Acta Veterinaria Hungarica 50 (1), pp. 21–29 (2002)

COMPARISON OF ECHOCARDIOGRAPHY AND GATED EQUILIBRIUM RADIONUCLIDE VENTRICULOGRAPHY IN THE MEASUREMENTS OF LEFT VENTRICULAR SYSTOLIC FUNCTION PARAMETERS IN HEALTHY DOGS

CS. HETYEY[1*], L. BALOGH[2], G. ANDÓCS[2], K. VÖRÖS[1] and GY. A. JÁNOKI[2]

[1]Department and Clinic of Internal Medicine, Szent István University, Faculty of Veterinary Science, H-1078 Budapest, István u. 2, Hungary; [2]National 'Frédéric Joliot-Curie' Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary

(Received September 26, 2001; accepted December 13, 2001)

Left ventricular systolic function was assessed in 12 healthy dogs with equilibrium radionuclide ventriculography. The results of the analysis were compared to traditional echocardiographic measurements. Left ventricular internal dimensions and volume were measured at the time of end-systole and end-diastole. Ejection fraction – one of the most informative parameters of cardiac function – was calculated in each animal. Values (e.g. EDD, ESD, EDV, ESV) measured by the scintigraphic method were significantly (Student's *t*-test, $p < 0.05$) higher than the data obtained by echocardiography. Ejection fraction (EF) was the only parameter that did not differ significantly when comparing the two imaging techniques. The difference between the results of parallel measurements was in inverse ratio to the size of the heart.

Key words: Radionuclide ventriculography, echocardiography, dog, ejection fraction

To reach the final diagnosis of cardiac diseases in living patients, it is necessary to apply imaging methods following the physical examination. Besides direct visualisation of the cardiac structures and large vessels, information must be obtained about the functional haemodynamic consequences of cardiac disorders. Deterioration of cardiac function can manifest itself in the decrease of systolic and/or diastolic function of the heart depending on the type of the disease. The decrease of left ventricular systolic output is the consequence of the evolved haemodynamic failures in many of the frequent heart diseases of the dog (e.g. dilated cardiomyopathy, mitral valve regurgitation, aortic stenosis, left-to-right shunts).

Previous studies have been done to measure the function of the canine heart by using radionuclide ventriculography (Sisson et al., 1989; Daniel et al., 1993). These authors also performed echocardiographic measurements; however,

[*]Corresponding author; E-mail: hcs@freemail.hu; Fax: +36 (1) 478-4137

their investigation did not specifically address comparing the diagnostic values of these two imaging methods.

The aim of the present study was to measure the characteristic parameters of left ventricular systolic function, comparing the value of a scintigraphic method and two-dimensional (2D) echocardiography. Functional parameters of the left ventricle were determined by radionuclide ventriculography and 2D-echocardiography for statistical comparison of the data and to evaluate the diagnostic applicability of this two imaging modalities.

Materials and methods

Animals

Twelve clinically healthy Beagles (5 males and 7 females) were examined. They were between 9 months and 3 years old (average 2 years), and weighed 8 to 13 kg (mean 11.5 kg). The animals were sedated with diazepam (0.5 mg/kg iv.), ketamine (10 mg/kg iv.) and xylazine (2 mg/kg iv.) and positioned in the standard right lateral recumbency for both imaging techniques. Simultaneous electrocardiographic (ECG) recording was performed during both imaging methods to determine the points of end-systole and end-diastole.

Echocardiography

Two-dimensional real time (2D) echocardiographic images of the heart were obtained using a 5 MHz phased-array sector scanner (Brüel and Kjaer Panther 2002, Denmark). Imaging was performed from a right parasternal position at the fourth to fifth intercostal space (Kienle and Thomas, 1995; Moïse and Fox, 1999). Standard 2D-real time measurements were obtained from long-axis images of the left ventricle immediately below the atrioventricular valve (Fig. 1). The measurements included left ventricular internal dimension at the time of end-diastole and end-systole. Left ventricular volume measurements were then calculated by the Teichholz method: $EDV = 7 \times LVID_d^3/2.4 + LVID_d$; $ESV = 7 \times LVID_s^3/2.4 + LVID_s$ where EDV is the end-diastolic volume and ESV is the end-systolic volume. LVID means the left ventricular internal dimension at the time of end-diastole and end-systole. The ejection fraction (EF) was calculated by the following formula: $EF = EDV–ESV/EDV \times 100$ (Kienle and Thomas, 1995; Moïse and Fox, 1999). The normal value of EF was measured between 39 and 61% by previous studies (O'Grady and Bonagura, 1986).

