Normal left ventricular systolic time intervals assessed by pulsed wave Doppler echocardiography in the Turkmen horse of Iran

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Key Words:
Echocardiography; pulsed wave Doppler; systolic time intervals; normal range; Turkmen horse.

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Received: 13 May 2009
Accepted: 7 April 2010

Abstract

The Turkmen horse is one of the oldest and purest breeds in the world. There is no information with regards to the normal echocardiographic parameters of this horse regarding to cardiac diseases. Pulsed-wave (PW) Doppler echocardiography was performed on 42 clinically normal 3- to 15-year-old racing Turkmen horses. There were 26 stallions and 16 mares. The left ventricular isovolumetric contraction time, pre-ejection period (PEP), and the left ventricular ejection time (LVET), were measured, and the values of the left ventricular total electromechanical systole (LVTES) and the PEP-to-LVET ratio were calculated. The most suitable window for the measurement of the aforementioned indices in PW Doppler echocardiography was the left parasternal window using the five-chamber apical view. The following values were acquired in PW Doppler echocardiography: PEP = 0.088 ± 0.018 s; LVET = 0.445 ± 0.031 s; LVTES = 0.533 ± 0.032 s; and PEP-to-LVET = 0.199 ± 0.046. These measurements can be used in the future as standard and reference values for the evaluation of cardiovascular disorders in the Turkmen horse.

Introduction

One of the primary investigations in cardiology is the assessment of the left ventricular systolic function (Cuesta Silva *et al*., 1977). Ultrasound techniques have fulfilled this purpose, because the method combines the fidelity and accuracy of invasive techniques with the advantages of a harmless procedure, which is important for the horse. In this species, the echocardiographic assessment of systolic function usually includes an evaluation of the ejection phase indices. The most relevant among these are the left ventricular fractional shortening (FS, %), the ejection fraction (EF), and to a small extent, the mean velocity of circumferential fiber shortening. Nevertheless, the measurements comprised in the denomination of systolic time intervals (i.e., the left ventricular pre-ejection period (LVPEP), left ventricular ejection time (LVET), total electromechanical systole (TES) and the PEP-to-LVET ratio), which are more accurate for the assessment of left ventricular performance have scarcely been used (Boon, 1998). As a result of this, there are no conclusive references with regards to the normal values of these intervals and the variations related to pathologies in horses (Lescure and Tamsali, 1983; Lescure and Tamsali, 1984; Long *et al*., 1992; Kienle and Thomas, 1995).

Turkmen horse is one of the oldest and purest breeds in the world. In spite of its small stature, the Turkmen horse has always achieved high ranks in both course and jumping competitions (Golshan, 2005). To date, there are no data on the normal echocardiographic parameters of this horse. To correct this deficiency, this study aimed to determine quantitative reference values of systolic time intervals by PW Doppler echocardiography in healthy Turkmen horses.

Materials and Methods

In the present study, 42 registered Turkmen racehorses (16 mares and 26 stallions) aged between 3 to 15 years (mean ± SD: 6.35 ± 3.42 yr), with a bodyweight that ranged from 310 to 450 kg (mean ± SD: 369 ± 37.8 kg), were examined. The Turkmen horse is bred in the north-eastern part of Iran near the border between Iran and Turkmenistan. This study was performed in this region. All animals had undergone at least 1 yr of training and were experienced in competitions. They are kept under similar hygienic, sanitary, and nutritional conditions. All horses were determined to be free from cardiac diseases on the basis of clinical, electrocardiographic (ECG), two–dimensional (2D), and color flow mapping Doppler echocardiographic examinations prior to the study. Horses with an early systolic grade 2/6 ejection murmur with the point of maximal intensity over the aortic valve (7 out of the 42 studied horses) were considered to be normal. A total of three out of 42 horses had a second-degree atrioventricular block during the examination. However, in these animals, all measurements were made from intervals of normal sinus rhythm. All horses were free from significant valvular regurgitation on color Doppler echocardiography.

