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Article *in* Journal of Feline Medicine & Surgery · March 2008

DOI: 10.1016/j.jfms.2007.06.015 · Source: PubMed

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Journal of Feline Medicine and Surgery (2008) **10**, 61–65
doi:10.1016/j.jfms.2007.06.015

Radiographic measurement of vertebral heart size in healthy stray cats

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Date accepted: 5 June 2007

The aims of this study were to determine vertebral heart size (VHS) in stray cats and to compare different radiographic views. This study was performed on 50 adult stray cats. All cats were short-haired and non-obese and were considered to be healthy based on physical examination and electrocardiography. Left and right lateral, dorsoventral and ventrodorsal radiographs were taken. The long and short axes of the heart were measured in millimetres. The thoracic vertebral length spanned by each dimension was measured caudally from the fourth thoracic vertebra. Mean $\pm$ SD and the correlation coefficient between the measurements were calculated with standard statistical software. The sum of the long and short axes of the heart expressed as VHS was 7.3 $\pm$ 0.49 vertebrae in right lateral, 7.3 $\pm$ 0.55 vertebrae in left lateral, 7.5 $\pm$ 0.68 vertebrae in dorsoventral and 7.5 $\pm$ 0.53 vertebrae in ventrodorsal. The differences between right and left lateral as well as dorsoventral and ventrodorsal views were not significant ($P > 0.05$). Absolute measurements and vertebral heart scale values were slightly smaller than those reported in the literature for mixed population of cats. It is, therefore, important to take the breed in to account.

The diagnosis of cardiac disease is made, using a combination of history, physical examination and diagnostic imaging, usually thoracic radiography. Root and Bahr (2002) and Buchanan and Bucheler (1995) mentioned that determination of heart size is important in evaluating patients with heart disease and an enlarged cardiac silhouette in radiography may be a reliable index of pathological cardiac changes. Heart size has been related mathematically to the dimensions of other structures on thoracic radiographs. Recently, a cardiac measurement technique, called the vertebral heart scale or size (VHS: sum of the long and short axes of the heart compared to mid-thoracic vertebrae), was investigated in dogs by Buchanan and Bucheler (1995), in growing puppies by Sleeper and Buchanan (2001), in normal and obese cats by Litster and Buchanan (2000a, 2000b) and in ferrets by Stepien et al (1999). This method compares cardiac dimension with the length of mid-thoracic vertebrae, which are an indication of body size. This technique can provide objective criteria for evaluation of the heart.

Different breeds of dogs have been reported to have higher mean VHS values or a wider range than the reference values reported by Buchanan and Bucheler (1995), but it is uncertain whether different populations of the cats have such differences (Lamb et al 2000, 2001, Bavegems et al 2005, Hansson et al 2005). Therefore, the aims of this study were to determine absolute and relative heart size in clinically normal stray cats by correlation of heart size and mid-thoracic vertebrae and comparison between different radiographic views.

Materials and methods

Cats

Fifty clinically normal adult stray cats (31 males, 19 females) weighing 2.9–3.7 kg were used for the study. They were short-haired, adult and non-obese cats that were collected for a study on zoonotic parasites during March to September

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1098-612X/08/010061+05 $32.00/0

2003. The cats had a normal cardiovascular system based on physical examination, electrocardiography and thoracic radiography.

Radiography

The cats were anaesthetised with ketamine hydrochloride (Rotexmedica, Germany). Radiographic views included right to left lateral (RL) and left to right lateral (LL), dorsoventral (DV) and ventrodorsal (VD) radiographs. Radiographs were taken at full inspiration, if possible, with focus to film distance of 100 cm and a tabletop technique.

Radiographic measurements

Measurements obtained in each view are described below and were made with adjustable caliper and recorded to the nearest 0.1 mm. Measurements were based on previously published method by Litster and Buchanan (2000b).