Radionuclide ventriculography

Following echocardiographic measurements, the dogs were placed in right lateral recumbency under the gamma camera (Nucline X-ring SPECT). The maximum visual separation of the two ventricles is obtained in this position (Daniel, 1996; Daniel and Bright, 1999). Low Energy High Resolution (LEHR) collimator was fitted with 18.9 cm × 18.9 cm detector mask. An *in vivo* method of labelling red blood cells was used. At first, 10 mg of pyrophosphate (PYP) was injected intravenously, followed by the injection of 740 MBq of $^{99m}TcO^{-}_{4}$ 15 min later (Daniel, 1996). Continuous ECG-gating was done for the imaging. Sixteen frames were formed in a 64 × 64 × 16-matrix array. Before imaging, the constant R to R interval was determined by the in-built programme of the computer. During data collection, cardiac cycles that were outside the 10% window of the preselected R to R interval were rejected. Finally the computer composed 16 frames from the cardiac cycle. The 'region of interest' (ROI) method was used for the image analysis (Daniel, 1996; Daniel and Bright, 1999; Moïse and Fox, 1999).

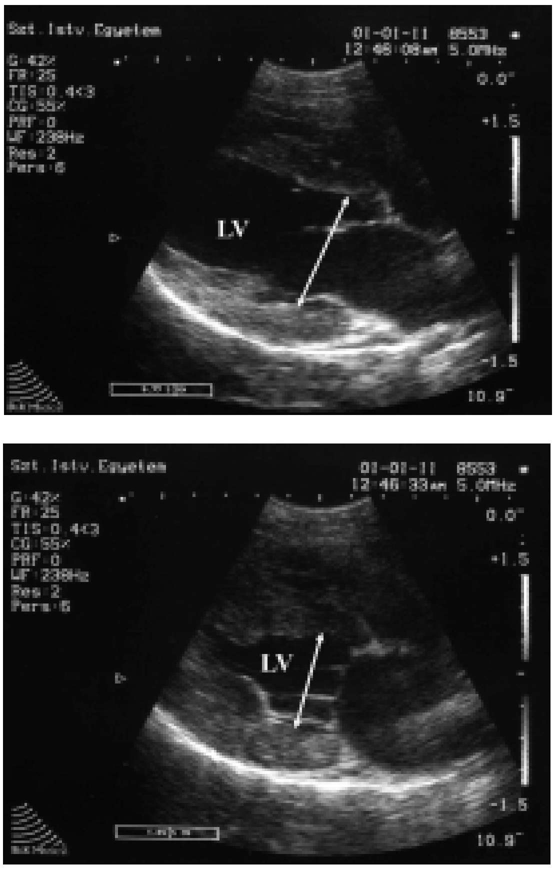

Fig. 1. Imaging the left ventricular internal dimension at the time of end-diastole (top picture) and end-systole (bottom picture). Measurements were obtained in right parasternal four-chamber long-axis view, immediately below the left atrioventricular valve. LV = left ventricle

The left ventricular contour was pointed at the end-systolic and the end-diastolic frames. Background ROI was drawn as a small square around the top of the heart and lungs. The EF was determined from the same formula that was used during echocardiography. EDV and ESV were calculated from the ventricular ROI of end-diastolic and end-systolic frames by the computer (Fig. 2).

