Original article

CARDIAC STRUCTURES MEASUREMENTS BY ECHOCARDIOGRAPHY IN CLINICALLY HEALTHY WARMBLOOD HORSES

S. P. SABEV

Department of Internal Diseases, Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

Summary


The present study was carried out in ten clinically healthy warmblood horses. Two-dimensional (B-mode) and M-mode echocardiography was performed. Right long-axis and short-axis parasternal approaches to the heart at the 4th intercostal space level and left long-axis approach at the 5th intercostal space level were used. The following parameters were established by M-mode echocardiography:

- IVS-S (cm) – 3.8±0.3
- IVS-D (cm) – 2.9±0.2
- LVID-D (cm) – 11.2±0.9
- LVID-S (cm) – 7.4±0.7
- LVFW-S (cm) – 3.7±0.6
- LVFW-D (cm) – 2.4±0.2
- AoD-D (cm) – 7.8±0.6
- AoD-S (cm) – 8.1±0.5
- LAD-S (cm) – 6.24±0.3
- Fractional shortening – 39.3±3.4%
- Ejection fraction – 71.9±3.8%
- Interventricular septal thickness fraction – 42.5±6.3%
- Left ventricular free wall thickening fraction – 64.2±8.5%
- LAD-S/AoD-D – 0.8
- Septal E-point (cm) - 0.84

In B-mode, five standard heart images were obtained and the following dimensions (cm):

- RAD-D – 5.9±1.9
- RVD-D – 7.2±0.4
- PAVD-D – 5.8±0.2
- RAVD-D – 4.6±0.2
- RAD-D – 6±0.1
- LAD-D – 10.4±0.6
- RV-D – 1.6±0.2
- LV-D – 3.1±0.6
- IVS-D – 3.4±0.2
- LAVD-D – 10.1±0.8
- LVPMD-D – 9.2±0.8
- LVD – 12.5±1.1
- AoV-D – 7.9±0.3
- LAD-D – 11.8±0.6
- LAV-D – 10.3±0.5
- LVPMD – 3.5±0.4
- LVPM-S – 5.8±0.6

The obtained values for cardiac structures’ dimensions and fractional shortenings are suggested for use as reference values in warmblood horses. The differences with previously published data were insignificant and could be attributed to the breed, exercise or technical details.

Key words: echocardiography, fractions, parameters, physiology, warmblood horses

INTRODUCTION

Echocardiography is a reliable non-invasive diagnostic imaging method for exploration of equine cardiac structures. It is distinguished with practical applicability, precision and repeatability (Kriz & Rose, 2002; Vajhi, 2013). Two-dimensional (2D) echocardiography combined with M-mode investigation is especially appropriate for determination of cardiac structure dimensions, which is essential for cardiac disease diagnostics (Long, 1992; Reef, 1998). Physiological parameters of car-
Cardiac structures measurements by echocardiography in clinically healthy warmblood horses

Cardiac chamber diameter and thickness, aortic and pulmonary artery base have been researched by a number of authors. Data about Thoroughbred horses (Patte-
son et al., 1995), Standardbred (Zucca et al., 2008), ponies and warmblood horses (Slater & Heritage, 1995) are reported. Studies in warmblood horses are relatively scarce and no information is available for some cardiac structures dimensions, including cardiac fractions.

During the interpretation of echographic parameters, a special attention is paid on the ratio between left atrial diameter and aortic diameter. In adult horses, it does not exceed 0.8 (Reef, 1998), whereas in foals and young horses the ratio is higher (Lescure & Tammzali, 1984; Stewart et al., 1984; Bonagura et al., 1985).

Bonagura et al. (1985) and Reef (1990) established that in healthy horses, the diastolic diameter at the base of the aorta was between 8 and 9 cm and was always bigger than that of the left atrium.

An important parameter of left atrioventricular outflow tract volume is the distance between the ventricular septum and so-called Е-point of the mitral valve. In healthy horses, the distance is under 1 cm whereas in animals with left ventricular dilatation it is higher (Reef, 1998; Zucca et al., 2008; Bonomo et al., 2011).

