

# Effects of xylazine and acepromazine on echocardiographic parameters in the healthy horse

Mohammad Reza Mokhber Dezfouli<sup>1</sup>, Hamid Tavanaeimanesh<sup>1</sup>, Amir farhang Houshang<sup>2</sup>, Kevin Corley<sup>3</sup>, Majid Masoudifard<sup>4</sup>, Sirous Sadeghian Chaleshtori<sup>1</sup> and Bahram Dalir-Naghadeh<sup>5</sup>

<sup>1</sup> Department of Internal Medicine, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran

<sup>2</sup> Department of Veterinary, Azad University of Shabestar, East Azerbaijan, Iran

<sup>3</sup> Veterinary Advances, 9 Ballysax Hills R56 DY00, The Curragh, Ireland

<sup>4</sup> Department of Surgery and Radiology, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran

<sup>5</sup> Department of Clinical Pathology and Internal Medicine, Urmia University, Urmia, West Azerbaijan, Iran

**Summary:** The aim of this study was to evaluate the effects of xylazine and acepromazine on the Doppler and M-mode echocardiography measurements in horses. Ten healthy crossbred horses were included in this study. Baseline echocardiography was performed in all horses. Xylazine (0.5 mg/kg IV) or acepromazine (0.01 mg/kg IV) was injected intravenously with a 4 week wash out period between drugs. Electrocardiogram was recorded simultaneously in the base-apex lead. The results showed that the heart rate in the xylazine group was significantly lower than in the control measurements ( $p = 0.021$ ). In the xylazine group, there were 2<sup>nd</sup> degree atrioventricular blocks in two horses. The diameter of the left ventricle at the end of diastole (LVID<sub>d</sub>) was decreased ( $p = 0.029$ ) and the interventricular septum thickness at the end of diastole (IVS<sub>d</sub>) ( $p = 0.008$ ) were increased in the xylazine group. Right ventricle internal diameter at the end of systole (RVID<sub>s</sub>) were increased in both treatment groups. Our results showed that acepromazine and xylazine have some detectable effects on echocardiographic measurements, but both the nature and the degree of these differences mean that they are unlikely to affect the diagnostic quality of the scan. Acepromazine at a dose of 0.01 mg/kg, used in horses undergoing echocardiographic examination, results in negligible changes in spectral and M-mode measurements.

**Keywords:** echocardiography, spectral Doppler, M-mode, xylazine, acepromazine

**Citation:** Dezfouli M. R. M., Tavanaeimanesh H., Houshang A. F., Corley K., Masoudifard M., Chaleshtori S. S., Dalir-Naghadeh, B. (2020) Effects of xylazine and acepromazine on echocardiographic parameters in the healthy horse. *Pferdeheilkunde* 36, 37–42; DOI 10.21836/PEM20200106

**Correspondence:** Hamid Tavanaeimanesh, Department of Internal Medicine, Faculty of Veterinary Medicine, University of Tehran, Qareeb street, Azadi Av. P.O.Box 14155–6453, Postal Code 1419963111 Tehran, Iran; hamidtavana@ut.ac.ir

**Received:** July 18, 2019 | **Accepted:** November 11, 2019

## Introduction

Echocardiography is an invaluable tool for the assessment of cardiac structure, chamber size and function. The temperament of some horses can make the procedure difficult or dangerous. However, sedation of recalcitrant horses is not recommended as these drugs may alter cardiac function causing inaccurate results.

The most commonly used drugs for standing sedation are the alpha<sub>2</sub>-agonists, which may be used alone or in combination with other drugs (e.g. opioids or phenothiazines). Acepromazine is a drug that exerts its sedative effects by the blockade of dopamine receptors in the central nervous system (Donaldson 2006). The main cardiovascular effects of acepromazine are mediated by peripheral alpha<sub>1</sub>-adrenoceptor blockade at the level of the peripheral arterioles, resulting in vasodilatation, a decrease in vascular resistance, and a compensatory increase in heart rate (Merlo and Rota 1999, Monterio et al. 2007). In contrast the alpha<sub>2</sub>-agonists result in peripheral vasoconstriction, bradycardia, and decrease in cardiac output (Bloor et al. 2002). Increase in incidence of second degree atrio-

ventricular block and transient hypertension is followed by hypotension (Wagner et al. 1991). In summary, acepromazine reduces blood pressure (Marroum et al. 1994) with different effects on heart rate (Hashem and Keller 1993) while xylazine decreases heart rate (Wagner et al. 1991).

