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TWO-DIMENSIONAL AND M-MODE ECHOCARDIOGRAPHIC MEASUREMENTS OF CARDIAC DIMENSIONS IN HEALTHY STANDARDBRED TROTTERS

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The aim of the study was to establish normal echocardiographic values of healthy Standardbred trotters not published previously. Twenty-three clinically normal horses weighing between 350 and 490 kg were examined in the same manner: first a thorough physical and then detailed echocardiographic examination were performed. Standardised two-dimensional (2D) and guided M-mode echocardiographic imaging techniques were used to measure interventricular septal thickness (IVS), left ventricular internal diameter (LVID), left ventricular wall thickness (LVW), left atrial internal diameter (LAID) in end-systole (s) and end-diastole (d) and aortic diameter (AOD) in end-diastole. Mean, range and standard deviation of the different parameters were calculated. The mean values (in centimetres) were as follow (2D/M-mode): IVSs: 4.6/4.7; IVSd: 3.1/3.0; LVIDs: 7.0/7.0; LVIDd: 10.7/10.7; LVWs: 3.9/3.9; LVWd: 2.7/2.7; LAIDs: 10.4/–; LAIDd: 11.3/–; AODd: 7.2/–. Results of two-dimensional and M-mode measurements were compared to each other and to normal values obtained from other breeds.

Key words: Echocardiography, measurement, horse, normal values, two-dimensional, M-mode

The first application of echocardiography in equine cardiology was the use of M-mode technique in the late 1970s (Pipers and Hamlin, 1977). Reports included M-mode measurements of normal cardiac dimensions in foals, adult horses and ponies, and described the value of M-mode echocardiography in the diagnosis of many cardiac diseases (Bayly et al., 1982; Lombard et al., 1983; Lescure and Tamzali, 1984; Stewart et al., 1984; O'Callaghan, 1985; Kvart et al., 1985; Reef, 1985).

Two-dimensional (2D) echocardiography (2DE) was introduced into equine medicine in the mid-1980s (Bonagura et al., 1985; Carlsten, 1987). Echo-

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cardiographic findings of several cardiac anomalies were reported (Pipers et al., 1985; Reef and Spencer, 1987; Reef et al., 1987; Bernard et al., 1990; Taylor et al., 1991; Vörös et al., 1991*b*; Reef et al., 1998). Papers also dealt with the validation and standardisation of the 2DE examination technique (Carlsten, 1987; Stadler et al., 1988; Vörös et al., 1990*a*, 1990*b*, 1991*a*; Vörös, 1997). Long et al. (1992) adapted the guidelines of the American Society of Echocardiography and established a standardised imaging technique for 2DE guided M-mode and Doppler echocardiography in the horse.

As echocardiography was introduced to equine cardiology, measurements of cardiac dimensions were started. Pipers and Hamlin (1977) published the first M-mode data, which was followed by other studies using M-mode and later 2DE techniques (Lescure and Tamzali, 1984; Stewart et al., 1984; O'Callaghan, 1985; Robine, 1990; Vörös et al., 1991*a*). These were nonstandardised imaging techniques. Long et al. (1992) published the first standardised, guided M-mode data and later Patteson et al. (1995) as well as Slater and Herrtage (1995) adapted the new standardised method and published reference values for adult Thoroughbred horses, small and large ponies and horses of mixed breed. Until recently there were no data about Standardbred trotter horses. However, reference echocardiographic values within a particular breed are important for purposes of comparison when evaluating cases of cardiac diseases.

The aim of this study was to establish normal echocardiographic values of the most important cardiac parameters in Standardbred trotters using a standardised technique (Long et al., 1992) and to compare these dimensions to the normal values of other breeds reported earlier.

Materials and methods

Animals

Twenty-three Standardbred horses were examined. All horses were under a normal training programme at the local trotting racecourse. Horses (8 mares, 7 stallions and 8 geldings) varied in age from 2 to 16 years (mean 6 years), body weight from 350 to 490 kg (mean 427 kg).

All animals were checked for their health status with detailed physical examination with particular attention to the cardiorespiratory system (Speirs, 1997*a, b*). Horses with cardiac murmurs or any kind of arrhythmia were excluded from the study.

