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Short Communication

# Topography and echobiometric parameters of the heart in *Boa constrictor constrictor*

Frederico Ozanan Barros Monteiro[1]*, Gustavo Lobato Mota [1], Juliana Nascimento Duarte Rodrigues [2], Rafael dos Santos Andrade[1], Thyago Habner de Souza Pereira[1], Ednaldo da Silva Filho[1], Sheila Canevese Rahal[3], Alessandra Melchert[3], Marcus Antonio Rossi Feliciano[4]

[1] Postgraduate Program in Animal Health and Production in the Amazon, Federal Rural University of Amazon, Belém, Pará, Brazil.
[2] Department of Veterinary, Federal University of Viçosa, Viçosa, Minas Gerais, Brazil.
[3] Department of Veterinary Surgery and Anesthesiology, School of Veterinary Medicine and Animal Science, Botucatu, São Paulo, Brazil.
[4] School of Agricultural and Veterinary Sciences, Jaboticabal, São Paulo, Brazil.

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With the advance of ultrasonic technology, new echocardiographic techniques have been developed and commonly used in veterinary medicine because it allows noninvasive, accurate, and reproducible evaluation. The aim of this study was evaluating the topography and echobiometric parameters of the heart in red-tailed boas raised in captivity. Biometric data were evaluated from the body and heart in 21 *Boa constrictor constrictor* (17 females and 4 males) using B-mode ultrasonography. The heart was in the first third of the total body length. The mean value of the snout–heart length corresponded to 29.15 ± 2.01% (mean ± standard deviation) of the body length. The statistical analysis showed a significant linear increase between body length/mass and biometric data ($P < 0.01$). The heart exhibited a topographical location compatible with arboreal/terrestrial habits.

## INTRODUCTION

Red-tailed boas are neotropical snakes, ranked among the largest in the world. They belong to the Squamata order, Boidae family and genus *Boa*. Despite the existence of several subspecies, red-tailed boas (*Boa constrictor constrictor*) can be commonly found in the pet trade around the world, because of their beauty and quite docile temperament.

In Brazil, the demand of animals for legally breeding wildlife as pets becomes a challenge to veterinarians, who have little information about these animals, when compared to the amount of existing data on the clinic and management of domestic pets (ANDRADE et al., 2012). Snakes do not have diaphragmatic muscle; therefore, the heart and lungs are in the coelomic cavity with other organs (KOLESNIKOVAS; GREGO; ALBUQUERQUE, 2007). Free-living snakes have arboreal and terrestrial behaviors, climbing on tree branches and hiding under ground foliage. They mostly feed on mammals, birds, and other reptiles (MARTINS; OLIVEIRA, 1998; VITT; VANGILDER, 1983).

The elongated shape of the body and terrestrial, arboreal, or aquatic habitats can influence the heart position in snakes. Hypotheses explaining the heart position have been related to gravity (SEYMOUR, 1987). Snakes that need to adopt more vertical postures (arboreal) exhibit a heart in the cranial portion. Consequently, blood flow to the head is less affected by gravity, reducing cardiac work (GARTNER et al., 2010). To evaluate the positions of organs in the coelomic cavity, the body length can be segmented into three

* Corresponding author: fredericovet@hotmail.com; frederico.monteiro@ufra.edu.br.

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distinct parts (cranial, medial, and caudal). Our hypothesis is that there is relationship between heart position, cardiac measurements, body length/mass and terrestrial/arboreal behavior of *B. c. constrictor* raised in captivity. In this context, echocardiographic techniques can commonly be useful to test those hypotheses because allow noninvasive, accurate, and reproducible evaluation. Therefore, the aim of this study was evaluating the topography and heart echobiometry by ultrasound.

## MATERIALS AND METHODS

This study was conducted at the Xerimbabo commercial snake breeding located in Santo Antônio do Tauá municipality, Pará state, and was registered with the Institute of the Environment and Natural Renewable Resources (IBAMA Registration Nº 434325).