To date, there is only limited published data about the effects of sedation on cardiac parameters measured by echocardiography (Patteson et al. 1995, Saponaro et al. 2013). In one study, detomidine was found to alter a number of measured parameters, including the end-systolic left ventricular diameter and heart rate (Patteson et al. 1995). Buhl and her colleagues also investigated the effects on echocardiographic parameters of detomidine, romifidine, and acepromazine in horses and showed that detomidine and romifidine significantly decreased the heart rate whilst acepromazine did not (Buhl et al. 2007). Menzies-Gow investigated the effects of acepromazine in 8 healthy horses, and found that the aortic and pulmonic diameters were significantly increased at the end-systole and that the interventricular septum was increased both in the end systole and in the diastole after drug administration (Menzies-Gow 2008).

To date, no study has been published evaluating the effects of sedation on spectral Doppler echocardiographic measurement across the heart valves in horses. Spectral Doppler highlights hemodynamics across the valves and main vessels, which aids the assessment of valvular heart disease.

The aim of this study was to evaluate echocardiographic parameters subsequent to acepromazine and xylazine administration. There is little information about the effects of these drugs on spectral Doppler parameters and this is the first study, which evaluates these parameters after administration of xylazine and acepromazine. Authors believed that using lowest doses of sedative drugs will not have significant effects on echocardiographic parameters, so in nervous horses they could help to decrease the risk of injury to clinicians as well as horses.

## Material and Methods

Ten crossbred female healthy horses weighing 385–451 kg were included in this study. All horses underwent clinical examination and were considered normal. Horses were placed in stocks for the duration of the experiment. The region between 3<sup>rd</sup> and 5<sup>th</sup> inter-costal spaces was clipped, and washed with surgical spirit, and covered with acoustic coupling gel. The horses were allowed to settle and adapt to the environment. Horses were acclimatized for 10 minutes prior to echocardiography. After this rest period, the echocardiographic examination was started.

The subject horses were injected with 10 ml of 0.9% saline intravenously, following which a complete set of baseline echocardiographic measurements were taken. These results constituted the control measurement. Subsequently, xylazine (0.5 mg/kg) was administered intravenously and the complete set of echocardiographic measurements was taken again, exactly following the procedure used to obtain the control measurements. Each horse was then given a four week wash-out period. Following this, a further complete set of echocardiographic measurements was taken after intravenous administration of 0.01 mg/kg acepromazine.

The depth of sedation was graded by the distance between the lower lip of the horses to the ground. (Cruz et al. 2011). Echocardiography was started 10 minutes after drug administration (Buhl et al. 2007, Menzies-Gow 2008). The echocardiographic examination was finished within 20 minutes. The differences between the onset of effect and the recovery time of xylazine and acepromazine was the limitation, which we tried to decrease by starting the study 10 minutes after injection of sedatives (Kalhor 2006). A simultaneous electrocardiogram was taken with a base-apex lead configuration. All echocardiographic examinations and measurements were performed by the same operators.

Echocardiographic images were acquired with an ultrasound device (Micro Maxx: SonoSite Inc, Bothell, WA, USA) with a phase array transducer (1–5 MHz). A right parasternal window was used to evaluate all valves. The pulse wave Doppler (PWD) gate was placed distal to each valve. Blood flow across tricuspid and pulmonary valves was evaluated at long axis

right ventricular outflow tract (RVOT), aortic flow at left ventricular outflow tract (LVOT), and the mitral valve in the four chamber view. For each view, four images were taken. The best two images were selected subjectively and their average values are reported. We evaluated spectral Doppler parameters such as peak velocity, velocity time integral (VTI), pressure gradients (PG), and pressure half time (PHT) across the heart valves.