Equipment

Ultrasonographic examinations were performed with a Brüel & Kjaer Panther 2002 ultrasound system, using a 3.2 MHz real-time convex array transducer (type 8556, Brüel & Kjaer, Naerum, Denmark). Maximum imaging depth of the equipment was 22.2 cm. The machine was equipped with computer software and calliper devices that permitted measurements at the time of the examination. The equipment allowed simultaneous 2D and M-mode imaging as well as simultaneous ECG recording which is essential for the exact determination of the end of diastole. Echocardiograms were documented on a TDK E-240 XQEB videotape (Bascharage, Luxembourg) using a Panasonic NV-SD3EE video recorder (Matsushita, Japan).

Examination technique

Images were recorded from the right and left sides of the thorax. The hair coat and skin surface were soaked thoroughly with surgical spirit and coated with acoustic coupling gel (Greenscan, Lina Medical ApS, Glostrup, Denmark). The forelimb was positioned slightly cranially and laterally from the body.

The location, rotation and angulation of the transducer to obtain the standardised images were determined and used as described by Long et al. (1992). The 'leading edge to leading edge method' was used for all measurements. End-diastolic M-mode measurements were taken at the onset of the QRS complex. End-systolic measurements were recorded during the maximum excursion of the interventricular septum.

Measurements

The following 2D and guided M-mode measurements were performed: interventricular septal thickness in systole (IVSs) and in diastole (IVSd), left ventricular internal diameter in systole (LVIDs) and in diastole (LVIDd), left ventricular wall thickness in systole (LVWs) and in diastole (LVWd). Standardised image planes were obtained by 2DE and these were used to guide M-mode views for the measurements. Points of two-dimensional measurements were used as reported by Patteson et al. (1995), the aortic diameter was measured at the level of the sinus of Valsalva. M-mode measurement points of intracardiac structures were applied as published by Long et al. (1992). Aortic diameter in diastole (AODd), left atrial internal diameter in systole (LAIDs) and in diastole (LAIDd) were measured only with the 2DE technique.

The first image from the *right hemithorax* was a reference, 2D right parasternal long-axis view. The ventricular inlets were visible. Location of the axial beam was through the right ventricle, the interventricular septum and the chordae tendineae of the mitral valve. The septum was almost horizontal across the image.

By rotating the reference view through 90° in counter-clockwise direction, a right parasternal short-axis view at the level of the chordae tendineae was obtained. The interventricular septum and the free wall of the left ventricle were intersected at right angles. When the beam bisected the left ventricle, M-mode imaging was performed. IVSs and IVSd were measured from this view.

Measurements of aortic diameter in diastole were performed from a right parasternal long-axis view by rotating the transducer through 30° (–45°) in clockwise direction with cranial and dorsal angulation. Location of the axial beam was through the left ventricular outflow tract and the chordae tendineae of the mitral valve in diastole, and the aortic and tricuspid valves in systole. The long-axis of the aorta was perpendicular to the axial beam in this view.

The first image from the *left hemithorax* was a 2D left parasternal long-axis reference view. The left ventricular inlet was visible. Location of the axial beam was through the chordae tendineae of the mitral valve, the interventricular septum and the right ventricle. The long-axis of the heart crossed the axial beam at right angles.

A left parasternal long-axis chordal view was obtained by angulating the transducer dorsally. The following parameters were measured in this view with 2D technique: LVIDs, LVIDd, LAIDs, LAIDd. For the best image of the left atrium, a rotation up to 40° in counter-clockwise direction was necessary.

For guided M-mode measurements, a left parasternal short-axis chordal level view was used. It was obtained by rotating the transducer through 90° in clockwise direction with a slight cranial and/or dorsal angulation. Location of the axial beam was through the left ventricle at the level of chordae tendineae of the mitral valve and the junction of the left ventricular wall and the interventricular septum. This was a true short-axis view of the left ventricle, and its lumen was as large as possible without including the mitral valve. The following dimensions were measured in this view: LVIDs, LVIDd, LVWs, LVWd.

Left ventricular M-mode and 2DE measurements were used to calculate the fractional shortening (FS) using the following equation:

FS (%) = 100 × (LVIDd-LVIDs) / LVIDd (Long et al., 1992)

For all parameters, three consecutive beats were analysed and the average was used for statistical analysis.

Repeatability

Intra-observer variability was performed on three horses. All the parameters were measured ten times over in 5 min.