Before imaging, the coat was shaved bilaterally from the 3rd to the 5th intercostal space between the mid-point of the shoulder and the point of the elbow. The shaved areas were then thoroughly rinsed with clean water, and acoustic coupling was obtained using large amounts of ultrasound gel. The echocardiographic examination was performed with a Sonosite – MicroMaxx (SonoSite Inc, USA) ultrasound machine, using a 1-5 MHz phase array transducer, with a maximal depth of 25 cm and 2D brightness mode (B-mode), color flow mapping, and spectral Doppler modalities. The ultrasound machine had an integrated ECG, where the ECG traces were displayed simultaneously on the echocardiograms. A base-apex lead system was used for ECG, with one electrode applied in the 6th intercostal space on the left side of the thorax along with a line parallel to the level of the point of the elbow, and the other electrode was placed on the top of the right scapular spine. All of the imaging stages were recorded digitally for subsequent analysis. During the examination, the animals were at rest, calm, and physically restrained only by the halter, in a quiet and relatively dark room. No chemical sedation was used.

PW Doppler measurements were made according to guidelines previously described by Goldberg *et al*. (1988) and Blissitt and Bonagura (1995). PW Doppler echocardiography was performed through the left parasternal window, starting from a five-chamber apical view, placing the gate on the arterial side (sinotubular junction [JT]) of the aortic valves (Figure 1). The sample volume was set at 5 mm for all measurements. Measurements were made from three consecutive cardiac cycles and the angle corrector was used. The following systolic time intervals were measured: left ventricular isovolumetric contraction time or PEP, LVET, left ventricular total electromechanical systole (LVTES) and PEP-to-LVET ratio.

With PW Doppler echocardiography, PEP was measured from onset of the QRS complex to the beginning of the spectral wave related to the aortic flow (Figure 1). The LVET was measured from beginning to the end of the aortic flow spectrum. Although LVTES was calculated adding PEP and LVET values, and the PEP-to-LVET ratio was obtained by dividing the corresponding values.

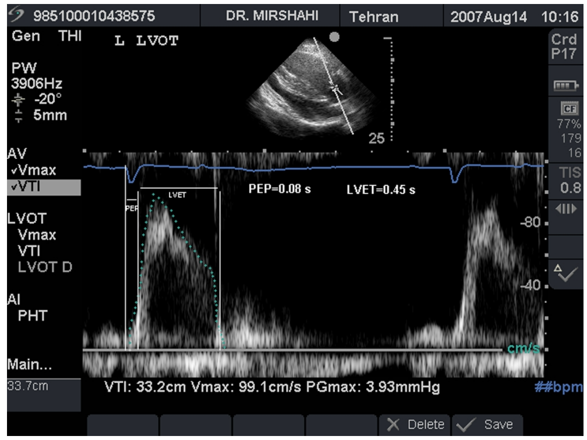

Figure 1: A left parasternal long-axis PW Doppler echocardiogram of the left ventricular outflow tract (LVOT) and aorta (Ao). PEP = pre-ejection period; LVET = left ventricular ejection time. PEP was measured from the onset of the QRS complex to the beginning of the spectral wave related to the aortic flow. LVET was measured from beginning to the end of the aortic flow spectrum. For both measurements, the caliper was placed in the center of the ascending or descending limbs of the spectral waveform as it crossed the baseline. An ECG is displayed to illustrate the timing of cardiac events.

Statistical analysis

All the statistical analyses were performed using SPSS version 15.0 Summary statistics included the mean, standard deviation, maximum, minimum, and coefficient of variation for each PW Doppler parameter. All parameters were compared between stallions and mares using independent-sample t-tests. Additionally, all means of PW Doppler parameters were compared between Turkmen horses and thoroughbred horses (Blissitt and Bonagura, 1995) using the single-sample t-test. To identify the influence of age, body weight, sex, and heart rate of the horses on the PW Doppler measurements, a multivariate linear regression analysis was performed using age, weight, sex, heart rate as independent variables, and PW Doppler measurements as dependent variables. For all these tests, a P-value less than 0.05 was considered to be significant.

Results and Discussion

The obtained PW Doppler echocardiographic parameters are shown in Table 1. It is acknowledged that, in humans, the measurement of systolic time intervals is a more reliable index of left ventricular systolic function than the assessment of ejection phase indices (Otto, 1999), which are helpful for the evaluation of pulmonary hypertension (Serwer *et al*., 1986; Dabestani *et al*., 1987; Feigenbaum, 1995). Similar to ejection phase indices, systolic time intervals do not allow for a direct assessment of myocardial contractility, but rather, they provide suggestions on the global activity of the ventricles (specifically the left ventricle). This is because, like the ejection phase

Table 1: Systolic time interval values obtained using of PW Doppler echocardiography in 42 normal Turkmen horses.

