

Thoracic evaluation and cardiac measurement using radiography in opossums (*Didelphis albiventris*)

Avaliação radiográfica de torác e mensuração cardíaca de gambás (*Didelphis albiventris*)

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Highlights

The measurement of VHS showed a significant difference between the sexes. Proportionally, the trachea of opossums has a larger diameter than other species. The thorax depth is considered an intermediate thorax when compared to dogs.

Abstract

Cardiac measurement by chest X-ray is very important in the cardiac characterization of dogs and cats, however, the wild animal clinic has a different reality. Opossums (*Didelphis albiventris*) are part of the Brazilian fauna and are frequently referred for clinical and radiographic evaluation. The objective of this research was to evaluate the thorax of skunks and establish the average of VHS and VLAS for these animals. Chest radiographs were performed in lateral and ventrodorsal projections to measure the VHS and VLAS, thoracic depth and tracheal diameter. The mean VHS was 7.85 (± 0.3) for males and 8.12 (± 0.5) for females and the measured VLAS was 1.19 (± 0.2) for both sexes. The mean value for thoracic depth was 1.13 (± 0.03) and the ratio between the diameter of the chest inlet and the diameter of the trachea was 0.25 (± 0.02), with no significant differences between the sexes. This is the first study that addresses the thoracic evaluation by tracheal and cardiac measurements of skunks through radiographic examination.

Key words: Cardiology. Marsupials. X-Ray. Wild animals.

Resumo

A mensuração cardíaca por meio de radiografia de tórax é muito importante na caracterização cardíaca de cães e gatos, porém, a clínica de animais silvestres tem uma realidade diferente. Os gambás (*Didelphis albiventris*) fazem parte da fauna brasileira e são frequentemente encaminhados para avaliação clínica e para avaliação radiográfica. O objetivo desta pesquisa foi avaliar o tórax de gambás e estabelecer a média de VHS e VLAS para esses animais. Foram realizadas radiografias de tórax em projeções laterais e ventro-

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dorsais, para mensuração do VHS e VLAS, a profundidade torácica e o diâmetro traqueal. O VHS médio foi de 7,85 ($\pm 0,3$) para os machos e 8,12 ($\pm 0,5$) para as fêmeas e o VLAS mensurado foi de 1,19 ($\pm 0,2$) para ambos os sexos. O valor médio da profundidade torácica foi 1,13 ($\pm 0,03$) e a relação entre o diâmetro da entrada do tórax e o diâmetro da traqueia foi de 0,25 ($\pm 0,02$), sem diferenças significativas entre os sexos. Este é o primeiro estudo que aborda a avaliação torácica a medida traqueal e cardíaca de gambás por meio de exame radiográfico.

Palavras-chave: Animais silvestres. Cardiologia. Raio-x. Marsupial.

Introduction

The thoracic radiographic evaluation is performed subjectively with a thorough analysis of thoracic structures and through measurements, with the heart being the main organ evaluated in this radiographic study. Cardiac measurement through thorax radiography is routine in dogs and cats and very important in their cardiac characterization (Buchanan & Bucheler, 1995; Castro et al., 2011; Litster & Buchanan, 2000; Mostafa & Berry, 2017; Vezzosi et al., 2020). However, this assessment is only subjective and relies on the experience of the evaluator when it comes to the clinic of wild animals and unconventional pets, with the cardiac measurement being neglected due to the lack of reference values and specialized literature (Schilliger & Girling, 2019; Werther, 2014).

Many species arrive daily at the Centro de Triagem de Animais Silvestres (CETAS), requiring additional diagnostic exams, especially the radiographic exam (Cavalcanti et al., 2021). The white-eared opossum (*Didelphis albiventris*), a marsupial widely distributed in South America, is one of the animals that have the highest number of care (Cáceres, 2002). Despite this, discussions on their anatomy are scarce (Bertassoli et al., 2013; Rigueira et al., 1987). Thus, determining

normality parameters is essential for a better understanding of possible alterations.

Little is known about cardiovascular diseases of this species and almost nothing is found in the available literature. However, the heart of opossums is susceptible to infections by protozoa such as *Trypanosoma cruzi* and *Leishmania*, which cause heart diseases (Hashem et al., 2020; Paiz et al., 2016; Zecca et al., 2020). Furthermore, hypertrophic heart diseases without a known etiology have already been reported in other marsupials, such as the common wombat (*Vombatus ursinus*) by Machida et al. (1997) and in kangaroos (*Macropus rufogriseus*) by Stern et al. (2009), showing the importance of cardiac evaluation in wild animals.

