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Echocardiographic evaluation of crab-eating foxes (*Cerdocyon thous*) in captivity[1]

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ABSTRACT.- Arruda A.F.D.P., Nascimento L.R., Tsuruta S.A., Milken V.M.F., Santos A.L.Q., Silva M.B., Dias L.G. & Mantovani M.M. 2025. **Echocardiographic evaluation of crab-eating foxes (*Cerdocyon thous*) in captivity**. *Pesquisa Veterinária Brasileira 45:e07407, 2025.* Faculdade de Medicina Veterinária, Universidade Federal de Uberlândia, Av. Pará 1720, Umuarama, Uberlândia, MG 38400-902, Brazil. E-mail: matheus.mantovani@ufu.br

The cardiac evaluation of wild animals is still a wide and largely unknown field for several species. Thus, the objectives of this study were to evaluate cardiac function through echocardiography and obtain echocardiographic values for crab-eating foxes under pharmacological restraint. This study was done with eight males and two females under pharmacological containment of intramuscular acepromazine with meperidine followed by intravenous propofol. In the two-dimensional mode, the diameter of the aorta and left atrium and the LA/Ao ratio were obtained. In M-mode, the internal diameter of the left ventricle was measured during diastole and systole, and the shortening fraction was calculated. In the transmitral flow using the pulsed Doppler mode, we analyzed the E-wave velocity peak, A-wave velocity peak, and E/A ratio. The analysis of the isovolumetric relaxation time was performed in the apical view of five chambers using an intermediate flow between mitral influx and aortic flow, and the E-wave deceleration time was calculated. The measurements of position and dispersion of all variables were calculated, and the respective confidence intervals were set at 95%. The Doppler echocardiographic values are closer to domestic dogs, the left ventricle internal diameter in diastole was lower, and the ejection fraction was closer to that of maned wolf (*Chrysocyon brachyurus*). Cardiology parameters found in this study can be used as specific values for this species in the evaluation of cardiac function, as well as in other additional studies in wild animal cardiology.

INDEX TERMS: *Cerdocyon thous,* cardiology, echocardiography evaluation, wild animals.

RESUMO.- [**Avaliação ecocardiográfica em cachorro do mato (*Cerdocyon thous*) em cativeiro.**] A avaliação cardíaca de animais selvagens constitui um campo de pesquisa ainda pouco explorado para diversas espécies. Nesse contexto, este estudo teve como objetivos a avaliação da função cardíaca por meio da ecocardiografia e a obtenção de valores ecocardiográficos para cachorros do mato submetidos a contenção farmacológica. O estudo foi conduzido em oito machos e duas fêmeas, os quais foram submetidos à contenção farmacológica com acepromazina intramuscular e meperidina, seguida de propofol intravenoso. No modo bidimensional, as seguintes medidas foram obtidas: o diâmetro da aorta, do átrio esquerdo e a relação AE/Ao. No modo M, foram medidas a dimensão interna do ventrículo esquerdo durante a diástole e a sístole, e a fração de encurtamento foi calculada. Utilizando o modo Doppler pulsado no fluxo transmitral, foram analisados o pico de velocidade da onda E, o pico de velocidade da onda A e a relação E/A. A análise do tempo de relaxamento isovolumétrico foi realizada no corte apical de cinco câmaras, por meio de um fluxo intermediário entre o influxo mitral e o fluxo aórtico, e o tempo de desaceleração da onda E foi calculado. Todas as variáveis tiveram suas medidas de posição e dispersão calculadas, junto com intervalos de confiança a 95%. Os valores ecocardiográficos obtidos com a técnica Doppler se aproximaram mais dos observados em cães domésticos, com o diâmetro interno do ventrículo esquerdo na diástole apresentando valores menores. Além disso, a

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fração de ejeção se assemelhou mais à observada em lobos-guarás (*Chrysocyon brachyurus*). Os parâmetros cardiológicos identificados neste estudo podem ser considerados como valores específicos para essa espécie na avaliação da função cardíaca, e podem ser utilizados como referência em estudos adicionais sobre a cardiologia de animais selvagens.