The fractional shortening and ejection fraction are indicative for left ventricular systolic function (Reef, 1998; Bilal & Meral, 2001; Marr & Bowen, 2010).

The fractional shortening shows the percentage of left ventricular diastolic diameter which is lost in systole. According to literature data, it averages 37.42± 3.86% (Patteson et al., 1995); 34±4% (Bonagura & Reef, 1998); 36.2±3.9 (Zucca et al., 2008) and 36.1±5.52% (Bilal & Meral, 2001).

The ejection fraction represents the fraction of the end diastolic volume, which is pumped by the heart with each heartbeat. Its average values are 71±5% (Koblisk et al., 1985); 77±2.1% (Young & Scott, 1998) and 62.9±7.56% (Bilal & Meral, 2001).

MATERIAL AND METHODS

The present study was conducted with 10 clinically healthy horses without any signs of cardiac disease (tachycardia, arrhythmia, cardiac murmur, cyanotic mucous membranes). Seven horses were owned by the Trakia University, and the other three – by private owners. The animals were from the warmblood type, destined for show jumping. According to the gender, the study cohort consisted of 3 mares, 4 stallions and 3 geldings. The horses were in training, with equal body weight and height, aged from 4 to 15 years. The average body weight was 530.8±28.03 kg, and the height from the ground to the top of the withers – 170.2±2.57 cm. The horses were housed freely in boxes 4×4 m of size, equipped with automated drinking troughs and were fed pelleted feed for racing horses and hay. Vaccinations and anti-parasitic treatments were performed according to a schedule.

Echocardiography was done with a portable colour Doppler ultrasound (6SV, SonoScape Ltd., Korea) and linear array micro-convex multifrequency probe C 311, with working frequency 2–4 MHz and penetration depth of 30 cm. The horses were examined in standing position in a box for fixing, after being preliminary accustomed to it and without any sedation. The approach for 2D (B-mode) examination was from the right side, in the 4th intercostal space, within a field restricted between lines passing through the shoul-
der joint and the olecranon tip (Reef, 1998). The images of left ventricle/left atrium were obtained from the left, in the 5th intercostal space along the long heart axis (LL-LV/LA). To facilitate the penetration of ultrasound waves, the skin of horses was impregnated with propanol before the exam and covered with ultrasound gel (Supersonic Ultrasound Gel, Korea). The topography of the ultrasound beam was consistent with the criteria of Stadler et al. (1988).

M-mode imaging studies were carried out in right transversal approaches with dorsal, perpendicular and ventral position of the transducer (Reef, 1998). The examined structures were previously visualised in B-mode. Maximum objectivity of measurements was achieved by perpendicular placement of the cursor in the widest part of the studied object in B-mode. Diameters of left atrium and the aorta were calculated in right short-axis view of the left ventricular outflow tract (RSh-LVOT). The aortic diameter was calculated at end diastole, coinciding with the beginning of the Q-wave of the ECG, and the left atrial diameter at systole (Stewart et al., 1984; Long, 1992; Reef, 1998). The distance between the interventricular septum to the E-point of septal mitral valve membrane (septal E-point), was calculated at the time of maximum opening of the valve during early diastole. For this purpose, the right short-axis medial view (RSh-MV) was used according to the recommendation of Reef (1998).

The thickness of the interventricular septum and left ventricular wall, as well as left ventricular systolic and diastolic internal diameters were calculated in right short-axis views at the level of the papillary muscle according to the criteria of Rewel (1991).

Each parameter was determined as mean arithmetic value of measurements of three non-consecutive cardiac cycles (three frames). Only frames of very good quality were used, divided by at least 5 heart beats. Measurements were performed in calm horses, when the heart rate was less than 45 min\(^{-1}\).

Electrocardiography was simultaneously performed for more precise determination of heart activity phases. For this purpose, a bipolar thoracic apex/base lead was used. Adhesive electrodes were attached as followed: positive electrode (LA) – heart apex, left, 6th intercostal space posterior to the olecranon; negative electrode (RA) – heart base, left, anterior to the scapula edge; neutral electrode (RH) – left side of the withers. To improve the conduction of cardiac biopotentials, ECG gel (TOP-RANK Electrodes Conductive Gel) was applied on the skin.

