Radiographic Evaluation of Cardiac Size in Gyr Falcons (*Falco rusticolus*)

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**Abstract:** Survey radiographs were obtained from clinically normal gyr falcons (*Falco rusticolus*) to evaluate cardiac size for this species. Cardiac and skeletal measurements were collected at the latero-lateral view namely, cardiac width (CW), thoracic width (TW), and at the ventro-dorsal view, cardiac length (CL) and sternal length (SL). The most practical technique for determining the cardiac size was by obtaining the CW, then comparing it to the skeletal measurements TW and SL. The results denoted that CW for both female and male gyr falcon is 81.70% to 83.50% of the TW, and 44.00% to 44.39% of the SL. Sex-related differences were determined by comparing the group means statistically, for both cardiac and skeletal measurements. In this study, the group mean of female and male gyr falcons for the CW, TW, SW, the calculated ratio for cardiac width to thoracic width (CW:TW) and cardiac width to sternal width (CW:SW) were not statistically different and the data from the participating falcons (n=167) can be used as reference values to evaluate cardiac size in gyr falcon.

**Key words:** gyr falcon, cardiac, measurement, radiographic, evaluation

**Introduction**

Cardiac disease is a clinical entity in birds¹ and several necropsy studies have suggested that heart disease may occur more frequently than once assumed.²,³ The reason for this is that clinicians are often presented with non-specific clinical signs for cardiac disease, as seen in several documented cases. For instance, a yellow-naped amazon (*Amazona auropalliata*) parrot presented with lethargy, inappetence, decreased vocalization, weight loss, moderately fluctuant coelom, muffled heart sounds, was diagnosed with pericardial mesothelioma.⁴ An African grey parrot (*Psittacus erithacus*), initially presented with ascites, was dyspneic and, radiographic evaluation revealed loss of cardiohepatic waist, was diagnosed with right-sided heart failure and ventricular enlargement.⁵,⁶ A jenday conure (*Aratinga jandaya*), presented with lethargy, weakness, dyspnea, and radiographic evaluation revealed enlargement of cardiac silhouette and hepatomegaly, was diagnosed with pericardial effusion and right ventricular tamponade.⁷ A moluccan cockatoo (*Cacatua molucensis*), presented with periodical dyspnea, syncope and bradychardia, was diagnosed with a dilated left ventricle.⁸ One particular case in birds of prey was that of a Harris hawk (*Parabuteo unicinctus*), initially presented with signs of
sudden collapse, and was diagnosed with congestive heart failure. Another case in birds of prey involved a red-tailed hawk (*Buteo jamaicensis*) presented with dyspnea, anorexia, and celomic distension, whole-body radiographs revealed an enlarged and lobulated cardiac silhouette was diagnosed with cardiomyopathy and right-sided congestive heart failure.

In captive gyr falcons, in common with other Falconiformes kept in confined spaces or limited to perches, sudden death is often seen without impending clinical signs. In these cases, cardiac pathology could be the underlying cause. In psittacines, it has been documented that inactive individuals are at risk for signs attributable to decreased blood flow in the aorta, brachiocephalic trunk, or carotid arteries. These conditions eventually result in cardiac failure which could be unrecognized, dismissing the etiology as non-cardiovascular in origin. Inactivity and/or poor diet are known predisposing factor for degenerative conditions of the heart and great vessels in birds.

Radiology is a sensitive test for the diagnosis of cardiac disease though it is relatively nonspecific to the type of heart disease. Avian radiology has demonstrated that the detection of cardiac and extracardiac changes resulting in modifications to the cardiac silhouette is important in cardiovascular assessment. The initial sign of enlargement of the cardiac silhouette may indicate severe and chronic volume overload, myocardial failure or pericardial effusion.

Using normal reference values of cardiac measurements for silhouette scoring, clinicians could identify initial stages of cardiac abnormalities that potentially could lead to cardiac arrest and death. There are reports that cardiac measurements are less useful than qualitative evaluation of heart size using echocardiography and other advanced imaging modalities. For instance, computed tomography and magnetic resonance imaging can be used, but radiology is readily available and is the most commonly used imaging modality in clinical practices.

