,3 ± 16,8).(7)

Peak pulmonary venous diastolic flow velocity in DPs was significantly higher in comparison to Retrievers (Table 2) and also to the DPs from another study, but there were no significant differences in these values in comparison to dogs from two other studies (Table 5).(6,7,13) This variations may be due to different sample volumes and depth of the sample (inter observer variability).

The s/d ratio in ours DPs did not statistically differ from the s/d ratio in Retrievers as well as DPs from O'Sullivan et al's publication and dogs from the literature. The values of the s/d ratio in dogs with normal left ventricular filling pattern are between 0,5 and 1,0 (12). In all Retrievers the s/d ratio value was less than 1 (0,36 – 0,89). In Schober's study s/d ratio values in all dogs of various breeds were between 0,5 and 1,0.(7) O'Sullivan et al in their study of diastolic function in DPs report of 50 % values of s/d ratio < 1 and 50 % > 1. (13) We observe s/d ratio > 1 only in one DP.

Atrial reverse velocity in pulmonary vein of DP was significantly higher in relation to Ar-wave velocity in Retrievers (Table 2) and other breeds. (Table 5), but was similar to normal DPs from another study.(6,7,13) Atrial reverse flow in pulmonary vein is produced by left atrial contraction in late diastole and is influenced by left ventricular compliance, left ventricular mid diastolic pressure, left atrial contractility and HR, which was higher in our DPs than in other dogs from literature. (2,7,8) Severely increased Ar-wave velocity could be a sign of restrictive filling of the left ventricle. At the same time an increased mitral E-wave to A-wave ratio appears. Values of the mitral E- to A-wave ratio were normal in DP from our study. Schober and Fuentes in one of their studies found an increased Ar-wave velocity in dogs with various cardiovascular diseases. The highest values were found in dogs with dilatative cardiomyopathy (12) In the study of diastolic function in normal DPs and DPs with dilated cardiomyopathy authors found no such connection. (13) High left atrial filling pressures also influence greatly on the increase of the Ar-wave velocity. The compliance of the left atrium in normal circumstances is greater than the compliance of the pulmonary vein system. At the left atrium filling pressure > 6 mmHg atrial reversal flow begins. Its velocity increases by increasing left atrial filling pressure. (14)

The average value of the mitral E-wave velocity in DP were higher than the values of the E-wave velocity in other breeds and boxers (Table 5), but did not differ significantly from the values of the E – wave in our group of Retrievers and DPs from another study. (6,7,13) Although we found no correlation between HR and E wave velocity it is known from other studies that higher heart rates increase E wave velocity therefore we can conclude that this was the case in our DP. (13) Mitral A-wave velocity in DP differentiate significantly from the values of A-wave velocity in Retrievers and from the values of A-wave velocity in other breeds and boxers (Table 5) and also DPs from the literature (6,7,13) Most likely the reason for higher E and A wave velocity were high heart rates, which is known to increase E and A wave velocity. O'Sullivan et al found that increase in HR result in an increase in mitral E – and A – wave. (13) DPs in our study had higher values of HR than dogs from other studies. (6,7,13)

The E-wave to A-wave ratio was lower in DP than in dogs from the literature, but yet in normal ranges. The E/A ratio in DP did not differ to the E/A ratio in Retrievers and DPs from the literature. (6,7,13)

Four DP (10,2%) had A-wave velocity higher than E-wave velocity and in these dogs E-wave to A-wave ratio was less than 1,0. The values of the E-wave to A-wave ratio less than 1,0 were also found by other authors in dogs more than 6 years old. (8) Our DP with the E/A < 1,0 were 4,5; 5, 6 and 8 years old.

