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ORIGINAL ARTICLE

Study of Cardiac Parameters by Pulsed Wave Doppler Echocardiography in Normal Healthy Markhoz Goat

Foad Sadi[1*], Siamak Alizadeh[2]

[1] *Department of Clinical Sciences, Faculty of veterinary Medicine, Mahabad Branch, Islamic Azad University, Mahabad, Iran.*

[2] *Department of Clinical Sciences, Faculty of Veterinary Medicine, Urmia Branch, Islamic Azad University, Urmia, Iran.*

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Abstract

Objective- The aim of this study was to test the repeatability, the variability, and to establish the reference values of PW measurements in healthy Markhoz goats.

Design- Retrospective study.

Animals- 20 female Markhoz goats.

Procedure- Using a standardized PW Doppler echocardiographic protocol, 20healthy adult unsedated female Markhoz goats were investigated three times at one day intervals by the same observer. Mitral, tricuspid, aortic and pulmonary flows were measured from a right parasternal view, and mitral and aortic flows were also measured from a left parasternal view. The difference between left and right side measurements and the intraobserver inter-day repeatability were tested and then the reference values of PW Doppler echocardiographic parameters in healthy adult female Markhoz goats were established.

Results- As documented in other species, all caprine PW Doppler parameters demonstrated a poor inter-day repeatability and a moderate variability. Tricuspid and pulmonary flows were best evaluated on the right side whereas mitral and aortic flows were best obtained on the left side and reference values are reported for healthy adult Markhoz goats.

Conclusion and clinical relevance - PW Doppler echocardiography allows the measurement of intracardiac blood flow indices in goats. The reference values establishment will help interpreting these indices of cardiac function in clinical cardiac cases and developing animal models for human cardiology research.

* Correspondence to: Foad Sadi, Department of Clinical Sciences, Faculty of veterinary Medicine, Mahabad Branch, Islamic Azad University, Mahabad, Iran.
E-mail: foadsadi@yahoo.com

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1. Introduction

Cardiovascular system is one of the important systems in domestic animals and treatment of cardiac diseases have been carried out on different species domestic animals. Pulsed wave (PW) Doppler echocardiography has been developed first in humans.[1,2] and then in several domestic animals species including dogs,[3,4] cats,[5] horses,[6,7] cattle[8] and sheep.[9] This technique has become a routine for the diagnosis and evaluation of heart disease in veterinary medicine [10]. It allows detecting the returning signal during a time interval specified by a sample depth ignoring all other signals. Blood cells flow moving around the chosen specific location is analyzed and gives information about direction, velocity, character and timing of the blood flow which cannot be assess without Doppler imaging.[2,10] So it provides a non-invasive tool to evaluate intracardiac blood flow, to diagnose regurgitant flow through the cardiac valves and intracardiac shunts and to assess systolic and diastolic function of the heart.[10,11] Accurate interpretation of Doppler echocardiographic variables requires reference values following standardized measurement guidelines in the studied species to interpret indices of cardiac function.[10]

The shape and size goats heart vary according to its breed and body size and they are animals easy to handle with a body and heart size comparable to that of humans. This makes the goat an attractive candidate for the development of animal models for human cardiology research, especially chronic models relying on measurements in awake or exercising animals[12,13] Although Markhoz breed is one of the important breeds in world, there is no data on Pulsed Wave (PW) Doppler echocardiography.

2. Materials and Methods

This study carried out in 20 adult female Markhoz goats with aged 24 to 30 months (mean age: 26.7 ± 2.1 months) and weighing 40 to 60 kg (mean body weight: 50.1 ± 6.3 kg). The selected goats were healthy and the absence of abnormalities on clinical and paraclinical tests. Before imaging, the hair was shaved on both sides, from the 3th to the 5th right intercostal space just caudal to the triceps muscle mass, from 3 to 5 cm below the right olecranon to 5 to 10 cm above it. The shaved areas were then copiously rinsed with water and acoustic coupling was obtained using ultrasound gel. Echocardiography examination were performed with an EX8000 Medison ultrasound machine, using 2-4 MHz phased array transducer. Echocardiography was prepared from the 4th and 5th intercostal spaces in the longitudinal and transverse views and on the left and right chest. The left ventricle was evaluated by B-mode and M-mode systems. Left ventricular end-diastolic and end-systolic, left ventricular free wall at end systole and end diastole, inter ventricular septum at end systole and end diastole, right ventricular at end systole and end diastole, the aortic root, left atrial, the gap between, mitral valve to septal ventricular end-diastole, the stroke volume and fractional shortening measurements were taken, respectively (Figure 1).