A ventricular short axis view at the level of chordae tendineae was used to record M-mode images. Left ventricular internal diameter at end diastole (LVID<sub>d</sub>) using the beginning of the QRS as the reference point, and left ventricular internal diameter in peak systole (LVID<sub>s</sub>), taken at the maximum upswing of the left ventricular free wall, were measured (Tavanaeimanesh et al. 2015). We used the same method for measuring of right ventricular diameters. Fractional shortening (FS) was determined by the following equation:

$$FS(\%) = (LVID_d - LVID_s) / LVID_d \times 100$$

Color Doppler images were also recorded on all valves and any regurgitation was evaluated based on the proposed method by Reef (Reef 1991) which were used for semiquantitation of the area of regurgitation:

- Insignificant – the regurgitant jet occupies a small area behind the valve.
- Mild – the jet occupies less than one-third of the chamber involved.
- Moderate – the jet occupies less than two-thirds of the chamber involved.
- Severe – regurgitant flow can be detected in greater than two-thirds of the chamber involved.

## Data Analysis

Initially, datasets were tested for normal distribution using the Kolmogorov-Smirnov test (UNIVARIATE procedure). Data associated with heart rate were log (base 10) transformed prior to analysis because of the lack of normal distribution. Data were analyzed using the General Linear Model (GLM) procedure including repeated measures in the model. LSMEANS statement was used to perform multiple comparisons. All analyses were performed using SAS (SAS 2008). Differences with  $P < 0.05$  were considered significant.

## Results

Spectral Doppler parameters of the aortic, pulmonary, tricuspid and mitral valve are shown in Table 1. There were no significant differences between the control measurements and any of treatment groups.

The heart rate declined in the xylazine group in comparison to the control measurements from  $42.96 \pm 1.73$  beats/min to  $37.11 \pm 1.43$  beats/min respectively ( $p = 0.021$ ) (Table 2). Two horses in the xylazine group showed 2<sup>nd</sup> degree atrio-ventricular blocks, but no arrhythmia was observed in the acepromazine group. In the control measurements, two of ten horses

had insignificant pulmonic regurgitation. At the dose used, there was no change in blood flow across the valves after acepromazine administration. Xylazine administration resulted in insignificant aortic regurgitation in one horse with pulmonary regurgitation.

M-mode parameters measurements are shown in Table 2. The interventricular septal thickness at the end of diastole (IVS<sub>d</sub>) increased from 2.10 ± 0.30 cm in the control measurements to 2.53 ± 0.43 after xylazine administration (p = 0.008). LVID<sub>d</sub> decreased from 9.04 ± 1.55 cm to 8.36 ± 1.42 cm (p = 0.0029). There was a large increase in right ventricular internal diameter at end-systole in both treatment groups.

**Table 1** Mean ± SD of spectral Doppler parameter. | Mittelwerte und Standardabweichungen

	Control	After Xylazine	After Acepromazine
	Mean ± SD	Mean ± SD	Mean ± SD
AV Vmax (cm/s)	106.55 ± 28.57	98.24 ± 16.98	101.25 ± 23.22
AV Vmean (cm/s)	65.61 ± 20.24	61.63 ± 13.49	63.91 ± 17.59
AV VTI (cm)	29.39 ± 10.16	29.72 ± 5.95	31.11 ± 11.72
AV PGmean (mmHg)	2.01 ± 1.09	1.77 ± 0.76	1.99 ± 0.92
PV Vmax (cm/s)	135.42 ± 23.45	118.23 ± 29.73	134.18 ± 27.62
PV Vmean (cm/s)	86.92 ± 11.14	77.03 ± 15.24	87.51 ± 14.73
PV VTI (cm)	44.30 ± 11.74	49.51 ± 11.20	45.84 ± 10.63
PV PGmean (mmHg)	4.10 ± 1.76	3.54 ± 1.76	3.25 ± 1.13
TV Vmax (cm/s)	84.19 ± 20.73	106.23 ± 33.71	92.65 ± 32.47
MV E (cm/s)	88.96 ± 14.12	83.86 ± 18.41	85.35 ± 19.11
MV E PG (mmHg)	3.31 ± 0.96	3.06 ± 1.10	3.07 ± 1.17
MV A (cm/s)	42.04 ± 10.39	37.04 ± 11.66	42.96 ± 15.08
MV Vmax (cm/s)	91.99 ± 17.01	89.47 ± 18.51	88.95 ± 20.59
MV Vmean (cm/s)	49.45 ± 6.80	47.51 ± 10.15	44.52 ± 10.29
MV PHT (ms)	64.31 ± 10.78	68.57 ± 13.38	73.92 ± 18.85
MV Decel (ms)	227.70 ± 26.71	243.90 ± 34.79	255.60 ± 26.19