Parameters	Mean	Max	Min	SD	CV (%)
PEP (s)	0.088	0.13	0.06	0.018	20.486
LVET (s)	0.445	0.53	0.4	0.031	6.977
PEP-to-LVET	0.199	0.321	0.125	0.046	23.225
LVTES (s)	0.533	0.61	0.465	0.032	5.987

PEP = pre-ejection period; LVET = left ventricular ejection time; LVTES = left ventricular total electromechanical systole; PEP-to-LVET = PEP-to-LVET ratio; CV = coefficient of variation.

Table 2: Comparison of normal systolic time interval values assessed by PW Doppler echocardiography between Turkmen and thoroughbred horses

	Turkmen horses (present study)	Thoroughbred horses (Blissitt & Bonagura, 1995)	P-value
PEP (s)	0.088 ± 0.018	0.075 ± 0.018	0.001
LVET (s)	0.445 ± 0.031	0.467± 0.031	0.001
PEP-to-LVET	0.199 ± 0.046	0.160	0.000

PEP = pre-ejection period; LVET = left ventricular ejection time; LVTES = left ventricular total electromechanical systole; PEP-to-LVET = PEP-to-LVET ratio. PEP, LVET, PEP-to-LVET had significant differences between Turkmen and thoroughbred horses. P-value <0.05 was considered to be significant.

indices, they are affected by preload, afterload and heart rate (Boon, 1998; Otto, 2000). However, there are clinical advantages for this situation, since any alteration of these phenomena will be reflected in the systolic time intervals.

When the measurement is carried out using PW Doppler, any window supplying the image of transaortic flow will be suitable for measuring; the alignment with flow is not critical, because systolic time intervals estimate time and not speed. Nevertheless, the five-chamber apical view obtained by left parasternal window was revealed to be the most practical for study of the aortic flow (Long *et al*., 1992; Boon, 1998).

Blissitt and Bonagura (1995) have published different values to those acquired in the present study (Table 2). In the present study, PEP was longer and LVET was shorter than pervious study in thoroughbred horses by Blissitt and Bonagura. Therefore PEP-to-LVET will be larger than thoroughbred horses. These findings may reflect differences in breed or training conditions. There were no significant differences in systolic time intervals measurements between stallions and mares. PW Doppler-derived systolic time intervals parameters were not significantly correlated with age, body weight, sex, and heart rate. In this study, the mean heart rate obtained during Doppler examination was 42 ± 2 beats/min.

When the systolic function is normal, the isovolumetric contraction period is short and any increase in blood pressure is faster at the onset of systole. A Doppler speed curve will reveal a short isovolumetric contraction time, fast blood acceleration, a short interval from the ejection onset to the point of maximum speed, and a ventricular ET set within normal values (Otto, 1999). In contrast, when systolic function is altered, the ejection period slowly lengthens, ET shortens, and the acceleration speed decreases while the time requested to reach maximal speed increases. Even with a normal ventricular function, intervals can be affected in relation to the preload and afterload dynamics. Independent of the reason why a preload decrease occurs, this reduction will cause an increase in the isovolumetric contraction time, because the ventricle will need a longer time to reach the pressure required for opening of the aortic valve while the ventricular ET is decreasing. The opposite phenomenon produces converse response.

An increase in afterload, causing the ventricle to work against a greater resistance, will also produce an increase of isovolumetric contraction period and ventricular ET. Pathological conditions affect the pattern of systolic intervals. As with aortic stenosis, the increase in blood flow resistance will determine a decrease of PEP and a prolongation of ventricular ejection, while failure of pump function (e.g., cardiomyopathy) or counter-current blood flow (e.g., interventricular communication without right hypertension, mitral regurgitation) will provoke an increase in isovolumetric contraction time and a decrease in ventricular ET (Atkins & Snyder, 1992).

As reported in the present study, there is no correlation between systolic time intervals assessed by PW echocardiographic parameters and age, body weight, sex, and heart rate. These findings suggest that PW echocardiographic measurements in horses may be affected by breed and possibly by athletic training. The parameters obtained in this study can be used as the standard and reference values for the evaluation of cardiovascular disorders in the Turkmen horse.

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