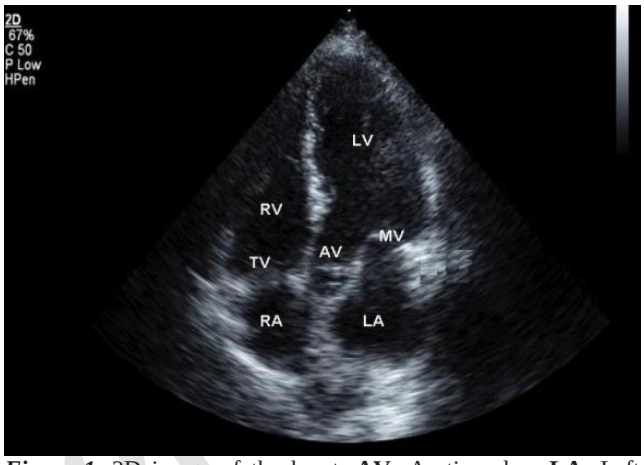

Figure 1. 2D image of the heart. **AV:** Aortic valve, **LA**: Left atrium, **LV:** Left ventricle, **MV:** Mitral Valve, **RA:** Right atrium, **RV:** Right ventricle, **TV:** Tricuspid valve.

In the 20 studied goats, the PW Doppler echocardiographic protocol was repeated 3 times at one-day intervals. By Doppler were obtained the mitral and tricuspid velocity spectrum. The peak velocity during the early ventricular filling called E_{peak} and during the atrial contraction called A_{peak} were measured (E_{max} and A_{max} respectively). This allowed the assessment of the mean velocity of the blood flow during the early ventricular filling (E_{mean}) and during the atrial contraction (A_{mean}). The ejection time (ET) of the E_{peak} and of the A peak were measured from the onset to the end of each peak. From E_{max} and A_{max}, the ratio E_{max}/A_{max} was calculated (Figure 2). By Doppler were obtained the aortic and pulmonary velocity spectrum .The peak velocity of the blood flow (V_{max}) was measured by placing the cursor at the maximal point of the blood flow profile. The area under the velocity wave form (VTI) was measured by manual tracing of the modal velocity envelope of the flow profile, thus allowing the measurement of the mean velocity of blood flow (V_{mean}). The ejection time (ET) was measured from the onset to the end of the spectral waveform, the time to peak (TTP) was measured from the onset of the Doppler waveform to the beginning of the maximum velocity plateau, the pre-election period (PEP) was measured from the onset of the QRS complex to the onset of the spectral waveform. From

the measured parameters, the ratio PEP/ET was calculated and the stroke volume (SV) and the cardiac output (CO) were obtained using the following standard formulae.

Then, mean ± standard deviation (SD) of measurements was calculated (for each of the parameters) and the analysis between indicators in all goats was conducted by ANOVA test**.**

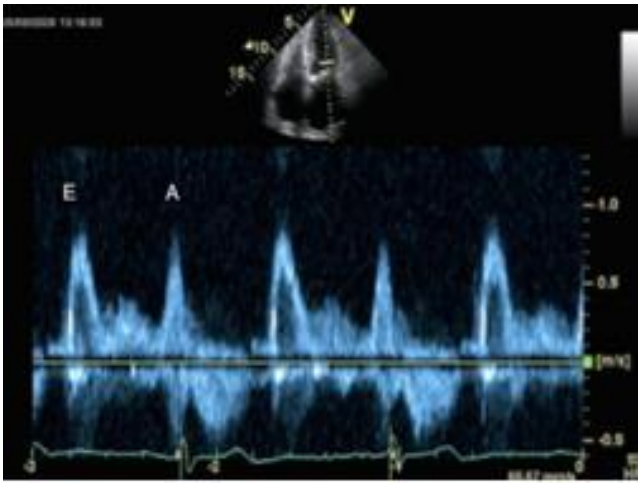

Figure 2. Pulsed wave Doppler of mitral inflow velocity.

3. Results

The mean HR during the echocardiographic examination was 91.55 ± 10.75 beats/minute and ranged from 70 to 120 beats/minute. The image quality and the Doppler spectra were good in all goats, except for the quality of the tricuspid flow and the right side aortic flow which were often poor. Moreover, obtaining a good quality 2D right parasternal view of the heart base at the level of the pulmonary valves before to shift in PW-mode appeared to be sometimes difficult. For this view, the transducer had to be advanced far forward under the forelimb, which required an assistant pulling the right forelimb forward and upward during the examination.