TERMOS DE INDEXAÇÃO: *Cerdocyon thous,* cardiologia, avaliação ecocardiográfica, animais selvagens.

INTRODUCTION

The crab-eating fox (*Cerdocyon thous* Linnaeus, 1758) is a small wild canid (Bueno & Motta-Junior 2004). This species can be found in several countries in South America, such as Uruguai, north of Argentina, Brazil, Ecuador, Colombia, French Guiana, Guiana, Suriname, Panama, Paraguay, Bolivian plane and Venezuela (Ramírez-Chaves & Pérez 2015). Currently, the lack of reference values in wild animals makes interpreting these animals' exams difficult. The imaging diagnosis is a great advance in the cardiological area due to the possibility of cardiological evaluation through noninvasive methods (Guglielmini et al. 2006, Estrada et al. 2009).

Echocardiography is a noninvasive method for anatomical and functional evaluation of the heart and an important diagnostic tool (Boon 1998). This allows for a spatial evaluation of the structures, cardiac movement, and blood flow characteristics. The precise and noninvasive diagnosis of cardiac alterations and the monitoring and determination of prognosis is possible through an echocardiographic exam. It has become one of the most important diagnosis methods in veterinary cardiology (Boon 1998, Kienle & Thomas 2004). Morrison et al. (1992) stated that among the main limitations of echocardiography is the variation between different breeds of dogs in the normality parameters. Breed is a factor that significantly affects the measurements of echocardiographic parameters in dogs. They also concluded that weight variations and body size affect the data in animals of the same breed.

The determination of echocardiographic values may aid in the treatment, management, and preservation of captive populations since these animals are constantly under anesthesia for handling and treatments. This knowledge is relevant for veterinary practice, granting subsidies for the clinical and surgical assistance and rehabilitation of these animals and generating a positive impact on the conservation of this species.

The objectives of this study were to evaluate the cardiac function through echocardiography and obtain echocardiographic values for crab-eating foxes that are clinically healthy, raised in captivity and under pharmacological containment.

MATERIALS AND METHODS

Ethical approval. This study was approved for the use of wild animals by the Ethics Committee on Animal Use (CEUA/UFU 126/14) and by "Instituto Chico Mendes da Conservação da Biodiversidade" (ICMBIO) through the "Sistema de Autorização e Informação em Biodiversidade" (SISBIO) under number 47114.

Ten young *Cerdocyon thous* adults were used, eight male and two female, clinically healthy, housed at "Laboratório de Ensino e Pesquisa em Animais Silvestres" (LAPAS) of "Universidade Federal de Uberlândia" (UFU), with an average corporal mass of 6.25 kg (5.2-7.4 kg).

All images were obtained at the Imaging Diagnosis Sector in the Veterinary Hospital of UFU using the echocardiographic appliance Esaote® model MyLab 30 VET Gold with electronic sectorial scanning transducer (7.5-4.5 MHz or 5.0-1.0 MHz) and with electrocardiographic monitoring in the monitor. The images were digitally stored for offline analysis, with three consecutive measurements of each variable by the same examiner.

The animals were sedated with 3 mg/kg de meperidine and 0.05 mg/kg acepromazine intramuscularly, induced and maintained with 3-5 mg/kg intravenous propofol according to the induction protocol of Conti-Patara et al. (2009). The animals were then trichotomized, due to the high density of the fur for the echocardiographic exam in two-dimensional mode, M-mode, pulsed Doppler (PW), continuous Doppler (CW), mapping of color flow (CFM) according to recommendations of Echocardiography Committee of the Specialty of Cardiology – American College of Veterinary Internal Medicine (Thomas et al. 1993) and the American Society of Echocardiography, with modifications suggested by Chetboul (2002) and Boon (2011).