Within the scope of inter-observer variability all the parameters were measured in the same two horses during three consecutive days.

Results

Range, mean values and standard deviations of the measured parameters are displayed in Tables 1 and 2.

Table 1

Range, mean values and standard deviations of guided M-mode and 2DE interventricular septal and left ventricular measurements (N = 23)

Parameters and image planes	Range		Mean		Standard deviation	
	M-mode	2DE	M-mode	2DE	M-mode	2DE
IVSs RSAC	4.2–5.2	4.2–5.5	4.7	4.6	0.3	0.3
IVSd RSAC	2.6–3.3	2.6–3.6	3.0	3.1	0.2	0.2
LVIDs M-mode: LSAC 2DE: LLAC	6.0–8.0	5.9–8.2	7.0	7.0	0.6	0.6
LVIDd M-mode: LSAC 2DE: LLAC	9.2–11.8	9.4–11.8	10.7	10.7	0.7	0.7
LVWs LSAC	3.3–4.7	3.2–4.8	3.9	3.9	0.4	0.4
LVWd LSAC	2.3–3.2	2.3–3.1	2.7	2.7	0.2	0.2
FS	23.4–43.0	27.4–41.8	34.7	35.1	4.1	3.4

IVS: interventricular septal thickness; RSAC: right short-axis chordal level view; LVID: left ventricular internal diameter; LSAC: left short-axis chordal level view; LLAC: left long-axis chordal level view; LVW: left ventricular wall thickness; FS: fractional shortening; s: end-systole; d: end-diastole. Each dimension is expressed in cm, except FS (%)

Table 2

Range, mean values and standard deviations of 2DE aortic and left atrial measurements (N = 23)

Parameters and image planes	Range	Mean	Standard deviation
AODd RLAA	6.4–8.5	7.2	0.5
LAIDs LLA	8.7–12.1	10.4	0.9
LAIDd LLA	9.8–13.9	11.3	1.0

AOD: aortic diameter; RLAA: right long-axis aorta level view; LAID: left atrial internal diameter; LLA: left long-axis view; s: end-systole; d: end-diastole. Each dimension is expressed in cm

The standard image planes from the right hemithorax were not used in cases of left ventricular measurements, because the left ventricular free wall and the entire cavity of the left ventricle were not visible in the majority of the horses. Therefore, left ventricular parameters were measured only from the left hemithorax. Another practical problem was that the imaging depth was not enough to measure accurately the left atrial internal diameter in six cases.

To compare 2DE and M-mode values, interventricular septal thickness and left ventricular free wall thickness were measured in short-axis using both methods. For more comparison, left ventricular internal diameter was measured in a 2D long-axis and an M-mode short-axis image plane.

Discussion

The standardised echocardiographic imaging technique published by Long et al. (1992), was found to be a suitable and reliable method by Patteson et al. (1995) and Slater and Herrtage (1995) for collecting qualitative and quantitative data of the equine heart. We had the same experience when performing the present study.

Although the breed used in the study was not large in size (average body weight 427 kg, range 350–490 kg), the depth of penetration of the 3.2 MHz transducer caused a limitation in some cases. In spite of this technical difficulty, the repeatability and the results showed only small variability.

No significant differences were found between the results of two-dimensional and M-mode measurements either in systolic or in diastolic values. The similarity of 2DE and M-mode results are probably due to the guided M-mode measurement method. There were no significant differences between fractional shortening values calculated from two-dimensional and M-mode measurements. There was little or no linear correlation between any of the dimensions measured and the body weight in this relatively homogeneous group.

Long et al. (1992) found no significant difference between measurements made from the right and the left hemithorax, therefore comparison of bilateral examinations was not performed in the present study.

Long et al. (1992) described the difficulties in imaging the left and right atria and a previous study published by Bonagura et al. (1985) reported the same about the right ventricle. We did not measure right atrial dimensions as it was impossible to image the whole atrium within one view. Nor did we measure right ventricular parameters because of problems with accurate image orientation.