The left ventricular fractional shortening (FS\%) was calculated using the equation:

$$\text{FS\%} = \frac{\text{LVDD}-\text{LVISD}}{\text{LVDD}} \times 100$$

where: LVDD=left ventricular internal diameter at end-diastole; LVIDS=left ventricular internal diameter at end-systole

The left ventricular ejection fraction (EF\%) was calculated by the formula:

$$\text{EF\%} = \frac{\text{LVDD}^2 - \text{LVISD}^2}{\text{LVDD}^2} \times 100$$

The interventricular septal thickness fraction (IVS-FS\%) was calculated as:

$$\text{IVS-FS\%} = \frac{\text{IVSS-IVSD}}{\text{IVSS}} \times 100$$

where: IVSD=interventricular septal thickness at end-diastole; IVSS=interventricular septal thickness at end-systole.
Cardiac structures measurements by echocardiography in clinically healthy warmblood horses

The left ventricular free wall thickening fraction (LVFW-FS%) was obtained as:

\[ \text{LVFW-FS\%} = \frac{\text{LVFWS} - \text{LVFWD}}{\text{LVFWS}} \times 100 \]

where: LVFWS = left ventricular free wall thickness at end-systole; LVFWD = left ventricular free wall thickness at end-diastole.

The data are presented as mean and standard deviation (SD). Three horses exhibited nervous behaviour which necessitated to postpone the exam until the heart rate went below 45 min⁻¹.

RESULTS

Two-dimensional B-mode imaging

In RL-RVOT view, the widest diastolic diameters of the right atrium, right ventricle and the pulmonary artery at the base of the semilunar valve were 5.9±1.9 cm, 7.2±0.4 cm and 5.8±0.2 cm. The right atrial diameter (RL-4c view) at tricuspid

Table 1. B-mode (2D) echocardiography measurements in healthy warmblood horses. Data are presented as mean ± SD, n=10

<table>
<thead>
<tr>
<th>Views</th>
<th>Structure</th>
<th>Value, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-long axis, cranial view of the left ventricular outflow tract (RL-RVOT)</td>
<td>RAD-D</td>
<td>5.9±1.9</td>
</tr>
<tr>
<td></td>
<td>RVD-D</td>
<td>7.2±0.4</td>
</tr>
<tr>
<td></td>
<td>PAVD-D</td>
<td>5.8±0.2</td>
</tr>
<tr>
<td>Right-long axis, caudal four-chamber view (RL-4c)</td>
<td>RAVD-D</td>
<td>4.6±0.2</td>
</tr>
<tr>
<td></td>
<td>RAD-D</td>
<td>6±0.1</td>
</tr>
<tr>
<td></td>
<td>LAD-D</td>
<td>10.4±0.6</td>
</tr>
<tr>
<td></td>
<td>RV-D</td>
<td>1.6±0.2</td>
</tr>
<tr>
<td></td>
<td>LV-D</td>
<td>3.1±0.6</td>
</tr>
<tr>
<td></td>
<td>IVS-D</td>
<td>3.4±0.2</td>
</tr>
<tr>
<td></td>
<td>LAVD-D</td>
<td>10.1±0.8</td>
</tr>
<tr>
<td></td>
<td>LVPMD-D</td>
<td>9.2±0.8</td>
</tr>
<tr>
<td></td>
<td>LVD-D</td>
<td>12.5±1.1</td>
</tr>
<tr>
<td>Right-long axis, medial view of the left ventricular outflow tract (RL-LVOT)</td>
<td>AoV-D</td>
<td>7.9±0.3</td>
</tr>
<tr>
<td>Left-long axis, caudal view of left ventricle/left atrium (LL-LV/LA)</td>
<td>LAD-D</td>
<td>11.8±0.6</td>
</tr>
<tr>
<td></td>
<td>LAV-D</td>
<td>10.3±0.5</td>
</tr>
<tr>
<td>Right-short-axis ventral view of left ventricle (RSh-LVPM)</td>
<td>LVPM-D</td>
<td>3.5±0.4</td>
</tr>
<tr>
<td></td>
<td>LVPM-S</td>
<td>5.8±0.6</td>
</tr>
</tbody>
</table>