In the two-dimensional mode, the dimension of the aorta (Ao) and the left atrium (LA) were measured in the transversal parasternal right view at the cardiac base level, obtaining the LA/Ao ratio (Hansson et al. 2002). In M-mode, we obtained the transversal cut of the left ventricle in the plane of the tendinous cords. We measured the thickness of the interventricular sept in diastole (IVSd), the internal diameter of the left ventricle in diastole (LVDd) and in systole (LVDs) and the thickness of the wall free from the left ventricle in diastoles (LVWd) (Fig.1-6). The calculation of the fraction of shortening was done with formula $FS = [(LVDd-LVDs)/LVDd] \times 100$ (Lombard 1984). The estimation was done for diastole (Vd), systole (VS) and ejection (LV) volume of the left ventricle, in ml, with the modified formula by Teicholz, $V = (7 \times LVDd^3)/(2.4 + LVDs)$, and the ejection fraction of the left ventricle (FE%), calculated by formula $FE\% = (Vd-Vs)/Vd \times 100$.

In pulsed Doppler mode, according to the described by Bonagura et al. (1998) and Pereira et al. (2009) in an apical four-chamber view, in the transmittal flow, we analyzed the peak velocity for E-wave, the deceleration of E-wave (DTE), the peak velocity of A-wave and the relation between E/A. The peak velocities of the aorta and pulmonary arteries were also registered. The analysis of the isovolumetric relaxation time (IVRT) was done in the apical five chambers cut through an intermediate flow between the mitral and aortic flow.

For statistical analysis of all data, SPSS 20.0 software was used. Position and dispersion measurements were calculated in all studied variables, and the retrospective confidence intervals were fixed at 95%.

RESULTS

The average, minimum and maximum values, the standard deviation and the variation coefficient in all echocardiographic data are summarized in Table 1. None of the animals presented any issues during chemical containment, allowing for the performance of the exams. Valvular insufficiency was not observed, nor was the turbulent flow in any of the evaluated animals in the mapping of the flow.

DISCUSSION

The echocardiographic values found for these 10 *Cerdocyon thous* are close to domestic dogs. However, the internal diameter of the left ventricle in diastoles was inferior (Bonagura et al. 1998, Boon 2011, Reis et al. 2017), and the ejection fraction was closer to maned wolf (*Chrysocyon brachyurus*) (Estrada et al. 2009).

The anesthesia of wild animals is considered risky due to the lack of reference standards for the species (Farias et al. 2018). All animals in this study were raised in captivity and used for handling routine exams, which made possible the induction of anesthesia similar to Conti-Patara et al. (2009) in their study on the effect of anesthesia in electrocardiography in old dogs. This protocol proved safe and allowed for the exams, as concluded by Reis et al. (2017), who also used

