RESUMO.- [Índice cardiotorácico e vertebral heart size (VHS) para a padronização do tamanho cardíaco do macaco-prego (Cebus apella Linnaeus, 1758) em imagens radiográficas computadorizadas.] Para a ava-
liação do VHS e ICT foram utilizadas radiografias torácicas de 10 macacos-prego (05 machos e 05 fêmeas) clinicamente saudáveis, oriundos do Centro de Triagem de Animais Silvestres de São Luís-MACETAS. Radiografias foram tomadas em projeções laterolateral e dorsoventral para cálculo do cardiothoracic ratio (CTR) e vertebral heart size (VHS). O CTR mostrou valores médios de 0.55±0.04 (machos) e de 0.52±0.03 (fêmeas) e não houve diferença estatística entre os sexos (p>0.05). O VHS evidenciou valores médios de 9.34±0.32v (machos) e 9.16±0.34v (fêmeas) e não houve diferença estatística entre os sexos (p>0.05). Houve correlação positiva entre CTR e VHS (r=0.78). Os diâmetros torácico e cardíaco demonstraram valores médios de 5.70±0.48cm e 3.16±0.40cm nos machos, respectivamente. Na fêmea, os valores foram 5.32±0.39cm e 2.94±0.32cm, respectivamente. Não houve diferença estatística entre os sexos. Nossos resultados mostram que a alta correlação encontrada entre CTR e VHS permitiu a verificação com precisão clínica similar entre os dois métodos para estimar alterações no formato do coração por meio de exames radiográficos de macaco-prego, tornando-se uma técnica fácil de aplicar que pode ser considerada na investigação de problemas cardiacos para esta espécie silvestre.

INDEX TERMS: CTR, VHS, heart silhouette, cutia, Cebus apella, wild animals.
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2,94±0,32cm. Não houve diferença estatística entre os se-
xos (p=0,05). Os nossos resultados demonstraram que a
alta correlação encontrada entre o VHS e o ICT permitiu
verificar precisão clínica semelhante entre os dois méto-
dos, para estimar alterações da silhueta cardíaca ao exa-
me radiográfico de macacos-prego, constituindo-se como
uma técnica de fácil aplicação, podendo ser conside-
rada na investigação de problemas cardíacos para esta
espécie silvestre.

TERMS DE INDEXAÇÃO: ICT, VHS, silhueta cardíaca, cutia, Cebus
apella, animais silvestres.

INTRODUCTION

Nonhuman primates have been reared to collect physio-
logical and biological data for scientific purposes since
1932 by Dr. Carlos Chagas, improving the management of
these animals, to carry out experiments related to disease
diagnosis and treatment (Andrade et al. 2007). Nonhuman
primates have been widely used as animal models in bio-
medical research (Yang et al. 2014), especially because of
their anatomical and physiological characteristics that are
similar to man, compared to other animal models (Nimri et

Thoracic x-rays are well-established in Veterinary Medi-
cine as a non-invasive method of investigating the thoracic
cavity in animals (Reichle & Wisner 2000). In this context,
radiographic images of the primate thorax can help elu-
cidate pathological processes intrinsic to the species and
help in the study of disease models, or further, for mor-
phometric studies of interest to primatology (Lawler et

The study of the normal pattern of thoracic x-rays in
nonhuman primates is essential to characterize abnorma-
lities that cause diseases in these animals. Although in-
numerable studies have been designed to establish both the
assessment criteria and the definition of the morphometric
parameters for several monkey species, such as Macaca
nigra and Macaca tonkeana (Schillaci et al. 2009,2010),
Macaca mulatta, Macaca fascicularis (Schillaci et al. 2010),
Callithrix jacchus (Wagner & Kirberger 2005) and the Rhes-
sus monkey, only one study was found in the literature on
the morphological aspects of the thoracic cavity in the tua-
ted capuchin (Alves et al. 2012).

Cardiac indices such as the Vertebral Heart Size (VHS),
already consolidated to estimate the size of the heart si-
luette in small animals (Buchanan 2000, Litster & Bu-
chanan 2000) and the cardiothoracic ratio (CTR) widely
used in medicine as a prediction of the heart function and
life span of cardiac patients (Michiue et al. 2010, Hasan et
al. 2012) are still only rarely used in nonhuman primate Ve-
terinary Medicine.