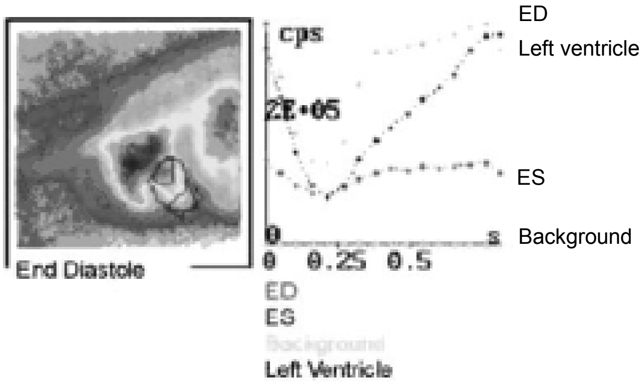

Fig. 2. Radionuclide ventriculography in a healthy dog. The regions marked in the left picture are the end-diastolic and end-systolic areas (ROI) of the left ventricle. The graph shows the ventricular activity (volume) during the heart cycle. ED = end-diastole, ES = end-systole, Left ventricle (black coloured graph) = all the left ventricular activity (volume) during the cardiac cycle. Time-activity curves were illustrated by background subtraction

Statistical analysis

Student's *t*-test was used for the statistical analysis to compare the results between the echocardiographic and scintigraphic measurements.

Results

The results of the analysis of the echocardiographic measurements are summarised in Table 1. The results of the image analysis of the scintigraphic measurements are shown in Table 2. Comparison of the results between the echocardiographic measurements and scintigraphic measurements (mean ± SD) are shown in Table 3. End-systolic and end-diastolic diameters of the left ventricles of all the 12 dogs were higher when measured by scintigraphy than the echocardiographic measurements. As a consequence, the calculated left ventricle volumes were also higher in radionuclide ventriculography. The higher the values of EDD and ESV were, the smaller differences were obtained between the parallel measurements (Fig. 3).

Table 1

Results of the 2D-echocardiographic measurements

No.	Age	Sex	Body weight	Pulse/ min.	EDD (mm)	ESD (mm)	EDV (mm^3)	ESV (mm^3)	EF (%)
1	9 months	female	8	90	29	20	5437	2500	54
2	9 months	male	10	102	33	25	7106	3992	43.8
3	9 months	male	10	92	36	25	8505	3992	53.1
4	2.5 years	male	13	100	33	26	7106	4332	39
5	3 years	female	12	120	32	24	6668	3665	45
6	2 years	female	12	110	36	27	8505	4686	44.9
7	2.5 years	female	8	120	31	22	6244	3055	51.5
8	2.5 years	male	12	110	39	27	10030	4686	53.3
9	1.5 years	male	11	120	37	27	8999	4686	47.9
10	2.5 years	female	12	100	36	25	8505	3992	53.1
11	3 years	female	10	120	34	25	7558	3992	47.2
12	1.5 years	female	10	84	37	23	8999	3353	62.7

EDD = end-diastolic diameter of the left ventricle, ESD = end-systolic diameter of the left ventricle, EDV = end-diastolic volume of the left ventricle, ESV = end-systolic volume of the left ventricle, EF = ejection fraction of the left ventricle

Table 2

Results of the scintigraphic measurements

No.	Age	Sex	Body weight	Pulse/ min.	EDD (mm)	ESD (mm)	EDV (mm^3)	ESV (mm^3)	EF (%)
1	9 months	female	8	90	38	27	9508	4686	50.7
2	9 months	male	10	102	44	30	12851	5833	54.6
3	9 months	male	10	92	45	30	13457	5833	56.7
4	2.5 years	male	13	100	51	40	17389	10566	39.2
5	3 years	female	12	120	38	28	9508	5055	46.8
6	2 years	female	12	110	40	28	10566	5055	52.1
7	2.5 years	female	8	120	43	30	12259	5833	52.4
8	2.5 years	male	12	110	47	34	14712	7559	48.6
9	1.5 years	male	11	120	45	30	13457	5833	56.7
10	2.5 years	female	12	100	45	30	13457	5833	56.7
11	3 years	female	10	120	43	30	12258	5833	52.4
12	1.5 years	female	10	84	44	26	12851	4332	66.3