AV: aortic valve, PV: pulmonary valve, TV: tricuspid valve, MV: mitral valve, Vmax: peak velocity, Vmean: mean velocity, VTI: velocity time integral, PGmean: mean pressure gradient, E: E wave peak velocity, E PG: E wave peak pressure gradient, A: A wave peak velocity, PHT: pressure half time, Decel: deceleration time

## Discussion

To date, there have been no published studies of spectral Doppler parameters after sedation in horses. These parameters can help clinicians to assess the valvular disease as they measure actual blood flow. Nevertheless, there is some limitation in spectral Doppler in equine medicine as it cannot calculate the actual blood flow across the valves due to angle dependency and also the limitation of the parasternal window in the horse. In our study, neither xylazine nor acepromazine altered any of the following: the velocity of blood across the valves, the pressure gradient, the velocity time integral, or the pressure half time.

**Table 2** Mean ± SD of M-mode parameters. | Mittelwerte und Standardabweichungen der M-Mode-Parameter

	Control	After Xylazine	After Acepromazine
	Mean ± SD	Mean ± SD	Mean ± SD
LVPWd (cm)	1.60 ± 0.33	1.58 ± 0.28	1.74 ± 0.35
RVWd (cm)	2.86 ± 0.46	2.31 ± 0.50	2.50 ± 0.27
RVIDd (cm)	1.63 ± 0.41	2.00 ± 0.63	1.82 ± 0.43
IVSd (cm)	2.10 ± 0.30	2.53 ± 0.43§	2.25 ± 0.35
LVIDd (cm)	9.04 ± 1.55	8.36 ± 1.42§	8.71 ± 0.37
LVPWs (cm)	2.35 ± 0.44	2.62 ± 0.59	2.95 ± 0.41
RVWs (cm)	3.05 ± 0.35	2.81 ± 0.46	3.00 ± 0.34
RVIDs (cm)	1.41 ± 0.36	2.11 ± 0.87§	1.56 ± 0.64§
IVSs (cm)	3.42 ± 0.55	3.25 ± 0.47	3.64 ± 0.51
LVIDs (cm)	5.01 ± 1.02	5.56 ± 1.61	4.38 ± 1.27
EPSS (cm)	1.98 ± 1.46	1.47 ± 0.44	1.25 ± 0.33
EF:SLOPE (cm/s)	19.26 ± 3.70	20.06 ± 3.55	17.66 ± 3.12
Ao (cm)	5.71 ± 1.37	5.97 ± 0.97	6.04 ± 0.75
LA (cm)	3.52 ± 0.70	3.81 ± 0.76	3.70 ± 0.66
FS (%)	42.17 ± 5.27	37.02 ± 6.61	45.29 ± 8.47
Heart rate (beat/min)	42.96 ± 1.73	37.11 ± 1.43§	43.67 ± 4.31

§ P < 0.05 versus pre-injection values

LVPWd: left ventricular posterior wall diastolic, RVWd: right ventricular free wall diastolic, RVIDd: right ventricular internal diameter diastolic, IVSd: interventricular septum diastolic, LVIDd: left ventricular internal diameter diastolic, LVPWs: left ventricular posterior wall systolic, RVWs: right ventricular free wall systolic, RVIDs: right ventricular internal diameter systolic, IVSs: interventricular septum systolic, LVIDs: left ventricular

The effect of acepromazine administration on heart rate is controversial, with some authors reporting an increase (Hashem and Keller 1993, Muir and Mason 1993) and others reporting no change (Walker and Geiser 1986, Marrum et al. 1994).

Similarly, acepromazine has been reported to either increase or decrease the cardiac output (Steffey et al. 1985). Acepromazine induced increases in arterial diameter and volumetric flow rate, and there was a trend towards increased blood velocity (Walker and Geiser 1986). A similar result was seen by Muir and Mason, where acepromazine caused a decrease in blood pressure and vascular resistance due to vasodilation (Muir and Mason 1993).