In Veterinary Medicine, a mean value has been sug-
gested for VHS for dogs between 10.5 vertebra (v) in ra-
diographic projections (Lamb et al. 2001, Nakayama et al.
2001, Lamb & Boswood 2002.). For nonhuman primates
the values of 9.42±0.44v have been suggested for Callithrix
jacchus (Wagner & Kirberger 2005), 10.7±0.69v for Aotus
spp. (Knowlen et al. 2013), 9.63±0.045v for Chlorocebus sa-
bæus (Young et al. 2013) and 9.12±0.63v for Cebus apella
(Alves et al. 2012). Values have been reported for the CTR
from 0.55 (Schillaci et al. 2010) to 0.58 (Xie et al. 2014) for
Macaca fascicularis, 0,59 for Macaca tonkeana and 0.58 for
Macaca nigra (Schillaci et al. 2009).

To our knowledge there are no references to date on the
CTR values for the tufted capuchin (Cebus apella), nor
a comparison of this technique with other measuring te-
techniques of the heart silhouette in thoracic x-rays, already
applied in nonhuman primates. Thus, considering that the
tufted capuchin (Cebus apella) is a typically South American
animal and that there are no data referent to the measuring
of the species, the objective of the present study was to ge-
genrate thoracic biometric data of the cardiothoracic ratio
that can help in clinical procedures, because these animals
are constant frequenters of the Wild Animal Screening Cen-
ters (Centros de Triagem de Animais Silvestres-CETAS), due
to involvement in accidents or predatory hunting. It is also
hoped to aggregate information on the cardiovascular pro-
file of the species as an animal model for studies of heart
diseases in humans.

MATERIALS AND METHODS

Animals

Ten healthy tufted capuchin monkeys were used (Cebus
apella), from the Wild Animal Screening Center (Centro de Tri-
agem de Animais Silvestres-CETAS) in São Luís-MA, Brazil. The
animals were separated into groups, consisting of five males
and five females with an average of two years of age. They were pre-
viously identified, weighed and submitted to clinical examination
and hematological profile (Wirz et al. 2008). The experimental
protocol was approved by the Brazilian Environmental Institute
and the Renewable Natural Resources Institute (IBAMA-SISBIO),
protocol number 02012.003909/2006.

Anesthetic protocol

The tufted capuchin were already in cages because they came
from rehabilitation or apprehension by the CETAS. Later they
were sedated using meperidine chlorhydrate (Meperidina®, Agri-
bands, 5mg/kg/IM). After this moment, chemical containment
continued with the association of xylazine chlorhydrate (Romp-
pum®, Bayer do Brasil, 1mg/kg/IM) and ketamine chlorhydrate
(Ketalar®, Pfizer do Brasil, 40mg/kg/IM). The animals were kept
under chemical containment using Propofol 1% (Fresofol®, Fre-
senius Kabi, 5mg/kg/IV) throughout the examination procedure.
The heart and respiratory function was assessed using both a
stethoscope to observe the normal heart sounds, respiratory fre-
ducity and air diffusion in the lung fields.

Radiographic examination

To carry out the radiographic examinations, the animals were
placed in ventral and lateral decubitus to obtain radiographic
images in dorsoventral and laterolateral projections of the tho-
racic region. An x Ray Tec 300mA apparatus was used, installed
in the Diagnostic Image Service from the Veterinary Hospital of
the State University of Maranhão-UEMA. The apparatus was cal-
ibrated with a 1m focus film-distance and exposure techniques
of 45kVp and 0.1mAs. The images were captured in a chassis con-
taining (18x24cm, phosphorus plates, AGFA Health Care, São Paulo,
Brazil). The chassis were read by an AGFA CR30-X digital image
processor and saved for later assessment.
Measuring the VHS (Vertebral Heart Size)

The VHS (Vertebral Heart Size) was measured according to the protocol established by Buchanan & Bücheler (1995), Litster & Buchanan (2000), that is the sum of the heart length and heart width at its greatest diameter and its later comparison with the vertebra bodies starting at T4 (Fig.1a). These measurements were taken and mean values were estimated to establish normality criteria. Because it is a wild species and in order to reduce the stress of containment and also knowing that the literature reports that there is no difference in the VHS values in animals between the right and left lateral decubitus (Litster & Buchanan 2000), this experiment was carried out taking the right decubitus as the base for all the measurements.

Statistics

The data were submitted to the Shapiro-Wilk and Kolmogorov-Smirnov normality error test and later the means of the male and female groups (VHS and CTR) were analyzed by the paired student t test, to interpret the parameters, considering a 5% confidence interval (p<0.05).