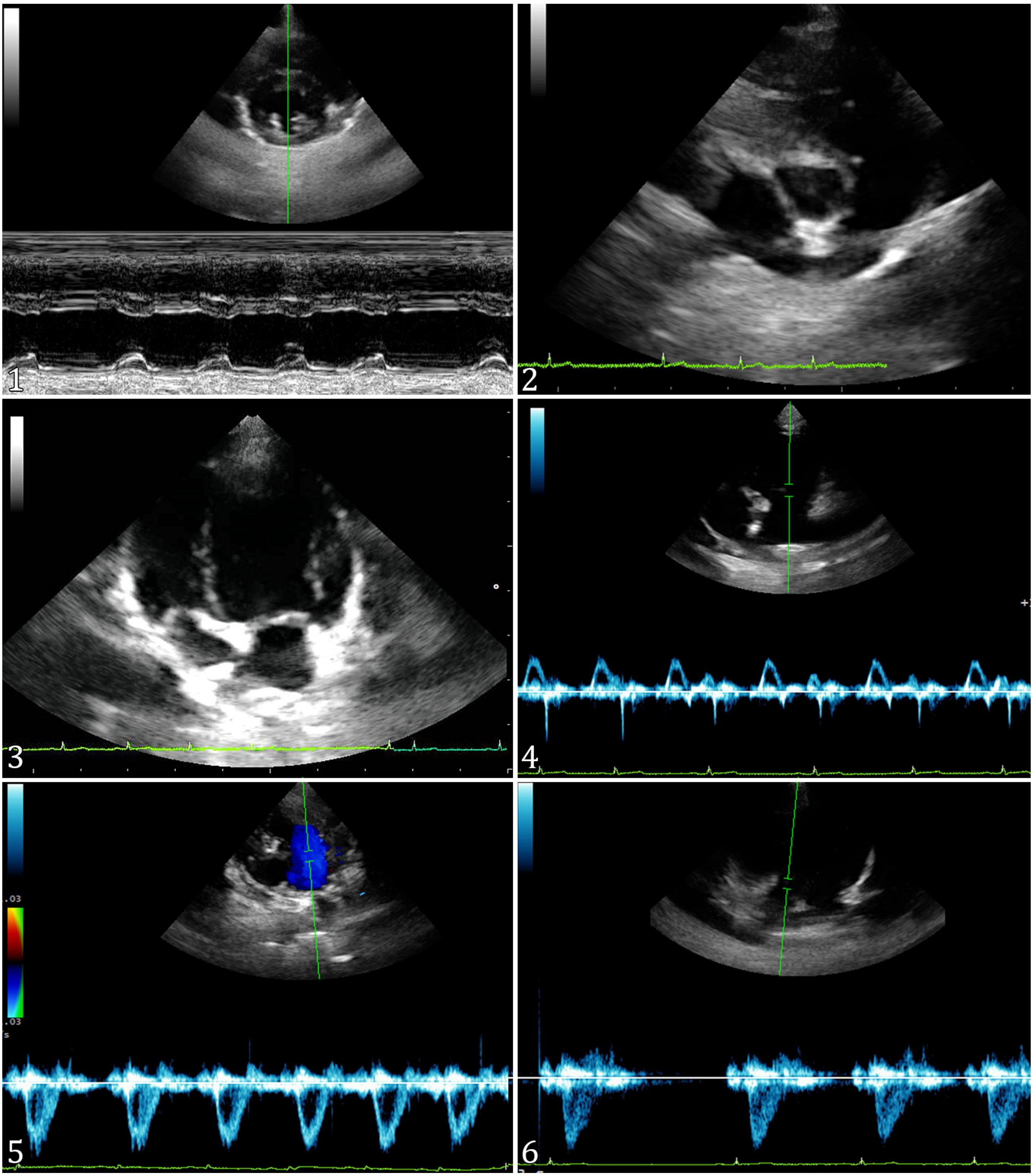

Fig.1-6. Determination of thickness of the interventricular septum in diastole (IVSd), the internal diameter of the left ventricle in diastole (LVDd) and systole (LVDs), and the thickness of the free wall of the left ventricle in diastole (LVWd), through unidimensional echocardiography (M-mode) in the transversal view of the left ventricle in the plane of the tendinous cords in *Cerdocyon thous*.

acepromazine and meperidine in the pharmacological containment of Rottweiler dogs.

All evaluated animals presented a good acoustic window and good quality echography images for analysis, similar to the described by Prada et al. (2012) in domestic dogs. Most animals presented tachypnea before the administration of anesthesia, later recovering the breathing pattern and decreasing the artifacts during the exam. Animal agitation and altered breathing patterns may interfere with echocardiographic measurements (Boon 1998).

The determination of the dimensions of the aorta and the left atrium is important. Their relation (LA/Ao) allows the detection of an increase in the left atrium in the initial stage of chronic degeneration of the mitral valve, which can go unnoticed by other complementary methods (Bonagura & Schober 2009, Prada et al. 2012). According to Olsen et al. (2010), in the two-dimensional mode, the ratio LA/Ao above 1.5 means an atrial increase in all the domestic dog breeds, and this limit can be inferior in some races, the average of this study being inside the normal standard. However, Guglielmini et al. (2006) found a value of 1.54 ± 0.10 for this ratio in wolves (*Canis lupus*), and Estrada et al. (2009) found the value of 1.39 ± 0.21 in maned wolf (*C. brachyurus*), values greater than this study. This demonstrates that, in wild canids, variations may occur similar to those in domestic dogs.