The least square mean value and the standard error to the mean of each blood flow measurements obtained on day 1, day 2 and day 3 and the multivariable ANOVA test were calculated to evaluate the repeatability of these measurements. Concerning the aortic flow, significant between days differences were observed for V_{max}, VTI, CO and CI. Almost all measurements of the pulmonary flow were significantly different between days except PEP and PEP/ET. Mitral and tricuspid flow velocities (E_{max}, E_{mean}, A_{max}, A_{mean}, E_{max}/A_{max}) and E_{peak} and A_{peak} mitral and tricuspid VTI were significantly different between days.

Comparisons of the PW Doppler echocardiographic measurements of the aortic and mitral flows obtained from the right and from the left side are shown in Tables 1 and 2 respectively. For the aortic flow, only PEP and PEP/ET were not significantly different whilst all other parameters were significantly different from the right and the left side. Most of the parameters, especially V_{max} and V_{mean}, were significantly higher when they were obtained from the left side than from the right side. For mitral flow, all parameters of A_{peak} but oasless than 120 beats per minute to obviate a stress effect. A color ET of E_{peak} were not significantly different from both sides. The mitral E_{max}, E_{mean} and VTI of E peak were higher when obtained from the left side than when obtained from the right side.

The results of the measurements of the aortic, mitral, pulmonary and tricuspid flows are shown in Tables 1, 2, 3and 4, respectively. Most of the parameters had low to moderate variability excepted for TTP of the aortic flow,

Table 1. Comparison of pulse wave Doppler echocardiographic parameters of the aortic flow obtained on the right and on the left side in 20 healthy adult Markhoz goats.

Parameters	**LS Mean ± SE Right side**	**LS Mean ± SE Left side**	**Mean ± SD**
V_{max} (m/s)	0.95 ± 0.004	1.07 ± 0.003	**1.02 ± 0.11**
V_{mean} (m/s)	0.70 ± 0.002	0.74 ± 0.001	**0.70 ± 0.07**
ET (ms)	255.78 ± 1.41	269.85 ± 1.30	**264.33 ± 22.87**
VTI (cm)	19.48 ± 0.14	20.75 ± 0.12	**20.11 ± 2.67**
PEP (ms)	48.70 ± 0.43	50.19 ± 0.43	**49.78 ± 6.25**
TTP (ms)	101.77 ± 1.44	81.98 ± 1.36	**92.18 ± 19.40**
SV (ml)	61.17 ± 0.15	66.11 ± 0.05	**64.11 ± 8.10**
CO (l/min)	5.40 ± 0.24	5.76 ± 0.14	**5.68 ± 0.91**
PEP/ET	0.18 ± 0.002	0.18 ± 0.002	**0.18 ± 0.02**

CO: Cardiac output, **ET:** Ejection time of the aortic flow, **LS Mean**: Least Square Mean, **PEP**: Pre ejection period of the aortic flow, **SD**: Standard deviation, **SE:** Standard error, **SI:** Stroke index, **SV:** Stroke volume, **TPP:** Time to peak of the aortic flow, **V_{max}:** Peak velocity of the aortic flow, **V_{mean}:** Mean velocity of the aortic flow, **VTI:** Velocity time integral of the aortic**.**

Table 2. Comparison of pulse wave Doppler echocardiographic parameters of the mitral flow obtained on the right and on the left side in 20 healthy adult Markhoz goats.

E_{peak} Parameters	**LS Mean ± SE Right side**	**LS Mean ± SE Left side**	**Mean ± SD**
V_{max} (m/s)	0.52 ± 0.002	0.50 ± 0.003	**0.50 ± 0.02**
V_{mean} (m/s)	0.37 ± 0.002	0.39 ± 0.002	**0.38 ± 0.02**
VTI (cm)	8.50 ± 0.9	9.12 ± 0.9	**8.78 ± 0.89**
ET (ms)	222.17 ± 2.32	224.24 ± 2.31	**224.02 ± 21.10**
A_{peak} Parameters			
V_{max} (m/s)	0.48 ± 0.003	0.50 ± 0.004	**0.50 ± 0.04**
V_{mean} (m/s)	0.30 ± 0.003	0.30 ± 0.002	**0.30 ± 0.03**
VTI (cm)	3.87 ± 0.05	3.86± 0.05	**3.87 ± 0.54**
ET (ms)	110.34 ± 1.34	110.04 ± 1.34	**110.15 ± 14.35**
E_{max}/A_{max}	1.02 ± 0.01	1.10 ± 0.01	**1.11 ± 0.11**

A_{max}: peak velocity of the mitral flow during the atrial contraction, **A_{mean}:** mean velocity of the mitral flow during the atrial contraction, **E_{max}:** peak velocity of the mitral flow during the early ventricular filling**, E_{mean}:** mean velocity of the mitral flow during the early ventricular filling, **ET:** Ejection time, **LS Mean:** Least Square Mean, **SD:** Standard deviation, **SE:** Standard error, **VTI:** Velocity time integral.

acc slope of the aortic and pulmonary flows, and Dec time and Dec slope of the mitral and tricuspid E_{peaks} that showed a high variability. For all flows, within-day variability was clearly lower than between-day variability.

