

Radiographic Measurement of Internal Organs in Spix's Macaws (*Cyanopsitta spixii*)

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Abstract: Radiology is an important diagnostic instrument in avian medicine, but standard measurement ranges for the objective evaluation of radiographs of birds are rare. To establish radiographic reference ranges for the critically endangered Spix's macaw (*Cyanopsitta spixii*), we measured radiographic silhouettes of the heart, liver, kidneys, spleen, proventriculus, and keel of the sternum on 29 radiographs taken under standardized conditions in adult and juvenile, clinically healthy birds. Ratios were determined for the proventricular diameter-to-keel height, the width of the heart to the width of the thorax, and for the "hourglass shape" (ratio of the width of the heart to the width of the liver). No significant differences were found between the sexes among the adult birds. Compared with adult birds, juvenile females had a significantly larger heart width (19.8 ± 1.4 mm versus 21.2 ± 0.7 mm), ratio of the heart width to the thorax width (0.86 ± 0.08 versus 0.94 ± 0.09), and horizontal width of the spleen (7.7 ± 0.6 mm versus 8.5 ± 0.4 mm). Results of radiographic measurements in the Spix's macaws were comparable to those published from other psittacine species. These reference ranges will facilitate a more objective radiographic evaluation of captive Spix's macaws.

Key words: internal organ measurements, radiography, diagnosis, avian, Spix's macaws, *Cyanopsitta spixii*

Introduction

The Spix's macaw (*Cyanopsitta spixii*) is the only member of the genus *Cyanopsitta* and is considered extinct in the wild since 2000 because of the loss of habitat and illegal trapping. There are roughly 80 individuals in captivity in Brazil, Switzerland, Germany, Spain, and the Philippines. Approximately 52 birds are held at the Al Wabra Wildlife Preservation (AWWP) in Qatar. Twenty-one new individuals have been bred in the past 5 years at AWWP. Intensive preventive health management of Spix's macaws is an important tool in the conservation effort for this species, and 3 recent publications¹⁻³ have reported on blood reference ranges and hand-rearing in Spix's macaws.

Because the physical examination in birds is limited for various physiologic and anatomic reasons, radiology is commonly used as a noninvasive, diagnostic tool in avian medicine.⁴ The air sacs provide a negative contrast that facilitates the evaluation of organs in the coelomic cavity. To be able to interpret radiographic images, knowledge of the size and position of internal organs in healthy birds is a prerequisite. Interpretation is based primarily on the subjective evaluation of size and shape of the depicted organ silhouettes and often depends on the experience and intuition of the diagnosing veterinarian. Few standardized measurements are published that can be used as guidelines for an objective approach by measuring defined distances. To our knowledge, the only published data of such measurements are the standard values of cardiac size described for red-tailed hawks (*Buteo jamaicensis*), screech owls (*Otus asio*), Canada geese (*Branta canadensis*),⁵ and different psittacine species, such as African grey parrots (*Psittacus erithacus*), Senegal parrots (*Poicephalus senegalus*), and orange-winged

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Figure 1. Ventrodorsal radiographic projection of a Spix's macaw, illustrating the measurements obtained to determine the widths of thorax (top line), hourglass waist (middle line), and liver (bottom line).

Amazon parrots (*Amazona amazonica*).⁴ Absolute measurements taken from radiographs vary with the focal film distance and the distance between the radiographic subject and the film. Therefore, a standardized protocol for the generation of radiographs must be followed to allow comparison; alternatively, the ratio of different shapes might be used to standardize for variation due to different distances. Suggested ratios in birds are the proventricular diameter to keel height, the width of the cardiac silhouette to the width of the thorax, and the width of the cardiac silhouette to the width of the coracoid bone.⁴⁻⁶

The aim of this study was to establish reference intervals for measurements of internal organs in radiographs of Spix's macaws to improve the health assessment of one of the rarest birds.