Only two previous published studies have described the effects of acepromazine on echocardiographic parameters in horses (Buhl et al. 2007, Menzies-Gow 2008). Menzies-Gow administered acepromazine at 0.03 mg/kg intravenously to eight healthy horses. She showed an increase in aortic and pulmonic diameters at the end of systole. The interventricular septal width was also increased, both at the end of systole and at the end of diastole after acepromazine administration. In addition, there was a significant decrease in the left atrial diameter at end diastole ( $LAD_d$ ). Sedation did not affect the remaining cardiac dimensions, neither any indices of cardiac function, nor the occurrence and severity of valvular regurgitation. Menzies-Gow concluded that diminishing in  $LAD_d$  may have been due to the hypotension induced by acepromazine. Buhl and others saw no effect of acepromazine (0.1 mg/kg) administration on  $LVID_s$ ,  $LVID_d$ ,  $LVFW_s$ ,  $LVFW_d$ ,  $IVS_s$  and  $IVS_d$ . There was no change in blood flow across valves in published studies (Buhl et al. 2007; Menzies-Gow 2008) or the current study. One study reported that detomidine and romifidine increased the frequency of valvular insufficiency whilst acepromazine decreased the occurrence of regurgitation (Buhl et al. 2007). The dose of acepromazine in the study of Buhl and her colleague was 0.1 mg/kg while it was 0.03 mg/kg in the study of Menzies-Gow. We used 0.01 mg/kg acepromazine only, and as all of these three studies started the echocardiography 10 minutes after administration of acepromazine, the differences between results of these studies could be due to differences in dose.

Vasodilators cause dilation in peripheral arteries resulting in an increase in blood flow velocity and turbulence; this appears to explain the findings of Nogueira et al. (2012) for the combination of acepromazine and buprenorphine in dogs. They used Duplex Doppler to evaluate blood flow. Femoral artery flow velocity increased after administration of the drugs, but flow volume was unaltered. In pigs, injection of vasoactive drugs caused peripheral vascular dilation, and turbulent blood flow (Fernández et al. 2003). These findings show that the increase in blood flow seen in peripheral arteries after administration of acepromazine is the result of vasodilation and flow turbulence and not of cardiac origin.

In a study in eight horses, administration of detomidine and romifidine caused an increase in the frequency of valvular regurgitation whilst acepromazine administration resulted in a decrease in the occurrence of regurgitation (Buhl et

al. 2007). In our study, only a single horse developed aortic regurgitation (<1 cm) after xylazine administration and acepromazine did not cause any regurgitation. It seems that acepromazine caused lesser regurgitation in comparison to other sedatives.

Xylazine decreases the heart rate (Wagner and Muir 1991), increases incidence of cardiac arrhythmia (McCashin and Gabel 1975) and raises blood pressure (Muir and Mason 1993). In one study, peripheral vascular resistance increased minimally after xylazine administration, also it has been shown that xylazine has less cardiovascular and cardiac depressive effects than detomidine or medetomidine (Yamashita et al. 2000). In another study, xylazine (1 mg/kg IV) administration resulted in no statistically significant change in cardiac indices such as fractional shortening and ejection fraction (Linardi et al. 2008). The changes in blood pressure are the result of changes in peripheral resistance rather than changes in cardiac output.

In an older study, sedation with xylazine resulted in a significant decrease in heart rate, systolic wall thickness and inotropic indices while there was a marked increase in the luminal dimensions (Pipers 1978). Patteson and colleagues (1995) showed that detomidine administration resulted in a significant increase in  $LVID_s$ , the diameter of aorta at the level of the sinus of Valsalva (AoS) and the pre-ejection period (PEP).  $LVFW_s$ ,  $IVS_s$ , FS and heart rate all decreased significantly. They ascribed the reduction in cardiac performance to a decrease in myocardial contractility or an increase in afterload and also suggest that preload is not substantially altered by detomidine, despite a marked reduction in heart rate. In another study, detomidine increased  $LAD$ ,  $LVID_s$ , aortic dimensions and decreased  $IVS_d$  and FS (Gehlen et al. 2004).

In the present study  $RVID_s$  was significantly increased after xylazine and acepromazine administration. An explanation for this is that there was an increase in pulmonary and aortic artery resistance as has been described for medetomidine (Saponaro et al. 2013). This increase in pulmonary and aortic resistance would in turn increase right ventricle afterload and therefore  $RVID_s$ . This reflects the study of Yamashita et al., who found that the effect of xylazine on peripheral increased vascular resistance (Yamashita et al. 2000).