EDD = end-diastolic diameter of the left ventricle, ESD = end-systolic diameter of the left ventricle (measured by the computer from the width of the ROI), EDV = end-diastolic volume of the left ventricle, ESV = end-systolic volume of the left ventricle, EF = ejection fraction of the left ventricle

Table 3

Comparison of the measurements results

	Echocardiographic measurements	Scintigraphic measurements
EDD	34.42 ± 2.78	43.58 ± 3.5*
ESD	24.66 ± 2.05	30.25 ± 3.51*
EDV	7805.2 ± 1279.5	12689.4 ± 2104*
ESV	3910.9 ± 651.9	6020.9 ± 1574*
EF	49.6 ± 5.9	52.76 ± 6.3

*Significantly different from echocardiographic measurements ($P < 0.05$); EDD = end-diastolic diameter of the left ventricle; ESD = end-systolic diameter of the left ventricle; EDV = end-diastolic volume of the left ventricle; ESV = end-systolic volume of the left ventricle; EF = ejection fraction of the left ventricle

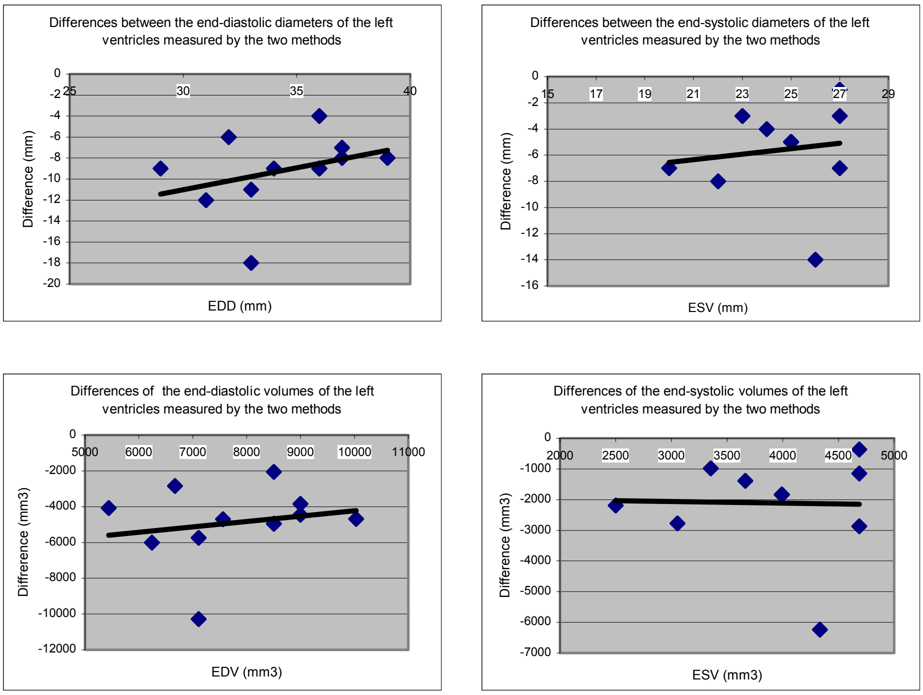

Fig. 3. The difference of left ventricular values of the two parallel measurements of 2D-echocardiography and radionuclide venticulography

Discussion

Determination of the functional characteristics of the heart is indispensable for evaluating the severity of cardiac diseases. An ideal technique is both informative and non-invasive. Echocardiography has been used for both morphological and functional assessment of the heart for decades (Boon et al., 1983; Thomas, 1984; Kienle and Thomas, 1995; Moïse and Fox, 1999). Nevertheless, the standards of imaging and measurement data are still changing because of the continuous progress in ultrasound machines and techniques (Boon et al., 1983; Thomas, 1984; Feiglin, 1989; Kienle and Thomas, 1995; Moïse and Fox, 1999). Due to the applicability of two-dimensional (2D) echocardiography, the volumes of the ventricles can be calculated by using different mathematical models (Feiglin, 1989; Kienle and Thomas, 1995; Moïse and Fox, 1999). However, the volumes calculated from the single diameter of a cardiac chamber in one certain moment of the heart cycle can be inaccurate, because it is calculated from two-dimensional data and only from one cardiac cycle. It is also important to mention that ideal imaging of the canine heart is not always possible due to the narrow intercostal space in some breeds, the lung-covered echocardiographic window, or reluctance of the patient.