There are published normal reference values on cardiac measurements, used for cardiac silhouette scoring as part of cardiovascular assessment, but the available references are limited. The
measurement of the cardiac silhouette include cardiac width (CW), cardiac length (CL), sternal width (SW), thoracic length (TL), coracoid length (CL) and each study presents only a selection of these parameters, if not all. For instance, one particular study on medium-sized psittacines (approximately 36-41% of the SL or 51-61% of the TW, respectively). Another study conducted on different species of Falconiformes demonstrated that differences were found in the CW, distance between ribs, and CW and CL between hawks and falcons. In a study in peregrine falcons (Falco peregrinus), SW was found to be the most precise and most accurate predictor of CW, while TW seemed inferior as a predictor because it was affected by respiratory movements. There are references stating that the most practical ratio is to determine the cardiac width to thoracic width ratio on the ventro-dorsal view, because these measurements are highly correlated in birds. In other references, it has been suggested that it is more practical to measure the cardiac silhouette at its widest point on the ventro-dorsal view, followed by comparison of this value with both the TW at the same level and the SL measured at the latero-lateral view.

The scope of this study was to establish normal reference values of the cardiac size in captive gyr falcons through measurements of the cardiac silhouette using standard radiography. It is important to note that this study does not cover the determination of measurements of the heart base vasculature and coelomic vessels, structures that can also be demonstrated clearly by digital radiography and are considered important during cardiovascular assessment. This has practical applications ante-mortem, in accurately diagnosing early signs of cardiac disease such as generalized cardiomegaly and left ventricular hypertrophy in patients.

Materials and methods

The birds

For the inclusion criteria of the study, all participating falcons were adult (> year old), captive-bred gyr (Falco rusticolus) falcons used mainly for falconry purposes.

Materials and data collection
In this study, radiographic films were obtained from 123 females and 44 male gyr falcons (*Falco rusticolus*) during the post-hunting health assessment (January) from the year 2006 to year 2012. Regardless of the respiratory phase, both radiographs during the inspiratory and expiratory phases were included, on the assumption that there was no significant variation. The radiographs were obtained using a high frequency diagnostic x-ray unit (Gierth HF 80/15 plus ultra leicht, GIERTH X-Ray international GmbH European Headquarters Am Suedspeicher 4 D-01587 Riesa, Germany) with the following specification: source 230 V 50/60 Hz; Output 80 kV, 15 mA, 1.99 sec and 50 kV. The radiology unit was set at 52 kV, 0.2 sec and 60 cm focal distance from the examination table. All falcons were examined and found clinically normal. The clinical examination, consisted of physical examination, endoscopic examination, survey radiographs in the ventro-dorsal and latero-lateral positions, with the birds assuming a symmetrical position, parasitology, hematology and biochemistry. Measurements were obtained from the 167 film radiographs in millimetre using a Vernier calliper. The data obtained from each falcon consisted of 2 cardiac measurements and 2 skeletal measurements. These included, on ventro-dorsal view, the cardiac width (CW) and thoracic width (TW), and on the latero-lateral view, the cardiac length (CL) and the sternal length (SL).

Each measurement was defined: CW, as the width of the heart in the ventro-dorsal view at its widest point; TW, as the width of the thoracic cavity (the distance between the ribs) at the same level that the width of the heart was measured, in the ventro-dorsal view; for SL, as the length of the sternum from the most cranial point to the carina to the most caudal point on the lateral view; for CL as the length of the heart between the base, and the apex, on the lateral view. The ratios were calculated, between CW:TW; CW:SL and CW:SW.

**Statistical analyses**

Descriptive statistics were generated for the cardiac measurements, skeletal measurements as well as the calculated ratios, consisting of the mean, standard deviation, standard error of mean, and percentiles $P_{2.5th}$ – $P_{97.5th}$ with a probability of 95% interval, using a commercially available software (SPSS Statistics 23.0, IBM, New York, USA). The Shapiro-Wilk’s test was conducted to determine
the normality of distribution of data for each cardiac measurement, skeletal measurements and calculated ratios.