Some methods of cardiac measurement were developed to increase accuracy and reduce subjectivity in the evaluation of radiographs. The VHS (vertebral heart scale), proposed by Buchanan and Bucheler (1995), and, more recently, VLAS (vertebral left atrial scale), developed to evaluate the size of the left atrium, being a complement to the cardiac evaluation, are among the most used.

Thus, this study aimed to perform a thorax evaluation and cardiac measurement in white-eared opossum (*Didelphis albiventris*).

Methodology

Thorax radiographs from adult 26 opossums (*D. albiventris*), being 13 females and 13 males with a body condition score between 3 and 5 (1–9) and whose history, inspection, and clinical records were within physiological standards for the species, were selected.

Right lateral projections for thorax depth, tracheal diameter, and VHS and VLAS measurement were evaluated. In addition, the morphology of the cardiac silhouette was also subjectively evaluated.

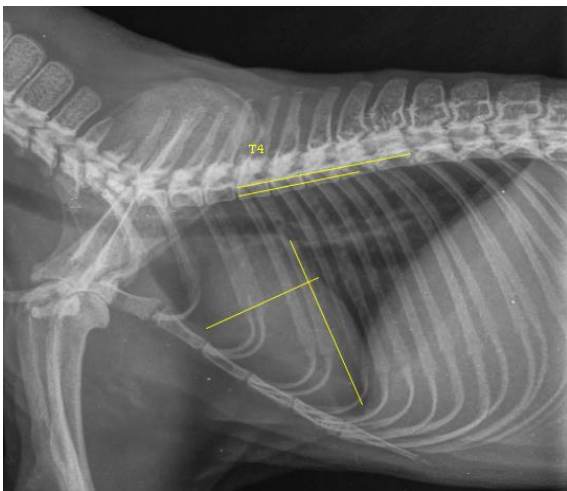
Thorax depth was measured by the ratio between thorax height and width, as proposed by Buchanan and Bucheler (1995). The measurement of the tracheal diameter was adapted from Harvey and Fink (1982), in which the ratio is obtained from the measurement of the entrance to the thorax, the cranioventral region of the first thoracic

vertebra, and the dorsal region of the middle third of the first sternebra (manubrium).

Cardiac measurement was performed by the vertebral heart scale (VHS) method, as proposed by Buchanan and Bucheler (1995). In this method, the major and minor axes are measured, their measurements are transposed in the spine from the fourth thoracic vertebra (T4), thus obtaining a value whose unit is coded in the number of vertebrae.

Left atrium measurement was performed as proposed by Vezzosi et al. (2020). On lateral radiographs, the left atrium was measured from the ventral edge of the left main bronchus to the point of intersection of the heart with the dorsal region of the caudal vena cava, being transposed from the fourth thoracic vertebra (T4), as in the measurement by VHS. The distance corresponding to the left atrium was transformed into values with units of vertebrae (Figure 1).

A



B



Figure 1. Radiographic examination of opossum (*D. albiventris*).

A) Aspect and measurement of VHS (vertebral heart scale); Transposition of the long axis and short axis dimensions in the vertebral body from the cranial edge of T4. Note the intercostal spaces and the number of sternebrae occupied. B) VLAS measurement. Note the measurement of the ratio of the left atrium area and the vertebral body from T4 in the yellow bars.

The radiographic exams were obtained in a RaiCenter® device and digitized in an AGFA CR15-x. The data were categorized into groups according to sex and subjected to the Shapiro-Wilk normality test, followed by Tukey's test with a significance level of $p < 0.05$ for comparison between sex means and descriptive statistics for data presentation. The program BioEstat® was used.

Results and Discussion

The mean value of the ratio between thorax height and width was $1.13 (\pm 0.03)$, which is considered an intermediate thorax when compared to the thorax of dogs (Buchanan & Bucheler, 1995; Castro et al., 2011).