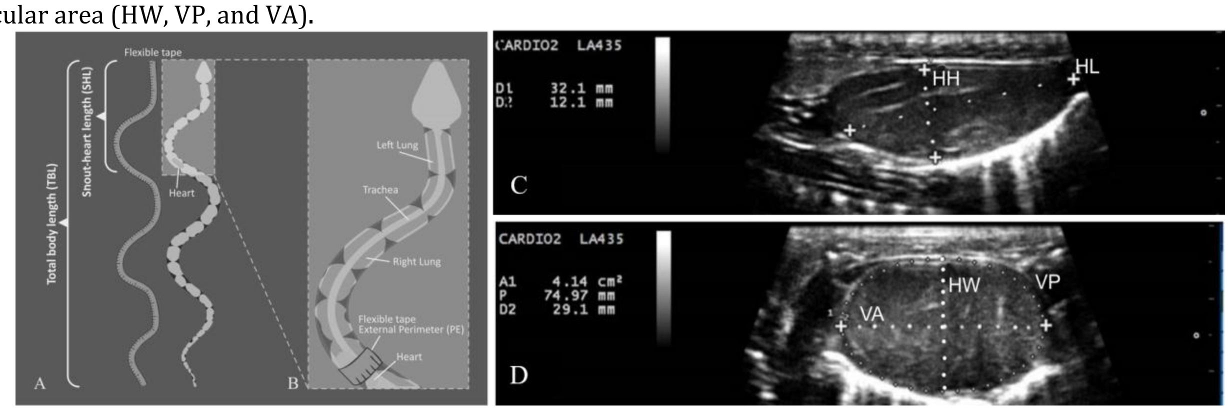
We housed 21 snakes *B. c. constrictor* comprising 17 females (154.10 ± 37.41 cm; 1.64 ± 1.08 kg) and 4 males (154.10 ± 39.26 cm; 1.62 ± 0.71 kg), in enclosures positioned in a north–south orientation to receive 12 h of daylight per day. The snakes were fed with adult *Rattus norvegicus* every 15 d, with the last feeding 7–10 d before the ultrasound examination.
Each animal was captured in an enclosure with an appropriate hook for snakes, positioned immediately behind the head, with subsequent manual restraint at the same position. All procedures were performed using only manual restraint, with the help of up to three people in a room with temperature of 20–23ºC, in order to reduce the metabolism and facilitate the restraint.

Three external biometric variables were measured: body length, snout–heart length (SHL), and external perimeter, which was obtained at the middle portion of the heart (Figure 1A and B). Those data were obtained with the aid of a Starrett® KTS flexible tape (Starrett, Itu, São Paulo, Brazil), measured precisely to the nearest millimeter. Body mass was obtained using a scale with a maximum capacity of 50 kg (Scales Pesola, Baar, Switzerland).

To assess the topographical position and measurements of the heart, the MyLab30 VET Gold® ultrasound system (Esaote, Genova, Italy) was used, equipped with a linear multifrequency transducer (6–18 MHz). The animals were positioned in ventral recumbency on a table measuring 80 × 80 × 73 cm, with an opening of 20 × 10 cm on the surface to facilitate the application of acoustic transmission gel and allow the contact of the transducer on the ventral surface of the skin. In order to obtain the largest cardiac diameter, B-mode ultrasound images were acquired during ventricular diastole at three different time points and the measurements were averages for analysis.

Heart echobiometry was performed as described by Conceição et al. (2014). The heart length and heart height (HL and HH) were measured in the sagittal plane (Figure 1C) and the heart width (HW) at the largest diameter of the transverse plane (Figure 1D) by positioning the transducer perpendicular to the ventricle after the departure of the vessels. Heart volume ($cm^3$) (HV) was calculated with the onboard computer by approximating the spheroidal geometric model from three linear measurements (HL x HH x HW x π/6). The ventricular perimeter and ventricular area (VP and VA) were simultaneously measured positioning the cursor around the ventricular contours during ventricular diastole (Figure 1D).

Figure 1 – Schematic diagram of the biometric measurements of red-tailed boas. (A) Body length and snout–heart length (SHL). (B) External perimeter (PE) of the middle portion of the heart. Images (C) and (D) show the heart echobiometry in *Boa constrictor constrictor*. (C) Heart sagittal scan, in which we measured the heart length and heart height (HL and HH). (D) Heart transversal scan at the largest ventricle diameter, where we measured the heart width, perimeter, and ventricular area (HW, VP, and VA).




Source: author's collection.

Basic parameters were calculated by descriptive statistics [mean, standard deviation (SD), and variance] for all analyzed variables. The results were analyzed considering the relationship between body length/mass and all biometric variables. Pearson's correlation was performed to compare SHL with body length. Multiple regression equations were performed using CurveExpert version 2.6.3. and set the best function to the plots. Differences with a probability value of 0.05 or less were considered significant. All values are expressed as the mean ± SD.