Table 3

Mean values and standard deviations of guided M-mode measurements made on healthy horses by different authors

Parameters	Patteson et al. (1995)		Slater and Herrtage (1995)		Sampson et al. (1999)		Present study	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
IVSs	4.2	0.5	4.6	0.5	4.1	0.5	4.7	0.3
IVSd	2.9	0.3	2.8	0.2	2.3	0.3	3.0	0.2
LVIDs	7.1	0.8	7.3	0.8	7.3	0.7	7.0	0.6
LVIDd	11.6	0.7	11.2	0.8	11.2	0.9	10.7	0.7
LVWs	3.9	0.4	3.8	0.3	4.4	0.3	3.9	0.4
LVWd	2.3	0.4	2.5	0.3	2.8	0.4	2.7	0.2
FS	38.7	5.5	35.1	4.6	35.1	3.6	34.7	4.1
Body weight	517	–	490	–	477	43.7	427	33.2
Number of horses	38		16		25		23	

IVS: interventricular septal thickness; LVID: left ventricular internal diameter; LVW: left ventricular wall thickness; FS: fractional shortening; s: end-systole; d: end-diastole. Each dimension is expressed in cm, except FS (%) and body weight (kg)

Table 4

Mean values and standard deviations of 2DE measurements made on healthy horses by different authors

Parameters	Robine (1990)		Vörös et al. (1991*a*)		Patteson et al. (1995)		Present study	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
IVSs	4.7	0.4	4.7	0.5	4.1	0.3	4.6	0.3
IVSd	3.3	0.5	3.8	0.3	2.7	0.2	3.1	0.2
LVIDs	8.8	1.2	7.3	0.9	7.5	0.7	7.0	0.6
LVIDd	12.1	0.8	11.3	1.4	11.9	0.6	10.7	0.7
LVWs	3.1	0.3	–	–	4.0	0.4	3.9	0.4
LVWd	2.4	0.4	–	–	2.5	0.3	2.7	0.2
AODd	6.2	0.6	7.8	0.4	8.7	0.5	7.2	0.5
LAIDs	10.5	1.2	12.6	1.3	12.9	0.8	10.4	0.9
LAIDd	11.4	0.7	11.0	0.8	12.8	0.8	11.3	1.0
FS	29.0	7.0	35.3	3.9	36.5	6.2	35.1	4.1
Body weight	585	27.6	482	44.8	517	–	427	33.2
Number of horses	16		18		38		23	

IVS: interventricular septal thickness; LVID: left ventricular internal diameter; LVW: left ventricular wall thickness; AOD: aortic diameter; LAID: left atrial internal diameter; FS: fractional shortening; s: end-systole; d: end-diastole. Each dimension is expressed in cm, except FS (%) and body weight (kg)

Comparison of echocardiographic measurements of different authors (Tables 3 and 4) involves difficulties. While Pipers and Hamlin (1977), O'Callaghan (1985) and Slater and Herrtage (1995) published data about cardiac parameters of heterogeneous groups of breed and body weight, Lescure and Tamzali (1984), Vörös et al. (1991*a*) and Patteson et al. (1995) examined homogeneous groups. Results of different studies also deviate because of different echocardiographic methods. Different training levels can be important factors, too. Rewel (1991) and Stadler et al. (1993) found significant differences in the interventricular septal thickness, left ventricular internal diameter in diastole and left ventricular wall thickness in systole between horses with different training level, but later Stadler and Robine (1996) reported no significant differences of heart dimensions between dressage, show-jumping and pleasure horses.

The results of Vörös et al. (1991*a*), Slater and Herrtage (1995), Patteson et al. (1995) and Sampson et al. (1999) are similar to ours. Larger deviations exist only in the diameter of the left atrium. The possible cause is the aforementioned technical difficulty of imaging the left atrium. Robine (1990) also measured similar intracardiac parameters on a population of horses with a mean body weight of 585 kg. Despite of the obvious deviation from the mean body weight of our horses (427 kg) only the left ventricular internal dimensions were larger in his study.

The population of the present work was 23 Standardbred trotters. This breed has not been the subject of quantitative investigation in previous publications. In a study by Carlsten (1987) ten Standardbred horses were examined by two-dimensional echocardiography, but there were no numerical data published. The echocardiographic measurements are affected by the breed in the dog (Morrison et al., 1992) and similarly in horse and pony breeds (Slater and Herrtage, 1995). This variation is obviously due to the large differences among dog breeds. When equine breeds with large body weight differences are compared, more alterations in linear cardiac parameters can be expected.

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