Decreasing in  $LVID_d$  as a result of xylazine administration is a consequence of the vasoconstrictive effect of xylazine, which causes an increase in vascular resistance and subsequently a reduction in preload. Buhl and colleagues reported a decrease in  $IVS_s$  and FS% after detomidine and romifidine administration and explained that this decline is the result of a reduction in systolic left ventricular performance.  $IVS_d$  was increased in our study, which may be the result of decreased preload and more bulging of the septum into the ventricle. Indeed, changes in  $IVS_d$  have an inverse relationship to  $LVID_d$ , as a reduction in  $LVID_d$  can result in an increase in  $IVS_d$  as a result of decreased pressure on the septum and vice versa. In our study, fractional shortening (FS%) was unchanged between groups demonstrating no change in cardiac performance or contractility after xylazine or acepromazine administration.

Two potential further weaknesses of this study are that the small sample size is sufficient for an experimental study, but maybe not be large enough to reflect field conditions and further that it was not a blinded or randomized trial. We used a low dose of acepromazine and xylazine with minimal effects on echocardiographic measurements with the aim of inducing a light sedation to calm the horses and improve their restraint. We found that low dose acepromazine or xylazine do not alter spectral Doppler measurements. However, xylazine can alter ventricular and septal dimensions as measured in M-mode and that acepromazine could alter the RVID<sub>s</sub>. These effects could also be the result of slower onset of acepromazine effect compared to xylazine.

It is worth considering that physiological stress and struggling activity in the horse will themselves alter haemodynamics by increasing the heart rate and blood velocity as a result of sympathetic activation, which could itself change Doppler parameters during examination. The present study suggests that if a sedative is required for echocardiography in the horse, acepromazine in low doses could be an appropriate choice. These results could be particularly relevant for the evaluation of valvular disease in highly-strung horses.

### Conflict of interest

The authors declare no competing interests.

### Ethical animal research

The study protocol was approved by the University of Tehran Research Council.

### Sources of funding

Facilities and research animals were provided by the University of Tehran. Study materials were paid for by the first author of the study.