Trachea diameter was determined based on the adaptation of Harvey and Fink (1982). This adaptation was necessary due to the opossum manubrium morphology and overlapping of limbs and clavicle in the analyzed projections. The ratio between the diameter of the entrance to the thorax and the trachea diameter was $0.25 (\pm 0.02)$, with no significant difference between the sexes. The value obtained for this group of opossums shows a larger-diameter trachea in this species compared to non-brachycephalic dogs, and almost twice the diameter of brachycephalic dogs (Souto et al., 2015).

Determining the normal size of the trachea is important to exclude or confirm diagnoses such as collapse, stenosis, and hypoplasia (Tappin, 2016). Bertassoli et al. (2013) reported the anatomical aspects of the trachea of opossums, evidencing that it differs from dogs and cats, but no study on radiographic appearance and measurement was found in the literature.

The cardiac silhouette of opossums on radiographic examination showed an elliptical and elongated shape and higher contact with the sternum, similar to that found in felines (Myer & Bonagura, 1982), but different from dogs, in which the shape is usually oval and less elongated (Castro et al., 2011). In the present study, the cardiac silhouette occupied approximately three sternbrae and three intercostal spaces (Figure 1). It had an oval shape in dorsoventral and ventrodorsal projections, appearing to be a little thinner and elongated than canine hearts (Myer & Bonagura, 1982).

The mean VHS was $7.85 (\pm 0.3)$ for males and $8.12 (\pm 0.5)$ vertebrae for females on the right latero-lateral and $7.19 (\pm 0.3)$ on the left latero-lateral, while VLAS reached $1.19 (\pm 0.2)$. Table 1 shows the long and short axes. The cardiac size of opossums found in this study for the values obtained on the right latero-lateral was similar to that found by Ghadiri et al. (2008) for health stay cats.

Table 1

Values of radiographic measurements of cardiac size evaluated using VHS (vertebral heart scale) on the right and left lateral projections and VLAS (vertebral left atrial scale) on the right lateral projection of adult opossums

	Mean	SD	Minimum	Maximum
RLL – Long axis	4.78	0.4085	4.0	6.0
RLL – Short axis	3.34	0.2654	3.0	4.0
RLL – VHS	8.12	0.5346	7.5	9.5
LLL – Long axis	4.08	0.3508	3.5	4.7
LLL – Short axis	3.10	0.1891	3.0	3.5
LLL – VHS	7.19	0.3499	6.5	7.7
RLL – VLAS	1.19	0.2019	1.0	2.5

*SD – Standard deviation; RLL – Right latero-lateral; LLL – Left latero-lateral; VHS – Vertebral heart scale; VLAS – Vertebral left atrial scale.

A statistical difference ($p < 0.05$) was observed between sexes, with a mean of 8.4 for female cardiac silhouettes and 7.8 for male cardiac silhouettes, differing from other studies (Bavegems et al., 2005; Buchanan & Bucheler, 1995; Marin et al., 2007), in which

males and females showed statistically equal values. The measurement of the long axis was believed to be responsible for this difference (Table 2), as this axis was longer in females than in males.

Table 2

Measurements of the long and short cardiac axes relative to the thoracic vertebrae in opossums

Sex	RLL – Long axis	RLL – Short axis	RLL – VHS
Female	5.02 a	3.38 a	8.40 a
Male	4.54 b	3.30 a	7.85 b

* RLL – Right latero-lateral; VHS – Vertebral heart scale;

*Means followed by different letters in the same column differ statistically from each other by Tukey's test at the 5% probability.

The VLAS determination (Figure 1) has been explored in radiographic examinations of animals in which cardiac remodeling is suspected, as observed for VHS. Several heart diseases can affect opossums and other

marsupials (Carnevali et al., 2017; Hashem et al., 2020). Thus, the data presented here may help in the evaluation and clinical decision-making in animals suspected of having heart diseases.

Conclusion

This is the first study addressing thoracic evaluation and tracheal and cardiac measurement of opossums (*Didelphis albiventris*) through radiographic examination. Based on the data obtained and presented, we conclude that the qualitative thorax evaluation is similar to that found in the literature for small animals. The mean value found for VLAS was 1.19 (± 0.2) vertebrae, with no difference between the sexes. However, the VHS evaluation in adult opossums showed that females had higher values than males, especially regarding the long axis. Therefore, the mean value of VHS found was 7.85 (± 0.3) for males and 8.12 (± 0.5) vertebrae for females.

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