Deceleration time of mitral E wave was in DP significantly longer in comparison to Retrievers (Table 2), other breeds and boxers (Table 5) (6,7) Similar DTE values as in our study were also found by authors assessing diastolic function of LV in DPs. (13) Mitral deceleration time reflects LV compliance and therefore viscoelastic properties of the LV, which are determined also by LV walls. Prolonged mitral deceleration time can indicate an impaired relaxation of the left ventricle. (12) The time interval of filling of the left ventricle can be prolonged also due to thinner left ventricular walls. The results in our study as well show the difference in the thickness of the left ventricular wall in DP and, Retrievers and other breeds. (6,7) The average left ventricular posterior wall thickness in systole in DP was significantly lower in comparison to Retrievers and to boxers, and the average interventricular septum thickness in diastole in DP was also significantly lower in comparison to boxers but not to our Retrievers. (6,7) The average body weight in DP was 35,1 kg, in Retrievers 29,95 kg and in Schober's boxers 30 kg of average body weight. (6)

Thinner left ventricular walls among other factors influence the left ventricular filling. The calculation of the Pearson's correlation factors also showed significantly negative correlation between the left ventricular posterior wall thickness and mitral deceleration time - thinner the wall, longer the mitral deceleration time. In contrary the Retrievers showed a positive correlation between DTE and IVSs and LVPWd. Similar values of the mitral deceleration time in normal DP were obtained by other authors. (13)

The isovolumic relaxation time values in DP were similar to those in Retrievers and in dogs of various breeds and normal DPs from the literature but were significantly longer from values of boxers (Table 5). (6,7,13) A short LV IVRT indicates an earlier mitral valve opening and can be seen in normal young individuals. The population of the examined boxers from Schober's study was younger (2,8 ± 1,7 years) than the population of examined DP (4.31 ± 2,38 years) and Retrievers (3,97 ± 2,07) in our study. That could explain the difference in IVRT values between DP and boxers.

Gender in our DP and Retrievers had no influence on the echocardiographic indices. A smaller number of examined DP and also Retrievers in our study than the number of examined boxers could be a reason for the difference in gender influence on echocardiographic indices between these studies. In boxers there was found higher diastolic pulmonary venous flow velocity and lower s/d ratio in females than in males. (6)

Age in our study had no influence of any echocardiographic diastolic indices in DP. In Retrievers we found a positive correlation between age and s/d ratio. Schober found significantly positive correlation between age and isovolumic relaxation time, but solely in the group of older dogs, not in the average of the whole group. Our DP were in average 4,31 years old, so there is not to expect the age to significantly impact the isovolumic relaxation time. The same goes for all the other parameters on which age in our study had no influence. (7) In DPs from the literature age negatively correlated with mitral E – wave and mitral E/A ratio and positively correlated with mitral DTE and IVRT. (13)

Body weight in our study also did not correlate with any of the diastolic indices in DPs nor in Retrievers. Insignificant influence of body weight on the diastolic indices in our study could be due to the narrow range of the body weight values in DP (26-53 kg) and also Retrievers (26 – 36 kg) in comparison Schober's study (2 – 43 kg) (8) Schober also states that most of the Doppler echocardiographic indices are not body weight dependent. (6) In DPs from the literature BW positively correlated with mitral E/A ratio, mitral DTE and IVRT. (13)

Heart rate was found to have much greater effect in other studies of diastolic function in dogs. (8) We found only a negative correlation between heart rate and mitral E- to A-wave velocity ratio in DP and a negative correlation between heart rate and IVRT in Retrievers. (Table 2) A negative correlation between heart rate and IVRT was also found in DPs from the literature. (13) At higher heart rates E-wave velocity is lower due to shorter duration of the early diastole. There is also shorter time period between the closure of the aortic valve and closure of the mitral valve (IVRT). Heart rate did not influence any other diastolic parameters in our study; this could be due to a smaller group of dogs of the same breed, with narrower range of heart rates. Other studies included dogs of various sizes with a large scale of heart rates. (8)

Correlations between individual echocardiographic indices in our study showed a negative correlation between E-wave velocity and the pulmonary venous s/d ratio in DPs (Table 3). At the high values of the atrio-ventricular pressure gradient the velocity of early filling of the left ventricle is high, so the correlation is logical. Due to strong ventricular suction in early diastole also the velocity of pulmonary venous diastolic flow is high. At higher E-wave velocity the s/d ratio decreases due to higher d-wave velocity. In Retrievers a positive correlation between LAD and s/d ratio was found. When the LAD is greater also the pressure gradient between pulmonary veins and left atrium in LV systole is greater and therefore the greater s/d ratio values.