(1) Right and left lateral cardiac long axes: Distance from ventral border of carina to cardiac apex in millimetre.
(2) Right and left lateral cardiac short axes: Perpendicular line to the long axis measurement, at the point of maximum cardiac width in millimetre.
(3) Ventrodorsal and dorsoventral cardiac long axes: Distance from midline of the cranial edge of the cardiac silhouette to apex in millimetre.
(4) Ventrodorsal and dorsoventral cardiac short axes: Perpendicular line to the long axis measurement, at the point of maximum cardiac width in millimetre.
(5) VHS measurement: In RR and LL views the caliper was repositioned over thoracic vertebrae, beginning with the cranial edge of T4 in each lateral views. In VD and DV radiographs, the sum of the heart axes was measured against the thoracic vertebrae in the RL view. The distance of the caudal caliper point was estimated to the nearest 0.1 vertebra. Long and short axes dimensions were then summed to obtain a value that indicated heart size relative to vertebral length or VHS.
(6) Right and left lateral T4−6: Total length (mm) of three vertebrae, measured from the cranial edge of the fourth thoracic (T4) to caudal edge of the sixth thoracic (T6) vertebra.
(7) Right and left lateral sternebrae: Length (mm) of three sternebrae, measured from the cranial border of the second sternebra to the caudal of the fourth sternebra.
(8) Chest depth: From the caudal margin of the seventh sternebra to the closest point on the ventral margin of the thoracic vertebrae, determined by making an arc with the caliper.
(9) Chest width: The maximum distance between the right and left interior borders of the thoracic cage at the level of ribs.

Statistical analysis

For all measurements, mean and standard deviation (SD) were determined. Standard statistical test (Student t-test) was used to compare statistically significant differences (at $P < 0.05$) between RL versus LL and VD versus DV measurements. Linear regression analyses (Pearson correlation coefficient, r) on correlation between the following measurements were assessed: RL and LL cardiac long axes (mm) versus T4 to T6 (mm), RL and LL cardiac short axes (mm) versus T4 to T6 (mm), RL cardiac long and short axes (mm) versus sternebrae 2 to 4 (mm) and RL and LL axes sum versus T4 to T6.

Results

Lateral radiographs

The means (±SD) of thoracic and cardiac measurements in RL ($n = 47$) and LL ($n = 42$) views are presented in Table 1. Right versus left recumbency did not significantly influenced measurements ($P > 0.05$). VHS was 7.3 ± 0.49 (range 6.3−8.5) vertebrae in RL and 7.3 ± 0.55 (range 6.3−8.5) vertebrae in LL views. The Kolmogrov−Smirnov test of normality shows that VHS of RL and LL views had a normal distribution ($P > 0.15$) (Figs 1 and 2). The depth of the thorax in RL and LL views was 61.9 ± 8.60 and 61.9 ± 7.60 mm, respectively, and the difference was not statistically significant. There were significant correlations between heart size and the length of T4 to T6 and sternebrae 2−4 in different views (Table 2).

Ventrodorsal and dorsoventral radiographs

The means (±SD) of thoracic and cardiac measurements in DV ($n = 44$) and VD ($n = 40$) views are presented in Table 3. There were no noticeable differences between measurements of the VD and DV radiographic views of the same animals ($P > 0.05$), with the exception that thoracic width in DV views was a significantly longer than in the VD views ($P < 0.05$). These values

Table 1. The mean (±SD) of thoracic and cardiac measurements in right lateral and left lateral views of clinically normal stray cats

Measurement	RL view	LL view	*P* value
Long axis (mm)	45.6 ± 5.53	46.2 ± 5.70	0.197
Long axis (V)*	4.3 ± 0.30	4.4 ± 0.35	0.66
Short axis (mm)	30.8 ± 3.50	30.0 ± 3.70	0.065
Short axis (V)*	2.9 ± 0.25	2.9 ± 0.30	0.214
Axes sum (mm)	76.3 ± 8.53	75.4 ± 9.10	0.328
Axes sum, VHS (V)*	7.3 ± 0.49	7.3 ± 0.55	0.689
Chest depth (mm)	61.9 ± 8.60	61.9 ± 7.60	0.339
Sternebrae 2–4 (mm)	46.4 ± 5.60	46.3 ± 4.90	0.355
†T4–T6 length (mm)	30.9 ± 3.41	30.9 ± 3.57	0.868

*Length measured in vertebrae.
†Cranial edge of fourth thoracic (T4) to caudal edge of sixth thoracic (T6) vertebra.

were not significantly longer than in lateral views. The mean VHS was 7.5 ± 0.68 (range 6.3–8.5) vertebrae in DV and 7.5 ± 0.53 (range 6.0 to 9.0) vertebrae in VD views. The Kolmogrov–Smirnov test of normality shows that VHS of DV and VD views had a normal distribution (Figs 3 and 4).