### References

- Bloor B. C., Ward D. S., Belleville J. P., Maze M. (2002) Effects of intravenous dexmedetomidine in humans: II. Hemodynamic changes. *Anesthesiology* 77, 1134–1142; DOI 10.1097/0000542-199212000-00014
- Buhl R., Ersboll A. K., Larsen N. H., Eriksen L., Koch J. (2007) The effects of detomidine, romifidine or Acepromazine on echocardiographic measurements and cardiac function in normal horses. *Vet. Anaesth. Analg.* 34, 1–8; DOI 10.1111/j.1467-2995.2005.00269.x
- Cruz F. S. F., Carregaro A. B., Machado M., Antonow R. R. (2011) Sedative and cardiopulmonary effects of buprenorphine and Xylazine in horses. *Can. J. Vet. Res.* 75, 35–41. PMID: 21461193
- Donaldson L. (2006) Management of sedation and anesthesia. In: *Doherty T., Valverde A.*, (ed) *Manual of Equine Anesthesia and Analgesia*. 2nd ed. London: Blackwell Publishing Ltd; 206–260.
- Fernández del Palacio M. J., Luis Fuentes V., Bonagura J. D., Schober K. E., Hatfield D. G., Laughlin M. H. (2003) Evaluation of Doppler ultrasonography for the measurement of blood flow in the femoral artery pigs. *Am. J. Vet. Res.* 64, 43–50; DOI 10.2460/ajvr.2003.64.43
- Gehlen H., Kroker K., Deegen E., Stadler P. (2004) Influence of detomidine on echocardiographic parameters and cardiac haemodynamics in horses with and without heart murmurs. *Schweizer Archiv für Tierheilkunde* 119–126 (In German); DOI 10.1024/0036-7281.146.3.119
- Hashem A., Keller H. (1993) Disposition, bioavailability and clinical efficacy of orally administered acepromazine in the horse. *J. Vet. Pharmacol. Therapeutics* 16, 359–368; DOI 10.1111/j.1365-2885.1993.tb00183.x
- Kalhor A. B. (2006) Sedative effects of acepromazine and xylazine in horses: a comparative study. *Pakistan J. Biol. Sciences* 9, 72–75; DOI 10.3923/pjbs.2006.72.75
- Linardi R. L., Canola J. C., Valadao C. A. A. (2008) Cardiovascular assessment in horses sedated with xylazine or amitraz. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 60, 329–334; DOI 10.1590/s0102-09352008000200008
- Marroum P. J., Aeschbacher G., Curry S. H. (1994) Pharmacokinetics and pharmacodynamics of acepromazine in horses. *Am. J. Vet. Res.* 55, 1428–1433; PMID:7998701
- McCashin F. B., Gabel A. A. (1975) Evaluation of xylazine as a sedative and preanesthetic agent in horses. *Am. J. Vet. Res.* 36, 1421–1429; PMID:1190582
- Menzies-Gow N. J. (2008) Effects of sedation with acepromazine on echocardiographic measurements in eight healthy thoroughbred horses. *Vet. Rec.* 163, 21–25; DOI 10.1136/vr.163.1.21
- Merlo M., Rota M. (1999) *Manual of Small Animal Anesthesia*. 2<sup>nd</sup> ed. Philadelphia: WB Saunders Co.
- Monteiro E. R., Teixeira Neto F. J., Castro V. B., Campagnol D. (2007) Effects of acepromazine on the cardiovascular actions of dopamine in anesthetized dogs. *Vet. Anaesth. Analg.* 5, 312–321; DOI 10.1111/j.1467-2995.2006.00328.x
- Muir W. W., Mason D. E. (1993) Effect of diazepam, acepromazine, detomidine, and xylazine on thiamylal anesthesia in horses. *J. Am. Vet. Med. Assoc.* 203, 1031–1037; PMID:8226249
- Nogueira R. B., Fernández del Palacio M. J., López J. T., Resende R. M. (2012) Effects of sedation with acepromazine maleate and buprenorphine hydrochloride on femoral artery blood flow in healthy dogs. *Res. Vet. Sci.* 93, 989–992; DOI 10.1016/j.rvsc.2011.10.004
- Patteson M. W., Gibbs C. C., Wotton P. R., Cripps P. J. (1995) Effects of sedation with detomidine hydrochloride on echocardiographic measurements of cardiac dimensions and indices of cardiac functions in horses. *Equine Vet. J.* 19, 33–37; DOI 10.1111/j.2042-3306.1995.tb04987.x
- Pipers, F. S. (1978) *Echocardiography in the horse*. PhD thesis, Ohio State University, Ohio, USA.
- Reef, V. B. (1991) *Advances in echocardiography*. *Vet. Clinics North America: Equine Practice* 7, 435–450; DOI 10.1016/s0749-0739(17)30508-4
- Saponaro V., Crovace A., De Marzo L., Centonze P., Staffieri F. (2013) Echocardiographic evaluation of the cardiovascular effects of medetomidine, acepromazine and their combination in healthy dogs. *Res. Vet. Sci.* 95, 687–692; DOI 10.1016/j.rvsc.2013.03.022
- Steffey E. P., Kelly A. B., Farver T. B., Woliner M. J. (1985) Cardiovascular and respiratory effects of acetylpromazine and xylazine on halothane anesthetized horses. *J. Vet. Pharmacol. Therapeut.* 8, 290–302; DOI 10.1111/j.1365-2885.1985.tb00959.x
- Tavanaeimanesh H., Mokhber Dezfouli M. R., Vajhi A., Rostam A., Akbarinejad V., Sadeghian Chaleshtori S., Corley K. T. (2015) The effect of 7.2% hypertonic saline solution on echocardiographic parameters of healthy horses. *Equine Vet. J.* 47, 741–744; DOI 10.1111/evj.12496
- Wagner A. E., Muir W. W., Hinchcliff K. W. (1991) Cardiovascular effects of xylazine and detomidine in horses. *Am. J. Vet. Res.* 52, 651–657; PMID:1854087

Yamashita K., Tsubakishita S., Futaoka S., Ueda I., Hamaguchi H., Seno T., Katoh S., Izumisawa Y., Kotani T., Muir W. W. (2000) Cardiovascular effects of medetomidine, detomidine and xylazine in horses. *J. Vet. Med. Sci.* 62, 1025–1032; DOI 10.1292/jvms.62.1025

Walker M. A. G. D., Geiser D. (1986) Effects of acepromazine on the hemodynamics of the equine metatarsal artery, as determined by two-dimensional real-time and pulsed Doppler ultrasonography. *Am. J. Vet. Res.* 47, 1075–1078; PMID: 3521404