4. Discussion

In this study, the cardiac window often appeared to be narrow as previously reported in goats.[14,18] But when a heart base view of sufficient quality was obtained, the recorded pulmonary outflow velocity spectrum was generally speaking of good quality, suggesting a good alignment of the transducer with the pulmonary blood flow, as previously reported in horses.[10,17] On the contrary, the tilted 2D right parasternal long axis four chambers view was in most of the goats of very good quality, but the obtained flows at the level of the mitral and tricuspid valves were generally underwhelming, as described in horses.[7,24] Moreover, a true left parasternal apical view as used in dogs to measure aortic, mitral and sometimes tricuspid flows[10,18] was not possible to obtain in goats because of the presence of gas in the reticulo-rumen.[15,24]

The repeatability of the PW Doppler measurements in our study was poor such as other species animals.[10,18,19] Moreover, slopes of intra-cardiac blood flows are generally the less repeatable Doppler parameters.[21] Aortic and pulmonary flow measurements were previously often reported as repeatable measurements[15,21,22] except in one study on horses in which they were poorly repeatable.[20] Recordings of the pulmonary flow from a left parasternal cranial long axis right ventricular outflow view or from a left parasternal short axis view with aorta and pulmonary artery, as used in small domestic animals[10,18,22] has not been investigated in this study but appeared to be difficult to obtain in goats. The variability of the PW Doppler measurements in our study was quite high, but was in accordance with previous studies in dogs, cats and horses.[7,18,19,22] The main source of variability could be the poor alignment of the transducer with the direction of the blood flow.[10,19,20]

Table 3. Doppler echocardiographic measurements of the pulmonary flow in 20 healthy adult Markhoz goats.

Parameters	**Mean ± SD**
V_{max} (m/s)	0.95 ± 0.10
V_{mean} (m/s)	0.70 ± 0.9
ET (ms)	265.5 ± 22.4
VTI (cm)	19.70 ± 2.45
PEP (ms)	50.8 ± 7.8
TTP (ms)	111.6 ± 26.2
SV (ml)	77.15 ± 11.06
CO (l/min)	7.04 ± 1.40
PEP/ET	0.17 ± 0.03

CO: Cardiac output, **ET:** Ejection time of the pulmonary flow, **PEP:** Pre-ejection period of the pulmonary flow, **SD:** Standard deviation, **SI:** Stroke index, **SV:** Stroke volume, **TPP:** Time to peak of the pulmonary flow, **V_{max}:** Peak velocity of the pulmonary flow, **V_{mean}:** Mean velocity of the pulmonary flow, **VTI:** Velocity time integral of the pulmonary flow

Table 4. Doppler echocardiographic measurements of the tricuspid flow in 20 healthy adult Markhoz goats.

E_{peak} Parameters	**Mean ± SD**
E_{max} (m/s)	0.60 ± 0.14
E_{mean} (m/s)	0.48 ± 0.11
VTI (cm)	10.15 ± 3.05
ET (ms)	219.5 ± 53.5
A_{peak} Parameters	
A_{max} (m/s)	0.50 ± 0.11
A_{mean} (m/s)	0.40 ± 0.10
VTI (cm)	4.81 ± 1.20
ET (ms)	116.8 ± 23.7
E/A	1.05 ± 0.15

A_{max}: peak velocity of the tricuspid flow during the atrial contraction, **A_{mean}:** mean velocity of the tricuspid flow during the atrial contraction, **E_{max}:** peak velocity of the tricuspid flow during the early ventricular filling, **E_{mean}:** mean velocity of the tricuspid flow during the early ventricular filling, **ET:** Ejection time, **SD:** Standard deviation, **VTI:** Velocity time integral