To determine statistically significant differences between the data from females and male gyr falcons, inferential statistics was used through the independent-sample test. With this test, the equality of variances was determined first by using Levene’s test, then the equality of means was determined, using the 2-tailed t-test with confidence interval of 95%. The T-test consisted of pooled t-test and Welch t-test. When the variance of the groups were equal, the pooled t-test (parametric test) was used while those with unequal variances were tested using the Welch test (non-parametric test). The conventional P-value of > 0.05 was applied, wherein P-value of > 0.05 indicates that significant differences exist between the data from the two groups. For the scope of this study, sex-related differences were also studied.

Results

The cardiac measurements and skeletal measurements for the gyr falcon are presented in Table 1. The calculated ratios are summarized in Table 2.

The results indicated that the group mean measurements and variance for CW, TW, SW, SL, ratio of CW:TW, ratio CW: SL in both females and males were equal after conducting the Levene’s test for equality of variances. Hence, it denotes that the statistics generated from the combined data for females and males for CW, TW, sternal SW, SL, calculated ratio of CW: TW, calculated ratio CW:SL for females and males can be use as reference values for cardiac size in gyr falcons. The measurements for the CL and the calculated ratio of CW:SW were statistically different between sexes (Table 1 and Table 2).

Discussion

The result of the study provided a standardized measurement and calculated ratios relative to skeletal landmarks for the gyr falcon species. The study specifically provided the normal reference range for the calculated ratio of CW:TW and between the CW:SL. The significance of this
information is that it is very practical and does not require complex computations. For instance, SW and TW were used to calculate predictive reference intervals for the size of the cardiac silhouette in peregrine falcons using regression equations,\textsuperscript{16,19} however, this may not be practical. The reason for this is that the measurement of the SW becomes difficult particularly, in cases where sternal landmarks are unapparent due to enlarged cardiac silhouette.\textsuperscript{18}

In this study, the calculated ratio for the gyr falcon was obtained from a significant number of individuals (n=167) which is more than the preceding studies on cardiac size. For the calculated ratio of the CW:TW, the CW was 81.70% to 83.50% more than the TW, regardless of sex and respiratory phase (Table 1). Moreover, for the calculated ratio of the CW:SL of gyr falcons, the result was 44.00% to 44.39%. It denotes that the CW:TW of gyr falcons was relatively higher than the values for other reported raptor and non-raptor species. This difference could be explained by the athletic nature of the species of interest in this study. In contrast to the participating gyr falcons of this study, a healthy medium-sized psittacine individual of 3 different species, had a CW:TW ratio that was 51% to 61% and had a CW:SL that was 35% to 41%.\textsuperscript{3,20} In published information for other falcons,\textsuperscript{16} the values were considerably greater with an upper limit of 70%, in contrast to the participating psittacine species.\textsuperscript{16,21} In a study on Falconiformes, the following cardiac measurements were derived: for the Harris hawk (n=48) with CW:TW of 54% to 61%, for the peregrine falcon (n=35) with CW:TW of 66% to 74%, for the saker falcon (\textit{Falco cherrug}; n=19) with CW:TW of 66% to 72%, and for the lanner falcon (\textit{Falco biarmicus}; n=13) with CW:TW of 65% to 72%.\textsuperscript{21}

Sex-related differences were evaluated (Table 2) and was absent for the cardiac and skeletal measurements particularly CW, TW, SW, SL, the calculated ratio of CW:TW and the calculated ratio of CW:SL. On the other hand, sex-related difference existed for the measurement of SL and calculated ratio of CW:SL.

The findings of this study are relevant to general falcon clinical practice because radiology equipment is more readily available in general clinical practice than other imaging modalities such as
ultrasound, computed tomography scanning (CTS) and magnetic resonance imaging (MRI). The study was carried out using radiographic films as there are still numerous practices that could not afford digital radiology equipment and continue using radiographic films.

Further investigation should be conducted about the effect of fitness training in gyr falcons by measuring the cardiac size in relation to skeletal structures, to determine any degree of physiologic cardiac hypertrophy, using radiographic films or digital radiographs.

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References