The shortening fraction FS in a unidimensional index allows the quantification of the systole function of the left ventricle (Boon 2011, Chetboul & Tissier 2012). The shortening fraction varies from 30 to 50% in domestic non-sedated dogs. However, there are significant differences between breeds (Boon 2011). In the present study, we found an average value in the reference bracket for domestic dogs. These findings corroborate with the data by Estrada et al. (2009), except for four animals which presented values below 30%. However, Guglielmini et al. (2006), reported an average of 11 ± 4%, 18% being the greatest value found in all wolves. Considering the dose-dependent effect, these authors attributed such values to sedation with receptor agonists α2-adrenergic. Reis et al. (2017), using the same drugs as this study in Rottweiler breed dogs, reported results similar to those found for FS. However, they are expected to have a lower value due to the adverse inotropic effect of meperidine (Tranquilli et al. 2013).

The ejection fraction (FE) is one of the systolic indexes most used in the echocardiographic practice. It reflects the fraction of the systole volume in relation to the final diastole volume. However, its broad variation bracket limits its applicability (Crippa et al. 1992, Bonagura & Schober 2009). This study found a value of 65.6 ± 8.29%, very close to the 62.91 ± 13.50% reported by Estrada et al. (2009) in maned wolf and by Reis et al. (2017) for Rottweiler dogs with and without the same sedatives as this study. The diameter of the left ventricle in systole (LVDs) is within the reference value for domestic dogs according to weight (1.25-2.22), however, in diastoles (LVDd) the value was below the reference (2.15-3.13) (Boon 2011). These values are directly proportional to the weight and breed of dogs (Morrison et al. 1992) and possibly have the same variations between species of wild canids. The aorta root (Ao) diameter, thickness of the interventricular septum and thickness of the parietal wall of the left ventricle also vary according to body weight. The data found in this

Table 1. Echocardiographic two-dimensional, M-mode and Doppler parameters measured in 10 crab-eating foxes (*Cerdocyon thous*) raised in captivity under pharmacological containment

Variables	Average±SD	Median ($P_{25\%} – P_{75\%}$)	Minimum and maximum	CI 95%
IVSd (cm)	0.51±0.09	0.52 (0.42 – 0.59)	0.37 – 0.66	0.4 – 0.5
LVDd (cm)	1.78±0.84	2.03 (1.48 – 2.28)	0.19 – 2.66	1.17 – 2.38
LVDs (cm)	1.33±0.46	1.44 (1.31 – 1.51)	0.11 – 1.87	1.0 – 1.66
LVWd (cm)	0.72±0.15	0.48 (0.47 – 0.52)	0.55 – 0.95	0.61 – 0.83
LVEDV-I (mL/kg)	2.20±0.13	2.22 (1.23 – 3.10)	1.10 – 3.31	1.25 – 3.20
LVESV-I (mL/kg)	0.95±0,12	0.9 (0.32 – 1.51)	0.8 – 1.6	0.34 – 1.50
EF Simpson (%)	64.6±4.29	63 (58.9 – 74.8)	53 – 79	40 – 71.9
EF (%)	65.6±8.29	65 (57.8 – 73.8)	55 – 77	59.7 – 71.5
FS (%)	34.3±6.18	33.5 (28.8 – 39.8)	27 – 44	29.9 – 38.7
LA (cm)	1.43±0.25	1.38 (1.23 – 1.72)	1.04 – 1.79	125 – 1.60
Ao (cm)	1.14±0.07	1.13 (1.10 – 1.18)	1.05 – 1.30	1.09 – 1.19
LA/Ao	1.24±0.22	1.23 (1.08 – 1.41)	0.88 – 1.55	1.09 – 1.40
E (m/s)	0.69±0.06	0.68 (0.63 – 0.75)	0.6 – 0.8	0.64 – 0.74
A (m/s)	0.46±0.10	0.45 (0.38 – 0.54)	0.34 – 0.68	0.39 – 0.54
E/A	1.53±0.26	1.53 (1.28 – 1.80)	1.17 – 1.92	1.33 – 1.72
DTE (ms)	97.6±22.4	105 (78 – 112)	62 – 134	81.6 – 114
IVRT(ms)	48±3.8	48 (47 – 52)	41 – 52	46 – 51
Aortic Fw. (m/s)	0.89±0.11	0.85 (0.80 – 0.96)	0.79 – 1.14	0.81 – 0.97
Pulmonary Fw. (m/s)	0.93±0.11	0.93 (0.84 – 0.98)	0.8 – 1.10	0.85 – 1.01