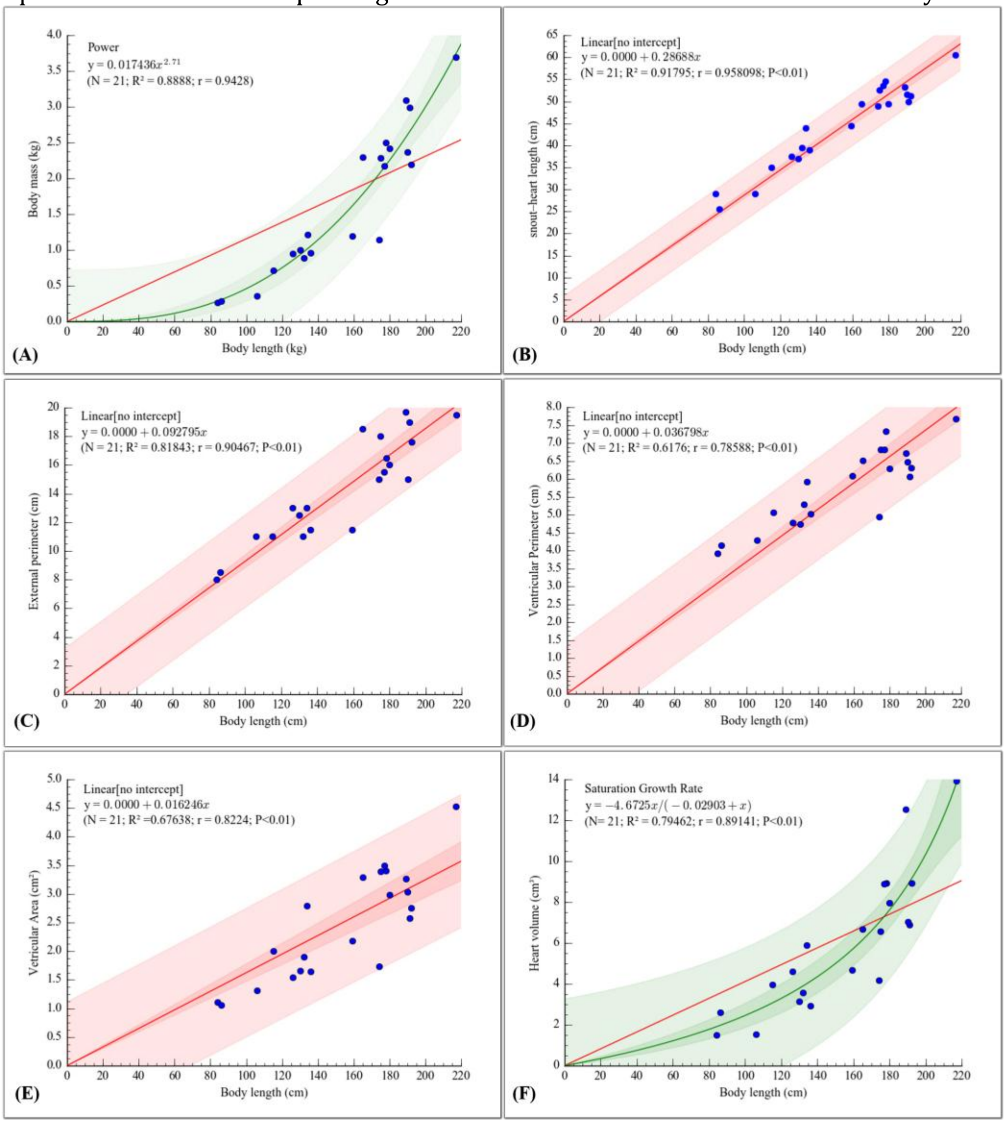
## RESULTS

In the studied snakes, the body length and mass did not differ significantly between males and females ($P > 0.05$).

The body mass was positively associated with body length, which was best explained by a power model ($R^2 = 0.89$, $P < 0.01$; Figure 1A).

The relationships among body length versus body mass, SHL, external perimeter, VP, and VA were best explained by linear models (Figures 2A, B, C, D, and E; respectively).

Figure 2 – Equations represent the relationship between the body length and body mass in *Boa constrictor constrictor*, where ''y'' represents the dependent variable and ''x'' is the independent variable, N (subjects), $R^2$ (determination coefficient), and r (correlation coefficient). The green line represents the best model fitted to the plots ± 95% CI, whereas the red line represents an expected linear trend with no intercept linear regression model among body length versus body mass (A), snout–heart length (B), external perimeter (C), ventricular perimeter (D), and ventricular area (E). The association between heart volume (HV) and body length was best explained by a saturation growth rate equation (F), whereas a linear equation was useful for explaining the association between heart volume and body mass.




The SHL represented 29.15 ± 2.01% of the body length. The minimum and maximum values were 26.18% and 34.52%, respectively, considering a 95% confidence interval. In addition, we observed a significant positive correlation between SHL and body length ($r = 0.96$; $P < 0.01$).

All relationships between heart biometric measurements and body length were significant, with coefficients of determination ($R^2$) ranging from 0.68 to 0.92 (Fig. 2). The linear models were best fitted to the body length and HL, HH, and HW. However, a saturation growth rate model was best adjusted to the body length and HV (Figure 2F), whereas the linear equation model (y = 3.4878x; N =21; $R^2$ = 0.84; r = 0.92; P < 0.01) had greater power to explain the association between body mass and HV.