RESULTS

The studied animals presented heart silhouette situated between the third and fifth intercostal space, in the mid mediastinum. The VHS in the males showed a mean value of 9.34±0.32v and for the females, 9.16±0.34v. When the VHS was assessed between males and females, there was no statistical difference (p>0.05). Thus, assuming there was no difference between males and females, the VHS was estimated for males and females as a mean value of 9.25±0.32v (Table 1).

![Fig.1](image1.png)

**Fig.1.** Digital radiographic image of the chest of a capuchin monkey. In (a) right laterolateral projection to obtain the calculation of VHS. In (b) dorsoventral projection to obtain the ICT. (A) Higher cardiac diameter. (B) Greater cardiac length. (MR + ML) represent the two largest distances from the vertical line that divides the right and left side of the heart.

Vertebral heart size (CTR)

The CTR was assessed by comparing the greatest widths of the heart silhouette and the distance between the thoracic walls at height T8, according to methodology described by Schillaci et al. (2009) for *Macaca fascicularis* and by Hasan et al. (2012) in humans. The heart width was measured at the two greatest distances (ML and MR) from the vertical line that divides the limits between the right and left side of the heart, at the point of its greatest diameter. Similarly, the thoracic width was measured at the point of greatest thoracic diameter (MTD), as follows:

\[
CTR = \frac{MR + ML}{MTD}
\]

For both the methods used, standardization was adopted so that the sections of thoracic x-rays were taken at the inspiration peak, to guarantee the greatest thoracic distension (Fig.1b).

![Fig.2](image2.png)

**Fig.2.** Linear correlation between VHS (right lateral recumbency) and Cardiothoracic ratio (CTR) in capuchin monkeys.

![Table.1](image3.png)

**Table.1.** Comparative values measured for the Vertebral Heart Scale (VHS) and cardiothoracic ratio (CTR) in capuchin monkeys

<table>
<thead>
<tr>
<th>Gender</th>
<th>VHS (right lateral recumbency)</th>
<th>CTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>9.34±0.32^a</td>
<td>0.55±0.04^a</td>
</tr>
<tr>
<td>Female</td>
<td>9.16±0.34^a</td>
<td>0.52±0.03^a</td>
</tr>
</tbody>
</table>

* Means followed by different letters in the same row differ statistically.

The vertebral heart size (CTR) presented a mean value of 0.55±0.03 for the males and 0.55±0.04 for the females and there was no statistical difference between the sexes (Table 1). Thus, calculating a CTR between males and females resulted in the average value of 0.55±0.04. The correlations between the VHS and CTR were positive (\(y=0.1069x-0.4346, \ r=0.78\)), taking the CTR as dependent variable (Fig.2).

The study of the thoracic and heart diameter in the males showed average values of 5.70±0.48cm and 2.16±0.40cm, respectively. In the females these values were 5.32±0.39cm and 2.94±0.32cm. Assessment of the differences in the means of the thoracic and heart diameters showed no significant difference between males and females (p>0.05) (Table 2).
Table 2. Comparative values measured for cardiac and thoracic diameters between females and males in capuchin monkeys

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic Diameter</td>
<td>5.70±0.48a</td>
<td>5.32±0.39a</td>
</tr>
<tr>
<td>Cardiac Diameter</td>
<td>3.16±0.40a</td>
<td>2.94±0.32a</td>
</tr>
</tbody>
</table>

*Means followed by different letters in the same row differ statistically.

The study of the correlations between the thoracic diameter ($y=0.734x+1.136$, $r^2=0.833$) and heart diameter ($y=x-0.275$, $r=0.972$) between males and females showed strong interaction between these variables (Fig. 3 and 4).

**DISCUSSION**

The morphological assessment of the thoracic cavity of the *Cebus apella* in our findings showed that the anatomic conformation varied little, similar to that observed in other nonhuman primates, such as *Callithrix jacchus* (Wagner & Kirberger 2005), *Chlorocebus sabaues* (Young et al. 2013) and *Macaca mulata* (Ji et al. 2013). This characteristic became essential to apply biometric tests that allowed discreet increases to be defined in the heart silhouette of these animals, enabling the early diagnosis of cardiovascular diseases (Schillaci et al. 2010).