SD = standard deviation, CI = confidence interval, IVSd = thickness of the intraventricular septum in diastole, LVDd and LVDs = internal diameter of the left ventricle in diastole and systole, respectively, LVWd = thickness of the parietal wall of the left ventricle in diastole, LVEDV-I = left ventricular end-diastolic volume indexed to body weight (kg), LVESV-I = left ventricular end-systolic volume indexed to body weight (kg), EF = ejection fraction, FS = shortening fraction, LA = dimension of the left atrium, Ao = dimension of the aortic root, LA/Ao = ratio of the left atrial and aortic root dimensions, E = velocity peak in the E-wave and transmitral flow, A = velocity peak of A-wave in the transmitral flow, E/A = ratio between E- and A-wave, DTE = deceleration time of E-wave, IVRT = isovolumetric relaxation time.

study is similar to the reported by Morrison et al. (1992) and Yamato et al. (2006), who studied dogs of the poodle breed with weights closer to the *C. thous*. These variables are part of the indexes of left ventricular function and are indicators of complacency in the left ventricle (Muzzi et al. 2000).

The diastoles index functions analyzed by pulsed Doppler in this paper were the E-wave (quick ventricular filling) and A-wave (atrial contraction) of the transmitral flow, the E/A relation, the deceleration time of the E-wave (DTE) and the time of isovolumetric relaxation (IVRT). The flow of the mitral valve was positive and laminar during diastoles, divided into two phases, E- and A-wave. The values found for E- and A-wave were similar to those reported by Muzzi et al. (2006) in non-sedated German Shepherd dogs. However, Reis et al. (2017) stated that the sedation protocol, using the same drugs as this study, caused a shortening in the A-wave and attributed this to a probable hypotension caused by acepromazine. However, in this study, there was no significant shortening of the A-wave. Guglielmini et al. (2006), in their study with wolves, considered their values in diastolic function compared to non-sedated domestic dogs, however, the values between the E- and A-wave were close, being 56.2 ± 10.6 and 54.3 ± 12.8 cm/s, respectively. According to Boon (1998), the relation E/A is normal between 1.0-2.0, as found in this study, and gives important information regarding the diastole function of the left ventricle. The alterations in the relaxation or ventricular complacency lead to the inversion of this relationship.

The isovolumetric relaxation time (IVRT) in healthy dogs varies from 38 to 54 milliseconds, and all animals in this study were in this bracket. This variable is altered by the reduced relaxation of the left ventricle or the increase in pressure in the left atrium, factors that will prologue or reduce IVRT, respectively (Bonagura & Schober 2009, Boon 2011). The deceleration time for the E-wave (DTE) in this study was 97.6 ± 22.4, an intermediate value between the averages found in different studies with domestic dogs (Muzzi et al. 2006, Cavalcanti et al. 2007, Silva et al. 2008, Pereira et al. 2009). The velocities of aortic and pulmonary flow were similar to those reported for dogs (Muzzi et al. 2006, Bavegems et al. 2007, Reis et al. 2017), with the velocity of the pulmonary flow superior to the observed in the aorta. Guglielmini et al. (2006) found slower flows that were attributed to the negative effect of anesthesia on the cardiovascular hemodynamics of wolves. However, the suboptimal alignment of the cursor cannot be completely excluded.

CONCLUSION

The present study made possible the generation of echocardiographic parameters for the *Cerdocyon thous* under pharmacological restraint and thus will contribute to the cardiological evaluation of these animals. It was important to realize the differences between the values obtained in relation to the domestic dog, confirming the need for studies in several species.

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Credit author statement.- André Luis Q. Santos and Matheus M. Mantovani designed the study, obtained the funding for the study and revised the manuscript. Ana Flávia D.P. Arruda, Liliane R. Nascimento, Suzana A. Tsuruta, Vanessa M.F. Milken, Maressa B. Silva, Luiza G. Dias and MMM conducted the experiments, collected and analysed all of the data, and helped to write the manuscript. MMM, MBS, LGD and AFDPA analysed the data and helped to write, edit and review the manuscript. All authors read and approved the final manuscript.

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