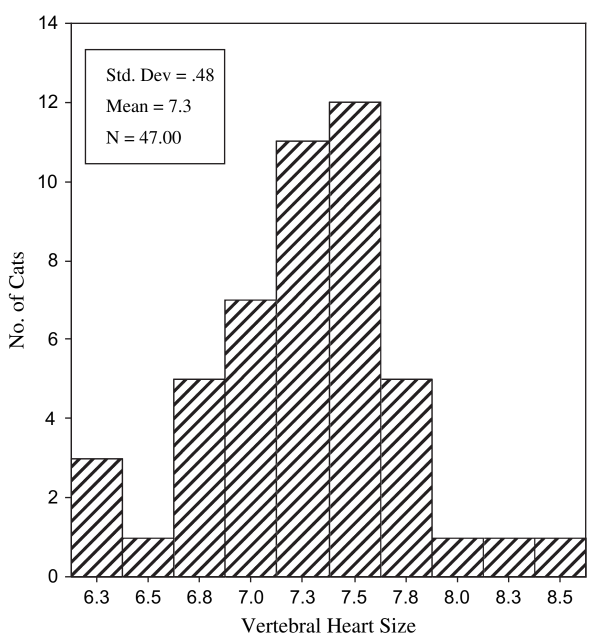

Fig 1. Distribution of the VHS in right lateral views of 47 clinically normal stray cats.

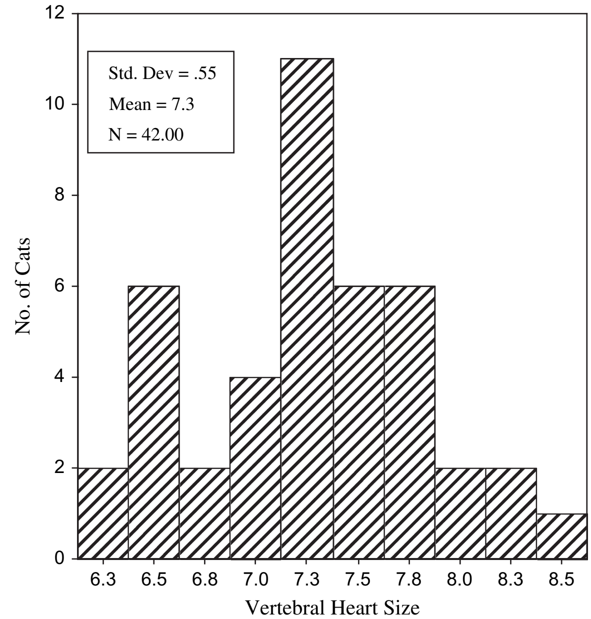

Fig 2. Distribution of the VHS in left lateral views of 42 clinically normal stray cats.

Discussion

VHS, as a cardiac measurement technique, has been previously described as helpful for small animal clinicians as starting point in evaluating heart size (Buchanan and Bucheler 1995). This study was carried out to determine whether the mean VHS of 7.5 ± 0.3 vertebrae on lateral radiographs and of 8.1 ± 0.45 or 8.2 ± 0.43 vertebrae on dorsoventral or ventrodorsal radiographs (respectively), as determined by Litster and Buchanan (2000b), was also applicable for stray cats. In the present investigation, mean VHS in both RL and LL radiographs was 7.3 vertebrae. The mean VHS of these stray cats on lateral radiographs was non-significantly smaller than the VHS reported by Litster and Buchanan (2000a, 2000b). For both DV and VD views mean VHS was 7.5 vertebrae. But the mean VHS of stray cats in our study on DV and VD radiographs was significantly smaller than the VHS stated by the latter study. Therefore, the stray cats' thoracic vertebrae and their hearts were on average slightly smaller than household cats.