VHS is a well-established technique in veterinary medicine (Jepsen-Grant et al. 2013) and correlates positively with the development of heart increases in companion animals (Guglielmini et al. 2012). However, there are few studies on wild animals using VHS as a diagnostic tool. Felkai et al. (2014) described the presence of residual pleural effusion, heart increase and cardiomegaly, associated to increases in the VHS values in *Cercopithecus neglectus*, confirmed later by echocardiographic examination. The VHS values found in our assessments (mean 9.25±0.32v, between males and females) were similar to those assessed for the *Callithrix jacchus* (9.42±0.44v), described by Wagner & Kirberger (2005). These authors, corroborating our findings, did not observe statistical difference for the VHS values between males and females in the species that they studied. Although there is difference in weight and size between males and females in the tufted capuchin, there is consensus in the literature available on the weak interaction between the body mass and the VHS values, both in companion animals and other nonhuman primates (Schillaci et al. 2008, Young 2012, Ji et al. 2013). Other monkey species, such as *Aotus* spp. (Knowlen et al. 2013) and *Macaca fascicularis* (Xie et al. 2014) have been widely studied in this sense. However, to our knowledge, to date only Alves et al. (2012) have standardized VHS values in the *Cebus apella* species.

The vertebral heart size is a widely accepted method to quantify the size of the heart silhouette and can provide information on the presence of cardiomegaly and congestive heart insufficiency, because it correlates positively with the myocardial function (Hammermeister et al. 1979, Hubbell et al. 1985, Kearney et al. 2002). The standardization of this index for the tufted capuchin in the present research (0.55±0.04) showed normality values greater than those observed in humans (Dimopoulos et al. 2013). Although it is a cardio thoracic ratio compatible with installed heart disease (Gustafsson et al. 2003) and Solomon et al. (2005), the animals studied did not present clinical or radiographic signs compatible with heart insufficiency to any degree. Allied to this, data previously reported by Schillaci et al. (2009), in monkeys of the *Macaca tonkeana* (0.59) and *Macaca nigra* (0.58) species and by Xie et al. (2014) for *Macaca fascicularis* (0.58) were similar to our findings, suggesting that the primates present higher CTR values than those observed in humans. Similar to our studies, these authors did not find significant statistical difference between males and females regarding the CTR measurements, suggesting that there is little or no influence of gender on this variable for the species. Xie et al. (2013) further reported that the growth-promoted alterations did not show significant differences in the thoracic conformation and biometry in young males and females of the *Macaca mulata* species. Nonhuman primates present heart diseases similar to those found in humans (Wolfe-Coote 2005, Liang et al. 2005). Advanced techniques such as computerized tomography and magnetic resonance are considered the gold standard in thoracic disease diagnosis, but are expensive and their use for non-human primates is still not global (Xie et al. 2014).

There is still no systematic study to acquire parameters measured in thoracic x-rays of tufted capuchin, making it essential to construct reference indices to base the analysis of the heart silhouette in the species.

The CTR calculated for the tufted capuchin studied, like
the heart and thoracic diameters, showed little variation. These results reinforce the hypothesis that the CTR is sensitive to diagnose discreet variations in the heart silhouette of these animals, and early diagnosis of heart diseases is possible. Gustafsson et al. (2003) and Solomon et al. (2005) reported that increase in the heart chambers reflects a range of pathological processes that can affect the cardiovascular function: hypertrophy, dilation and heart remodeling, established markers in acquired heart diseases. Dimopoulos et al. (2013) demonstrated in humans that CTR greater than 0.55 is associated to cardiomegaly. These authors considered a CTR between 0.48 and 0.55 as a moderate heart increase index.

These reference data are scarce for nonhuman primates. Only Felkai et al. (2014) describe a CTR of 0.68 (68%) for Cercopithecus neglectus with an acquired heart disease associated to 7-10% fractional shortening. In our studies, we observed strong interaction between the VHS and CTR values (y = 0.1069x - 0.4346. r=0.78), a relationship that has not yet been discussed in the literature for nonhuman primates. These values allowed us to infer that both the VHS and the CTR can be used as reliable measuring methods to assess the heart silhouette in tufted capuchin. Because CTR can be carried out in sternal decubitus (dorsoventral projection), animals with pleural or important pericardial effusion that do not accept very well lateral decubitus, can be preferentially studied by the vertebral heart size method.

CONCLUSIONS

The present study demonstrated that the CTR, until now only used in human medicine, when compared to the VHS (a cardiac index consolidated in veterinary medicine), showed positive correlation and clinical precision in its application.

In tufted capuchin, the animal model used in the present study, the CTR was shown to be a diagnostic and investigative tool, and is an option in the choice of a method to assess increases in heart silhouette in these animals.

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REFERENCES


Schillaci M.A., Jones-Engel L., Heidrich J.E., Benamore R., Pereira A. & Paul