In the studied goats, the mean values of the mitral velocity spectrum obtained from a tilted left parasternal long axis four chamber view were significantly different from those obtained from a tilted right parasternal long axis four chamber view, except for all parameters of the A_{peak} and for ET of the E_{peak}. Moreover, E_{max} and E_{mean} were lower when the measurements were performed from the right side than from the left side, which suggests that in goats, the mitral flow should be interrogated from the left rather than from the right hemi thorax. This result is in agreement with previous studies on other domestic animals since, to record the mitral flow, a tilted left parasternal long axis four chambers view is recommended in horses,[7] and a left parasternal apical view is recommended in sheep[9] and in dogs [4].The E_{max}/A_{max} ratio is a parameter often used to evaluate the left ventricular diastolic function in man.[2,23,24] Independently of the side from which it is measured, the E_{max}/Amax ratio of the mitral flow was rather similar to the tricuspid flow E_{max}/A_{max}. On the contrary to what was reported in sheep [9], in most goats of this study, E_{max} was higher than Amax for both mitral and tricuspid flows, and only one goat had $E_{max}/A_{max} < 1$ for mitral flow obtained from the right side. The same was observed in 8 of 40 investigated healthy horses[7] and was explained as a more accurate alignment of the transducer with the A wave of atrial contraction than with the E wave of the early rapid ventricular filling. Measurements of E_{peak} and A_{peak} seemed also to depend on HR. In goats as in sheep, it has been reported than the A_{peak} is closer to the E_{peak} with increasing HR, and when HR was more than 120 beats/min, fusion of the two peak can occur.[9] Measurements of aortic velocity spectrum are very interesting because they allow assessing left ventricular SV and CO.[2] In this study, except for PEP and PEP/ET, the aortic velocity spectrum measurements obtained from the tilted left parasternal long axis five chambers view were significantly higher than those obtained from a tilted right parasternal long axis five chambers view. This is in agreement with the results obtained in horses,[7] and could be explained by a better alignment between the transducer and the blood flow from the left hemi thorax.

By performing this study, the parameters of healthy heart echocardiography were obtained in the Markhoz goats that can be used as a reference values in goats. Meanwhile, heart disease in goats is diagnosed by comparing these reference values with the obtained from the echocardiography.

Conflict of interests

None declared.

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چکیده

بررسی پارامترهای قلبی به وسیله اکوکاردیوگرافی داپلر امواج ضربه‌ای در بزهای به ظاهر سالم نژاد مرخز

فواد سعدی[۱]، سیامک علیزاده[۲]

[۱] گروه علوم درمانگاهی، دانشکده دامپزشکی، واحد مهاباد، دانشگاه آزاد اسلامی، مهاباد، ایران.

[۲] گروه علوم درمانگاهی، دانشکده دامپزشکی، واحد ارومیه، دانشگاه آزاد اسلامی، ارومیه، ایران.

هدف- ارزیابی جریان خون داخل قلب و پارامترهای قلب نیازمند یک منبع مرجع می‌باشد.هدف از این بررسی بدست آوردن مقادیری مرجع از اکوکاردیوگرافی داپلر امواج ضربه‌ای در بزهای سالم نژاد بز مرخز می‌باشد.

طرح مطالعه- تحقیق مجدد.

حیوانات- ۲۰ راس بز مرخز.

روش کار- در این بررسی از ۲۰ راس بز سالم اکوکادیوگرافی داپلر امواج ضربه‌ای به صورت سه بار در روز و بدون استفاده از آرامبخشی بعمل آمد و جریان خون در دریچه میترال ودریچه سه لختی و عروق آئورت و ریوی در نمای راست اطراف جناغی اندازه‌گیری شد.در ادامه به همین شکل جریان خون در دریچه میترال ودریچه سه لختی و عروق آئورت و ریوی در نمای چپ اطراف جناغی اندازه‌گیری شد.میان اندازه‌گیری‌های چپ و راست تفاوت‌های وجود داشت که با تکرار آنها مقادیری مرجع بدست آمد.

نتایج- نتایج حاصل از انجام اکوکاردیوگرافی داپلر امواج ضربه‌ای در بزهای سالم نشان داد که جریان خون در عروق آئورت و ریوی در نمای راست جناغی و جریان خون در دریچه میترال و دریچه سه لختی در نمای چپ جناغی در بهترین شکل ارزیابی و بررسی می‌شوند.مقادیربه دست آمده به عنوان مرجع برای بز مرخز سالم بالغ گزارش گردید.

نتیجه‌گیری و کاربرد بالینی- اکوکاردیوگرافی داپلر امواج ضربه‌ای اندازه‌گیری شاخص‌های جریان خون را در داخل قلب در بز میسر می‌سازد.مقادیر به دست آمده به عنوان مرجع می‌تواند در تفسیر شاخص‌های عمالکردی قلب در بزهای بیماری که علایم بیماری قلبی را به صورت بالینی نشان می‌دهند موثر باشند و همچنین در تحقیقات قلب در موارد انسانی تاثیرگذار باشند.

واژه‌های کلیدی- اکوکاردیوگرافی، بز مرخز، مقادیر مرجع.