RAD-D: maximum right atrial diameter at end-diastole; RVD-D: maximum right ventricular diameter at end-diastole; PAVD-D: end-diastolic pulmonary artery diameter at valve base; RAVD-D: end-diastolic right atrial diameter at tricuspid valve base; LAD-D: maximum left atrial diameter at end-diastole; RV-D: right ventricular myocardial thickness at end-diastole; LV-D: left ventricular myocardial thickness at end-diastole; IVS-D: interventricular septum thickness at end-diastole; LAVD-D: left atrial diameter at mitral valve base at end-diastole; LVPMD-D: left ventricular diameter at the papillary muscle at end-diastole; AoV-D: aortic diameter at the sinus of Valsalva at end-diastole; LVPM-D: diastolic left ventricular myocardial thickness at the papillary muscle; LVPM-S: systolic left ventricular myocardial thickness at the papillary muscle.

270
valve base in diastole was smaller (4.6±0.2 cm) than the widest diameter (6±0.1 cm). The widest left atrial diastolic diameter (10.4±0.6 cm) did not differ significantly from the diameter at the mitral valve base (10.1±0.8 cm).

The diastolic left ventricular thickness of the myocardium (3.1±0.6 cm) exceeded twice the right ventricular thickness (1.6±0.2 cm). The left ventricular diameter at the papillary muscle in diastole was 9.2±0.8 cm, while the largest diameter through the widest part was 12.5±1.1 cm. The maximum diastolic aortic diameter measured through the sinus of Valsalva in RL-LVOT view was 7.9±0.3 cm. Left diastolic atrial diameters measured at the widest part and the mitral valve base in diastole were 3.7±0.6 cm and 2.4±0.2 cm respectively. The left myocardial thickness in the papillary muscle zone in systole was 5.8±0.6 cm, and in diastole – 3.5±0.4 cm (RSh-LVPM view).

Cardiac structure dimensions obtained in 2D B-mode are outlined in Table 1.

**M-mode imaging**

The systolic interventricular septal thickness was 3.8±0.3 cm, and the diastolic one – 2.9±0.2 cm. The systolic and diastolic left ventricular free wall thickness values were 3.7±0.6 cm and 2.4±0.2 cm respectively. The internal left ventricular diameter in systole was 7.4±0.7 cm, whereas in diastole – 11.2±0.9 cm. Heart fractional shortening and ejection fraction percentages were as followed: FS – 39.3±3.4%, IVS-FS – 42.5±6.3%, LVFW-FS – 64.2±8.5%, EF – 71.9±3.8%. The distance between the interventricular septum and septal mitral valve leaflet (septal E-point) was 0.84 cm. The ratio between systolic left atrial diameter and diastolic aortic diameter was 0.8.

**Table 2.** M-mode echocardiography measurements in healthy warmblood horses. Data are presented as mean ± SD, n=10

<table>
<thead>
<tr>
<th>Heart structure</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVS-S (cm)</td>
<td>3.8±0.3</td>
</tr>
<tr>
<td>IVS-D (cm)</td>
<td>2.9±0.2</td>
</tr>
<tr>
<td>LVID-D (cm)</td>
<td>11.2±0.9</td>
</tr>
<tr>
<td>LVID-S (cm)</td>
<td>7.4±0.7</td>
</tr>
<tr>
<td>LVFW-S (cm)</td>
<td>3.7±0.6</td>
</tr>
<tr>
<td>LVFW-D (cm)</td>
<td>2.4±0.2</td>
</tr>
<tr>
<td>AoD-D (cm)</td>
<td>7.8±0.6</td>
</tr>
<tr>
<td>AoD-S (cm)</td>
<td>8.1±0.5</td>
</tr>
<tr>
<td>LAD-S (cm)</td>
<td>6.2±0.3</td>
</tr>
<tr>
<td>FS (%)</td>
<td>39.3±3.4</td>
</tr>
<tr>
<td>IVS-FS (%)</td>
<td>42.5±6.3</td>
</tr>
<tr>
<td>LVFW-FS (%)</td>
<td>64.2±8.5</td>
</tr>
<tr>
<td>EF (%)</td>
<td>71.9±3.8</td>
</tr>
<tr>
<td>LAD-S/AoD-D</td>
<td>0.8</td>
</tr>
<tr>
<td>Septal E-point (cm)</td>
<td>0.84</td>
</tr>
</tbody>
</table>

