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Estimation of vertebral heart size and cardiothoracic ratio in Persian cats

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Abstract

The study aimed to determine the reference values related to vertebral heart size (VHS) and cardiothoracic ratio (CTR), which are effective in the evaluation of the thorax diseases and especially cardiomegaly of the brachycephalic cats using the morphometric data of thorax and heart obtained from the radiographic images of the thoracic region of the Persian cats. It was determined that lying position during radiography did not affect VHS and CTR values. Also, the sex factor did not have a significance on these values. The fact that the VHS value of 8.16 thoracic vertebrae averagely found in the Persian cats is higher than 7.5 thoracic vertebrae value averagely stated in the studies conducted with the cats of different breeds is considered since the breed is brachycephalic.

KEYWORDS

brachycephalic, cardiothoracic ratio, Persian cat, vertebral heart size

1 | INTRODUCTION

Today, veterinarians use thorax radiograph frequently in determining heart size in a clinical environment. The radiographic determination of cardiomegaly is possible with the vertebral heart size (VHS). Cardiomyopathies are the most common form of heart disease in cats (Kittleson, 2005). Hypertrophic cardiomyopathies are the main cause of heart failure in cats (Riesen et al., 2007). It has been determined that the vertebral heart size used in determining cardiomegaly in the radiographic studies in cats is 7.5 thoracic vertebrae on average (Litster & Buchanan, 2000a). The mentioned method has also been examined in several dog breeds, and the reference values have been determined (Buchanan & Bücheler, 1995; Gülanber et al., 2005; Greco et al., 2008; Gugjoo et al., 2013; Jepsen-Grant et al., 2013; Bodh et al., 2016). It has been reported that VHS is larger in dog breeds with brachycephalic head structure (Jepsen-Grant et al. 2013). It has been determined that the use of VHS method is more appropriate in cats compared with dogs in terms of the uniform thorax shapes, and it has been stated that the VHS measurements are higher than the normal value in cats in the 3. months and it decreases to normal levels in the 6. and 12. months (Gaschen et al., 1999). It has been stated that VHS method is more effective compared with the echocardiographic measurements providing size of short-axis only in terms of demonstrating the changes in both long and short axes of the heart (Buchanan, 2000).

Another method in determining cardiomegaly is the cardiothoracic ratio (CTR). DV and VD in animals are obtained by dividing the short-axis value which has the widest heart silhouette in chest radiograph to the widest distance of the thoracic wall (at the 8th thoracic vertebral level) (Schillaci et al., 2009; Azevedo et al., 2016).

2 | MATERIALS AND METHODS

Thirty adults, male, and female Persian cats with no heart problem were used in the study. Radiographs were taken in four positions: DV (dorsoventral), VD (ventrodorsal), RL (right lateral) and LL (left lateral). The radiograph was taken without using anesthesia and during maximum inspiration as much as possible. The DV and VD images of a cat were taken in the same radiographic period with the RL and LL images.

2.1 | Measurements

The measurements obtained from the radiograph were performed in accordance with the methods reported by Azevedo et al. (2016), Litster and Buchanan (2000a), Schillaci et al. (2009) and Ukaha (2013).

2.2 | Lateral radiographic measurements (RL-LL)

Long axis (LA): The distance from the ventral edge of tracheal bifurcation (carina) to the apex of the heart was measured in cm. The number of the thoracic vertebrae corresponding to this distance starting from the cranial edge of T_4 was estimated based on 0.1 vertebrae approximately.

Short axis (SA): It was measured perpendicular to the widest region of the heart, where caudal vena cava merges with the caudal edge of heart and the long-axis of the heart. After the measurements were performed in cm, they were adapted on the thoracic vertebrae and it was measured in vertebrae.

Vertebral heart size (VHS): The sum of long and shortaxes obtained from the lateral image.

Caudal vena cava diameter (CVCd): The vertebral measurement by adapting to the thoracic vertebrae after the measurement in cm was obtained vertical to the vein length at the point, wherewith heart image and caudal vena cava intersects.

Figure 1 shows the measurement points obtained from the lateral X-ray images.

2.3 | Dorsoventral and ventrodorsal radiographic measurements (DV/VD)

Long axis (LA): The measurement (in cm) of the distance from the middle line of the cranial edge of cardiac silhouette to the apex of the heart and the vertebral measurement of this measurement on the right lateral radiographic image.

Short axis (SA): The vertebral measurement on the right lateral radiographic image after the measurement of the distance drawn perpendicular to the long-axis measurement in the widest place of the heart silhouette.

Vertebral heart size (VHS): The sum of long and short axes obtained from DV and VD images.

Cardiothoracic ratio (CTR): The proportioning of the widest short-axis value in DV and VD images of the heart silhouette with the distance between the pleural surfaces of costae at the 8th costae level.

Figures 2 and 3 show the measurement points obtained from the dorsoventral and ventrodorsal X-ray images.

3 | RESULTS

3.1 | Lateral radiographs

In the lateral radiograph of the Persian cats, it was found that the basis cordis of the heart was craniodorsal and its apex cordis was caudoventral and the heart is generally placed in the 4. intercostal space and 6. or 7. intercostal space and 5. and 7. intercostal spaces. The shape of the heart is conical and its angle between its long-axis and sternum is slightly higher in the male cats and it was determined to be averagely 40 degrees in the male and female cats.