Radionuclide ventriculography involves more functional information but without spatial information (Thomas, 1984; O'Grady and Bonagura, 1986; Berry, 1996; Daniel, 1996; Daniel and Bright, 1999). During this imaging method the cardiac cycle is divided into 16 parts represented by 16 frames. Because this method is based on the evaluation of some hundreds of heart cycles, the data collected in the 16 moments of the heart cycles are multiplied and yield a statistically significant number of measurements. Thus, the mean of each of the chosen 16 frames represents the true morphologic status of the heart during the heart cycles because it is based on the data collected from hundreds of heart cycles. However, some difficulties occur in radionuclide ventriculography imaging. First, the animals should be motionless for the 10–12 minutes of imaging, which can only be achieved by general anaesthesia. Second, if there is any kind of arrhythmia the different length of heart cycles will result in different timing of events of the cardiac cycle, thus the preselected frames will contain false results. To eliminate this problem the following measures can be taken: In case of sinus arrhythmia (which is normal in dogs) atropine can be administered. Another method is the 'bed beat rejection'-technique (Daniel et al., 1993). This technique is based on the determination of the average length of the heart cycles before the data collection, which is used later during the data collection as a filter for the measured heart cycles. Only the data of those cycles will be taken into consideration the lengths of which will not differ by more than 10% from the predetermined average cycle length. All the heart cycles outside this range of cycle length will be rejected. During our measurements, we used the 'region of interest' (ROI) techniques for the image analysis (Sisson et al., 1989; Daniel et al., 1993; Daniel and Bright, 1999). End-diastolic and end-systolic frames were used. During the application of ROI techniques an area can be selected and the changes of radioactivity of this region can be followed during the examination. In the case of the left ventricle, changes in radioactivity means the changes of the area (volume) of the chamber during the heart cycle. Naturally, from the measured volume curves many different kinds of functional cardiac parameters can be calculated using different mathematical formulas [e.g. ejection fraction (EF), peak ejection rate (PER), time to peak ejection rate (TPER), peak filling rate (PFR), time to peak filling rate (TPFR), stroke volume (SV) etc.] (Van den Brom and Stokhof, 1989; Daniel et al., 1993; Daniel and Bright, 1999).

Previous studies have been performed to validate radionuclide ventriculography and to measure a lot of functional parameters that can be determined by this method. The aim of the present study was to compare the most informative functional parameters of the left ventricle by the two imaging methods. More healthy dogs were examined by up-to-date imaging techniques. During this study, higher left ventricular values were recorded by radionuclide ventriculography compared to two-dimensional (2D) echocardiographic measurements. This is in agreement with the data of previous publications, where both the functional values and the left ventricular diameters were also higher when measured by scintigraphy compared to echocardiography (Sisson et al., 1989; Daniel et al., 1993). In the present study, ejection fraction of the left ventricle did not differ significantly when measured by the two different methods.

In addition, the differences between the two types of measurements were in inverse ratio to the diameter of the left ventricle. This means that closer agreement was found between the two examination methods in cases of larger hearts.

In conclusion, radionuclide ventriculography is an informative diagnostic method in determining left ventricular function in dogs but it requires general anaesthesia. It might provide a more accurate determination of cardiac chamber size changes during the cardiac cycles compared to echocardiographic measurements, which are based on only a few static images of the cardiac cycles. The measured values seem to be in close agreement with each other in animals with a larger heart size. Nevertheless, radionuclide ventriculography is not expected to replace the more convenient echocardiography in the veterinary practice of the near future. 2D-echocardiography might be accurate enough for the clinical evaluation of canine cardiac function.

Acknowledgements

This work was supported by grant No T-034465 of the Hungarian Scientific Research Fund (OTKA), by NKB-98-KUT-2/12. The authors thank Mr Jenő Reiczigel, Ms Réka Király and Dr Andor Kerekes for the statistical analysis of the data.

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