Materials and Methods

The health examinations of Spix's macaws at AWWP were performed under general inhalation anesthesia. For this procedure, the birds were anesthetized with isoflurane in oxygen (induction:

5% isoflurane in 1 L/min oxygen; maintenance: 2%–2.5% isoflurane in 1 L/min oxygen). All radiographs were taken with a commercial x-ray unit (Gierth HF100 Ultraleicht plus, Gierth X-ray International GmbH, Riesa, Germany) and film with factor $\times 100$ (Super RX Fuji medical x-ray film, Fujifilm Europe GmbH, Düsseldorf, Germany). The focal-film distance was 75 cm, and the exposure was 40 kV for 0.08 seconds. The object film distance was also constant for all radiographs. Birds were radiographed during inspiration both in lateral and ventrodorsal projections.

From the collection of 55 sets of radiographs available at AWWP from 2004 to 2007, 29 sets (53%) were chosen for the present study comprising 22 adult birds (>1.5 years; 76%), with a mean body mass (weight) of 305 ± 22 g (13 females; 9 males), and 7 juvenile birds (0.6–1.5 years; 24%), with a mean weight of 288 ± 15 g (6 females; 1 male). The criteria for choosing a set of radiographs were 1) the bird was considered healthy at the time the radiographs were taken (according to the individual health records), and 2) the positioning of the bird was considered correct, which, in the ventrodorsal projection, was when the spine and the carina sterni were either completely superimposed or differed by no more than 8 mm.

In the ventrodorsal views, we measured the width of the base of the cardiac silhouette (HW) and thorax at the widest point (TW), the maximum width of the liver (LW), and the waist of the "hourglass" shape (Fig 1). These values were used to calculate the ratio of the width of the heart to the width of the thorax (HW:TW) and the ratio of the hourglass shape (ratio of the width of the heart to the width of the liver [HW:LW]). On the lateral radiographs (Fig 2), the length of the superimposed kidneys and the size of the spleen were measured. The size of the spleen was measured vertically and horizontally, with the radiograph showing the spine of the bird in a horizontal position. The height of the keel of the sternum (HK) and the width of the proventriculus (PW) were measured, and the values were used to calculate the ratio of the width of the proventriculus to the height of the keel (PW:HK). The proventriculus was measured at the widest point, and the keel of the sternum was measured as described by Dennison et al.⁶

All organ measurements were taken with a vernier caliper directly from the radiographs, and the mean, standard deviation, and minimum and maximum values for each measurement were determined. Differences between the sexes and between adult and subadult birds were compared