In Retrievers also a positive correlation between mitral E/A ratio and LVDd and a positive correlation between mitral E/A ratio and EDVtz were found (Table 4). When the LVDd is greater also the transmitral pressure gradient is greater and therefore the greater E/A ratio values.

In conclusion we can say that DPs show some differences in pulmonary venous flow and deceleration time of mitral E comparing to Retrievers which can be most likely due to breed specifics as it was shown for systolic parameters in this breed. (5) Some differences of course may be a consequence of physiologic conditions such as heart rate and also to inter observer variability due to different sample volumes and different depth of sampling in the pulmonary vein which can change conditions affecting these parameters.

In summary we can conclude that this normal sample of DP and Retriever populations were chosen carefully and that these echocardiograpic values of diastolic function can serve as a basis for further studies.

## Study limitations

Larger groups of DP and Retrievers with a wider age range would enable us to see age and weight related influence on diastolic echocardiographic parameters. To get more exhaustive information of diastolic function more parameters could be evaluated such as mitral A wave duration, mitral E at A wave velocity, pulmonary vein atrial reverse flow duration, the relation between pulmonary venous Ar wave and mitral A wave duration. Tissue Doppler analysis of diastolic function would give us even more insight into LV diastolic properties in examined dogs. This should be a challenge for further studies.

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## EHOKARDIOGRAFSKI DIASTOLIČNI INDEKSI LEVEGA PREKATA PRI ZDRAVIH DOBERMANIH IN PRINAŠALCIH

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**Povzetek:** Namen študije je bil ovrednotiti diastolično funkcijo levega prekata s pomočjo doplerkse ehokardiografije pri zdravih dobermanih (DPs; n=39) in ugotoviti učinek spola, starosti, telesne mase in srčne frekvence na diastolične vrednosti. Diastolične vrednosti dobermanov smo primerjali z enakimi parametri pri skupini prinašalcev (n=20). Pri dobermanih smo našli naslednje korelacije: negativno korelacijo med srčno frekvenco in razmerjem mitralnega pritoka (E/A), negativno korelacijo med hitrostjo E vala mitralnega pritoka in pojemalnim časom mitralnega E vala (DTE) in negativno korelacijo med prosto steno levega prekata v diastoli in DTE. Starost, teža in spol pri dobermanih niso vplivali na diastolične indekse levega prekata. Pri prinašalcih smo našli naslednje korelacije: negativna korelacija med premerom levega prekata v diastoli in razmerjem mitralnega pretoka E/A, pozitivno korelacijo med debelino medprekatnega pretina v sistoli (IVSs) in DTE, pozitivno korelacijo med prosto steno levega prekata v diastoli in DTE in pozitivno korelacijo med dimenzijo levega atrija in sistolično-diastoličnim razmerjem pljučnega venskega pritoka. Telesna masa pri prinašalcih ni prav nič vplivala na diastolne indekse levega prekata. V obeh skupinah tudi spol ni vplival na diastolne parametre.
Statistično značilne razlike v diastolnih parametrih med dobermani in prinašalci so bile naslednje: diastolni val pljučnega pritoka ($P = 0,0316$), sistolni val pljučnega pritoka ($P = 0,0035$), atrijski reverzibilni val pljučnega pritoka ($P < 0,001$) in mitralni val A ($P = 0,0179$) so bili pri dobermanih značilno večji in tudi DTE ($P < 0,001$) je bil značilno daljši. Razlike smo našli tudi v primerjavi s skupino različnih psov in bokserjev v literaturi.
Ugotovitve kažejo na to, da so pri dobermanih možna nekatera odstopanja od diastoličnih parametrov v primerjavi z drugimi pasmami, kar je najverjetneje pasemsko pogojeno, oziroma je razlika lahko v vrednostih diastoličnih parametrov posledica razlik v fiziološkem stanju pasem, npr. različnih srčnih frekvenc ali pa posledica različnega vzorčenja.

**Ključne besede:** veterinarska medicina; kardiologija, veterinarska; levi prekat, delovanje-fiziologija; diastola-fiziologija; ehokardiografija; psi