Hansson et al (2005) concluded the VHS values for heart size can be affected by several factors. Individual variations in actual heart size and vertebral length between dogs need to be considered as well as narrowed disc spaces. The observer performing the measurements is also a cause for variation (Hansson et al 2005).

Table 2. Correlation coefficients between cardiac measurements versus T4 to T6 vertebrae and sternebrae 2–4 in different radiographic views

	RL view	LL view	DV* view	VD* view
Long heart axes vs T4 to T6	$r = 0.46$†	$r = 0.44$‡	$r = 0.39$‡	$r = 0.54$‡
Long heart axes vs sternebrae 2–4	$r = 0.58$†	$r = 0.48$†	$r = 0.47$	$r = 0.54$†
Short heart axes vs T4 to T6	$r = 0.37$‡	$r = 0.38$‡	$r = 0.39$‡	$r = 0.39$‡
Short heart axes vs sternebrae 2–4	$r = 0.55$†	$r = 0.37$†	$r = 0.48$†	$r = 0.50$†

*For DV and VD views vertebral and sternal measurements were made in RL views.
†Significant correlations at $P < 0.01$.
‡Significant correlations at $P < 0.05$.

Part of the variability in the measurements may arise from the method described by Buchanan and Bucheler (1995), which requires observers to estimate the proportion of the last vertebra covered by each heart measurement. The differences between our findings with previous study also may be due to interbreed or interpopulation variations of the cats. Hence, we used only short-haired cats with narrow range of body sizes whereas Litster and Buchanan (2000b) used various ages, breeds and sizes of the cats in their study. Age can also influence the VHS because Gaschen et al (1999) suggested that clinically normal kittens had relatively larger hearts (or smaller vertebrae) at 3 (VHS > 8.5 vertebrae) and 6 (VHS > 8.0 vertebrae) months of age than at 9 or 12 months of age, at which time their VHS values decreased to reference ranges in cats in Litster and Buchanan (2000b) study. Although the cats used in this study weighed between 2.9 and 3.7 kg, we think body condition is not the reason for this difference, because previous study (Litster and Buchanan 2000a) found no significant difference between absolute or VHS measurement in obese and non-obese cats.

Otherwise, differences in the mean VHS in this study with that of Litster and Buchanan (2000b) might not be due to the experience of the observer because Hansson et al (2005) believed that the VHS method for heart size is independent of observer experience but dependent on the individual observers' selection of reference points and transformation of long and short axes dimensions into VHS units. Nakayama et al (2001) found a low coefficient of variation among observers, but the study included only observers who were experienced interpreters of thoracic radiographs. In a study by Lamb et al (2000) including three observers with different experience (veterinary radiologist, medicine resident, and veterinary nurse), the observers recorded similar mean values but a maximum likely difference of >1.0 vertebra.

Interbreed variations of the VHS have been described in dogs, and it has been suggested that it would be more reliable to determine specific

Table 3. The mean (±SD) of thoracic and cardiac measurements in dorsoventral and ventrodorsal views of clinically normal stray cats

Measurement	DV view	VD view	P value
Long axis (mm)	46.5 ± 5.73	46.6 ± 5.28	0.933
Long axis (V)*	4.4 ± 0.41	4.4 ± 0.38	0.900
Short axis (mm)	31.5 ± 4.28	31.5 ± 3.60	0.351
Short axis (V)*	3.0 ± 0.38	3.1 ± 0.33	0.087
Axes sum (mm)	78.1 ± 9.02	78.4 ± 8.04	0.495
Axes sum, VHS (V)*	7.5 ± 0.68	7.5 ± 0.53	0.197
Chest width (mm)	69.8 ± 8.60	67.2 ± 7.26	0.034

*Length measured in vertebrae.