IVS-S: interventricular septum thickness at end-systole; IVS-D: interventricular septum thickness at end-diastole; LVID-D: left ventricular internal diameter at end-diastole; LVID-S: left ventricular internal diameter at end-systole; LVFW-D: left ventricular free wall thickness at end-diastole; AoD-D: aortic diameter at end-diastole; AoD-S: aortic diameter at end-systole; LAD-S – maximum end-systolic left atrial diameter; FS: left ventricular fractional shortening; EF: left ventricular ejection fraction; IVS-FS: interventricular septal thickness fraction; LVFW-FS: left ventricular free wall thickening fraction.

The results from M-mode echocardiography are presented in Table 2.

Fig. 1 and 2 show details from M-mode echocardiography exams. Fig. 3 depicts left atrial and left ventricular measurements in two-dimensional B-mode.

**DISCUSSION**

The examination of the right ventricular outflow tract in B-mode has established
smaller diastolic right ventricular and right atrial diameters as well as larger diastolic pulmonary artery diameter than those reported by Robine (1990) and Kroker (1994) in warmblood horses. Our results in RL-4c view were close to those of authors except for the right atrial dimensions in the tricuspid valve area and in the largest part. In those points, observed dimensions were smaller and averaged 4.6±0.2 cm and 6±0.1 cm, respectively. The measurements in the aortic valve area (AoV-D) were comparable to those reported by Slater & Herrtage (1995). The left ventricular myocardial thickness in RSh-LVPM view at systole was bigger than that established by Kroker (1994).

The detected variations could be attributed to individual features of examined horses on one part, and to some technological differences as the ultrasound beam topography on the other. The differences in the training regimen of studied subjects have also some influence on established results.

Compared to similar examinations in Thoroughbreds (Patteson et al., 1995) and Standardbreds (Zucca et al., 2008), in this study we demonstrated a smaller diastolic left atrial diameter, which is attributed to the more intensive physical exercise in racehorses.

In available literature sources, data about the cardiac parameters in warmblood horses obtained in M-mode echocardiography are limited. Our results about the left myocardial thickness, left ventricular diameter and interventricular septum thickness confirm the data found out by Slater & Herrtage (1995). Systolic interventricular septum was thinner than that established in warmblood horses, which in our view could be attributed to breed-related variations. The comparisons with Thoroughbreds and Standardbreds revealed comparable dimensions.

Cardiac fractional percentages (FS, IVS-FS and LVFW-FS) in examined
horses were within the reference ranges, indicating a preserved contractile ability of the myocardium. They did not differ considerably from fractional shortening values in Thoroughbreds and Standardbreds. The ejection fraction (EF), the LAD-S/AoD-D ratio and the septal E-point were within the reference ranges, confirming that the horses included in this study were clinically healthy.
In conclusion, we suggest the reported ultrasound measurements could be used as reference values in warmblood horses. The existing differences in some of parameters were insignificant and could be attributed to breed-specific features, the different training schedule or equipment-related features.

REFERENCES


Young, L. & G. Scott, 1998. Measurement of cardiac function by transthoracic echocardiography: Day to day variability and repeatability in normal Thoroughbred hor-

Correspondence:
Dr. Sasho Sabev
Department of Internal Diseases,
Faculty of Veterinary Medicine,
Trakia University,
6000 Stara Zagora, Bulgaria
e-mail: s_sab@gbg.bg

Paper received 22.01.2014; accepted for publication 25.04.2014