## DISCUSSION

Previous measurements of the heart, liver, gallbladder, spleen, and kidneys of red-tailed boas may be influenced by the body length and mass, but not by sex (CONCEIÇÃO et al., 2014; ANDRADE et al., 2016). These studies did not assess the position of the heart in the coelomic cavity. Thus, the data related to heart echobiometry at this work are very similar to those reported in another study performed with the same species (CONCEIÇÃO et al., 2014). However, the most important particularity between the two experiments is that, here, we conducted external measurements to evaluate and associate the real position of the heart with body length and mass. In general, captive animals are fed with rats or neonates each 15-30 days. The body mass of the ingested prey can influence in the heart position and measurements (SCHROFF et al. 2012). It is worth mentioning that in the present study we used adult rats after a minimum of 7–10 days of fasting, so heart evaluation must be compared for this feeding period.

One of the most obvious morphological characteristics of snakes is an elongated tubular body (ANDRADE et al., 2016). This feature determines the increased length of the organs in the coelomic cavity and produces interesting adaptive physiological consequences, particularly in relation to the cardiovascular system (GARTNER et al., 2010). These data can be used to explain our results, as a significant relationship among body variables, SHL, external perimeter, VP, and VA was observed and best explained by linear models.

In the present study, the snakes had hearts located similarly to terrestrial/arboreal species. This can be associated with behavioral adaptation to gravity, because some studies have hypothesized that snake's cardiovascular system is influenced by (hydrostatic) gravitational pressure gradients, the intensity of which varies according to behavioral characteristics in relation to terrestrial, arboreal, or aquatic habits (GARTNER et al., 2010; SEYMOUR, 1987; SHEEHY; ALBERT; LILLYWHITE, 2016). Thus, gravitational pressure elevations may impede venous return, promoting circulatory complications and tissue edema (SHEEHY; ALBERT; LILLYWHITE, 2016). In this context, the position of the heart in the coelomic cavity leads to adaptive mechanisms optimizing cardiac function to facilitate the appropriate pumping of blood to all tissues of the body in these reptiles (GARTNER et al., 2010).

The heart is in anterior body portion in terrestrial and arboreal serpents, but in medial portion in aquatic snakes (SEYMOUR, 1987). Gartner et al. (2010) investigated 155 taxa representing seven major families and subfamilies of snakes, with different habits (arboreal, terrestrial, semiaquatic, fossorial, and aquatic). They observed a linear isovolumetric growth in SHL based on body length. In addition, anatomical studies have determined that snakes from the *Boa* genus have a heart position between 30% and 34% of the SHL (GOMES et al., 1989), which is compatible with our results. These findings reinforce the adaptive hypothesis of gravity effect on the circulatory system in red-tailed boas. Therefore, we believe that this adaptive feature improves blood flow when boas need to climb trees in search of food.
Limited literature is available on cardiac morphometric parameters of reptiles, especially in snakes. Arboreal snakes showed posterior-positioned heart, slenderest body, and smallest heart size (GUIMARÃES; GAIARSA; CAVALHERI, 2013).

Terrestrial snakes showed an anterior heart, less flattened body, and largest heart size. Although the heart position, as possible adaptation to arboreal lifestyle, was found in the literature, data and analyses in the present study did not address this issue directly. Therefore, this study focusses on the relationship between body size and heart position in red-tailed boas. The present study showed strong relationship between heart variables and body length/mass showing linear growth rate. Previous studies have shown that body length and mass are highly correlated with cardiac measurements (CONCEIÇÃO et al., 2014; SCHROFF et al., 2012). In addition, a positive correlation among HL,body length and body mass has been found for Boidae snakes (SCHROFF et al., 2012). The echocardiographic biometry observed in our study were highly like those reported in another study performed with the same species (ANDRADE et al., 2012). In both studies, data indicate that heart variables are better related with body length than body mass. However, those variables can be determinant of a predicted heart volume, because if we think that the cardiac output is related with body surface area, which is calculated using the body length and mass, the heart volume should be dependent of both.

Morphometric data and their analysis can be important to better understanding of the heart in reptiles. Indeed, one important question is to examine if heart position and dimensions increase with snake body mass/size. In the present study, all exterior dimensions of heart are closely and strongly related with exterior dimensions of red-tailed boas. Therefore, correct assessment of snake heart dimensions and their relationship through those variables could offer useful dimensional landmarks.

## CONCLUSION

Therefore, our study showed that the topographical location of the heart in *B. c. constrictor* is compatible with the arboreal/terrestrial habits of the species. Moreover, it was observed that biometric data of the cardiac parameters indicate a positive correlation with the total body length and mass.

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