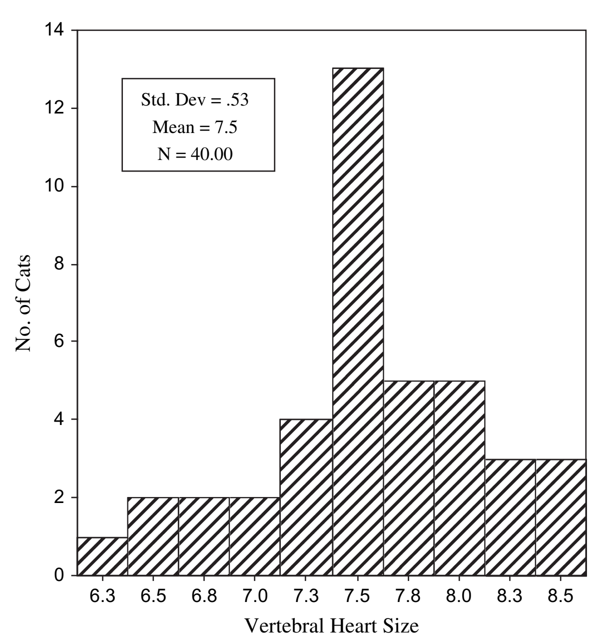

Fig 3. Distribution of the VHS in ventrodorsal views of 40 clinically normal stray cats.

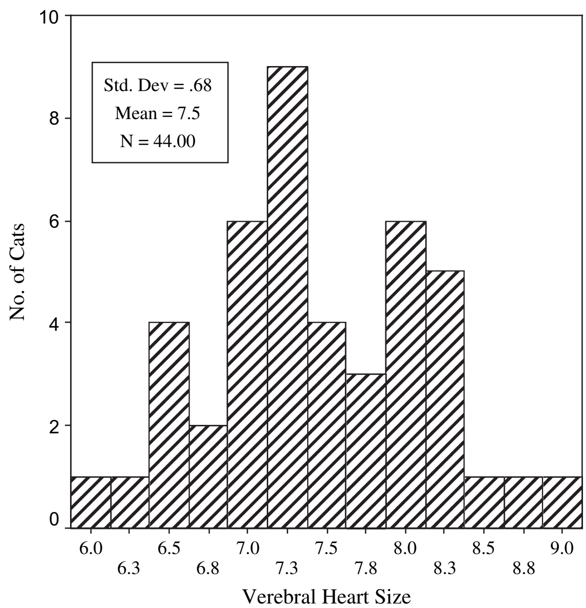

Fig 4. Distribution of the VHS, dorsoventral views of 44 clinically normal stray cats.

values for individual breeds by studying larger numbers of dogs of each breed. The use of one breed of cats in our study eliminated variations that could be caused by breed (Lamb et al 2000, 2001, Hansson et al 2005, Bavegems et al 2005).

In accordance with the Litster and Buchanan study, significant correlation between heart size and vertebral (T4 to T6) and sternebrae 2–4 length was evident on RL, LL, DV and VD radiographs; therefore, an index of vertebral length was selected by several authors as an indicator of body size.

We found no statistical difference between RL and LL VHS in our study. It may be due to the central location of the vertebral column in the body and thus the similar mean values of the heart axes and T4 to T6 vertebral length in both lateral radiographs. To our knowledge there are no reports comparing RL versus LL VHS in cats. Thus, there seems to be no preference between RL over the LL views for measuring VHS. Buchanan and Bucheler (1995) found right versus left lateral recumbency did not significantly influence measurements. However, Bavegems et al (2005) found a significant difference between RL and LL radiographs in Whippets, with a larger VHS on LL views.

For the DV and VD views, differences between the VHS were not significant which reflects results obtained by the Litster and Buchanan (2000b) study. The similarity of heart sizes in DV versus VD projections in the present study indicated that one projection has no advantage over the other. In contrast, there were noticeable differences between VHS measurement in DV and VD views of the same dogs (Buchanan and Bucheler 1995). The mean VHS for Whippets on VD radiographs was significantly larger than the VHS on DV views (Bavegems et al 2005). Finally, in accordance with results Litster and Buchanan (2000b) study, stray cats did not have a remarkably larger VHS in DV or VD radiographs in comparison with the lateral radiographs.

Acknowledgment

This work was supported by the vice chancellor of research of Shahid Chamran University of Ahvaz.

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