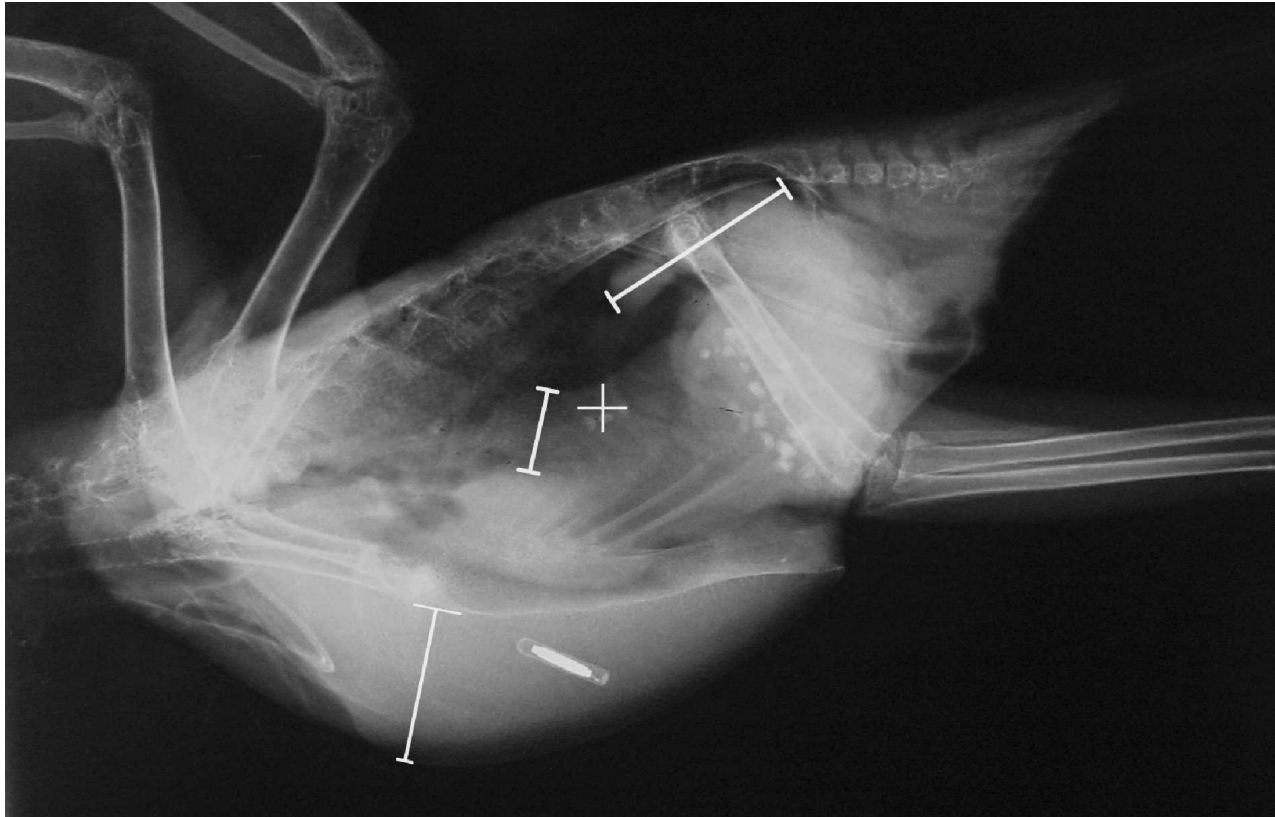


Figure 2. Lateral radiographic projection of a Spix's macaw illustrating the measurements obtained to determine the height of the keel of the sternum (bottom line), the width of the proventriculus (middle line), the horizontal and vertical lengths of the spleen (+), and the lengths of the kidneys (top line).

by *t* test with SPSS 16.0 software (SPSS Inc, Chicago, IL, USA). The level of significance was set at $P < .05$.

Results

The measurements obtained are summarized in Table 1. Because the outlines of the organs could not always be identified, the proventriculus was measured on only 18 radiographs (62%), and the spleen was seen on only 22 sets (76%). No significant differences in mean values were found between the sexes among the adult birds. Heart width differed significantly between the adult and juvenile females (adults [mean \pm SD], 19.8 ± 1.4 mm; juveniles, 21.2 ± 0.7 mm, $P = .04$). Significant differences were also found in the ratio of the heart width to thorax width (adults, 0.86 ± 0.08 ; juveniles, 0.94 ± 0.09 , $P = .04$) and the horizontal width of the spleen (adults, 7.7 ± 0.6 mm; juveniles, 8.5 ± 0.4 mm, $P = .02$).

Discussion

The results of this study show that measurements of the radiographic anatomy of Spix's

macaws are comparable with those of other psittacine birds. The parameters measured in this study show a distinct consistency. In relation to the heart width, the standard deviation was 6.5%, which is within the range of the 4.0%–7.4% deviation published for other psittacine birds.⁴ The reference ranges provide reliable guidelines for future radiographic evaluation of internal organs of the Spix's macaws. The 2 parameters that showed the widest variation in size or length were the liver and kidneys; therefore, those values appear less suitable for diagnostic purposes. Currently, the best way to identify kidney enlargement was described by Bauck⁷ and explained in detail by Simova-Curd et al.⁸ According to these authors, on the lateral radiograph, the kidneys should not extend ventrally beyond an imaginary horizontal line parallel to the spine that passes through the ventral border of the acetabulum.

In the present study, we found significant differences between juvenile and adult birds. Although the differences may appear small, when evaluating radiographs, these differences need to be considered. The difference in spleen size is of

Table 1. Organ measurements taken from radiographs of clinically healthy Spix's macaws (N = 29). Birds were 22 adults (13 females; 9 males), mean weight 305 ± 22 g; and 7 juveniles (6 females; 1 male), mean weight 288 ± 15 g.

Variables	Mean	SD	Min	Max
HW, mm	19.9	1.3	17.5	22.5
TW, mm	37.7	1.5	36.0	40.0
LW, mm	23.3	1.8	20.0	28.0
Hourglass waist width, mm	13.7	1.5	12.0	16.0
Spleen vertical width, mm (n = 22)	7.3	1.1	5.5	9.0
Spleen horizontal width, mm (n = 22)	7.9	0.7	6.5	9.0
Kidneys length, mm	27.9	1.8	26.0	30.5
PW, mm (n = 18)	9.4	1.0	8.0	11.0
HK, mm	21.8	1.3	19.4	23.8
HW : TW	0.53	0.03	0.46	0.60
HW : LW	0.86	0.09	0.65	1.05
PW : HK	0.44	0.06	0.35	0.53

Abbreviations: SD indicates standard deviation; Min, minimum; Max, maximum; HW, heart width; TW, thorax width; LW, liver width; PW, proventriculus width; HK, height of keel of sternum.

special importance because it may mislead the clinician to diagnose an infection.

When the results from Spix's macaws are compared with those published for 3 other psittacine species,⁴ an increase in heart and thoracic width with increasing body weight is evident (Fig 3). Generally, the ratio of heart width to thorax width appears to be 50% in psittacine birds.

Slight differences in the interspecific pattern, however, can lead to a deviation in the calculated

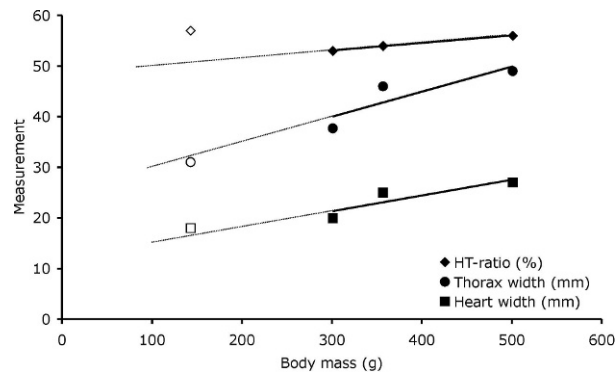


Figure 3. Comparisons of mean heart width, thorax width, and heart width : thorax width (HT) ratio (%) by weight in 4 psittacine species. Species are indicated by symbols above their mean body mass (weight). Data originate from this study and from studies of Senegal parrots (n = 7; mean body weight = 143 g),⁴ Spix's macaws (n = 29; mean body weight = 301 g), orange-winged Amazon parrots (n = 6; mean body weight = 357 g),⁴ and African grey parrots (n = 46; mean body weight = 501 g).⁴ Senegal parrots are indicated by open symbols. Dotted lines indicate the extrapolated linear regression lines derived from the measurements on the other 3 species.

ratio, as shown by the seeming outlier position of the Senegal parrot in Figure 3 for the heart : thorax ratio. These findings indicate not only that species differences may occur but also that such ratios must be used cautiously; most likely, only major deviations from the values given here can be considered as diagnostic indicators.

Recently, the proventricular diameter of the keel-height ratio was evaluated in psittacine birds.⁶ In that study, the authors found that ratios < 0.48 indicate a normal proventricular diameter and that this ratio had a sensitivity of 100% and specificity of 100% in the diagnosis of gastric disease. In our data, the mean value of proventricular diameter to keel-height ratio was 0.44, which is in accordance with the results in study mentioned. However, 6 birds (21%) had values > 0.48 , and of these, 4 birds (67%) were classified as juveniles. It is well known that, in juvenile psittacine birds, the proventriculus is enlarged, especially when the birds are still eating soft food. Therefore, it could be argued that these 4 birds had an age-related, enlarged gastric diameter. The remaining 2 birds (33%) were older than 1.5 years, and age-associated gastric dilatation is not a likely explanation. Although birds were considered healthy at the time the radiographs were obtained, subclinical disease cannot be ruled out. Differential diagnoses for gastric dilatation are heavy metal toxicosis, neuropathic gastric dilatation, proventriculitis, and gastrointestinal obstruction (eg, foreign body).

In conclusion, the results of this study provide basic reference ranges for the objective evaluation of important coelomic organs in the Spix's macaw, critically endangered species.

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