The measurements of the right and left radiographs of the cats were obtained separately in the male and female cats. Upon comparison of the right and left measurement values, it was determined that the difference observed within the sexes based on the directions was not statistically significant ($p > .05$). But, it was determined that the measurement values of male cats were generally higher compared with females (Table 1).

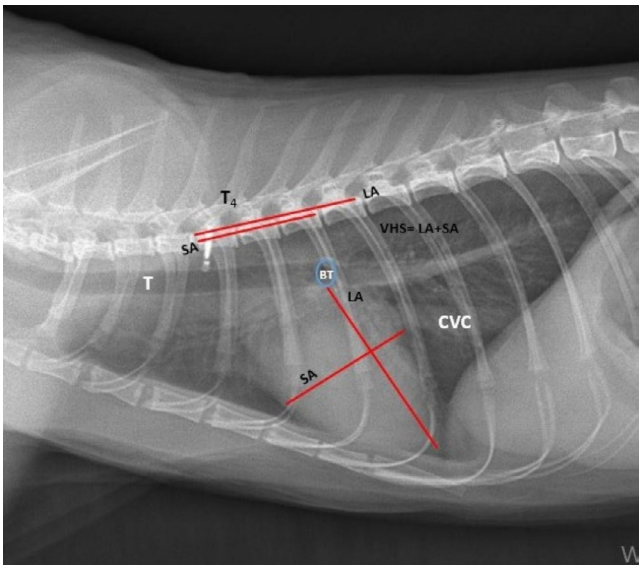

FIGURE 1 The measurements obtained from the lateral X-ray images. LA: long axis; SA: short axis; T4: 4th thoracic vertebrae; T: trachea; BT: bifurcatio trachea; CVC: caudal vena cava

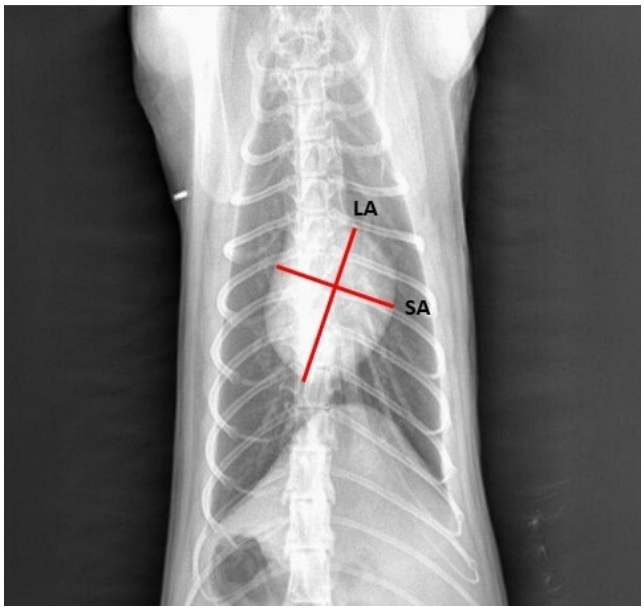

FIGURE 2 The measurements obtained from ventrodorsal X-ray images. LA: long axis; SA: short axis

FIGURE 3 Cardiothoracic ratio (CTR) measurement method in dorsoventral thoracic radiographs. A: The widest short-axis of the heart (cm); B: distance between the pleural surfaces of costa at the level costa 8 (cm); CTR: cardiothoracic ratio

vertebral level in the males and at the 3.50 vertebral level in the females in terms of vertebral value.

As there was no statistically significant difference between the VHS values in the comparison of the lateral radiograph between the sexes, it was determined that the VHS value obtained from the right and left radiographs for the Persian cats in the histogram distribution table obtained as a result of the assessment performed on 30 Persian cats was averagely 8.16 ± 0.44 vertebrae (between the range of 7.40 and 9.00 vertebrae) (Figure 4).

3.2 | Dorsoventral and ventrodorsal radiographs

Dorsoventral and ventrodorsal images were evaluated over 28 cats (14 males and 14 females).

In the examination of the measurement values obtained from the DV and VD X-ray images of the cats and the data of cardiothoracic ratio, no statistical difference was determined in the male and female cats due to lying position ($p > .05$) (Table 3).

For this reason, the comparison between the sexes is made on the average values of both lying positions. In the comparison of these values, a statistically significant difference was not observed between the sexes (Table 4).

TABLE 1 Comparison of measurement values obtained from right and left lateral X-ray images in male and female cats

			Male				Female		
Measurement	Side	*N*	Mean (v)	*SD*	*t* value	*N*	Mean (v)	*SD*	*t* value
Long axis (LA)	RL	15	4.69	0.32	0.683^{NS}	15	4.61	0.23	0.298^{NS}
	LL		4.73	0.30			4.70	0.25	
Short axis (SA)	RL	15	3.47	0.36	1.000^{NS}	15	3.55	0.30	0.314^{NS}
	LL		3.47	0.33			3.45	0.23	
Vertebral heart size (VHS)	RL	15	8.15	0.52	0.812^{NS}	15	8.15	0.46	0.965^{NS}
	LL		8.20	0.54			8.15	0.37	
Caudal vena cava diameter (CVCd)	RL	15	0.76	0.11	0.588^{NS}	14	0.72	0.07	0.521^{NS}
	LL		0.78	0.09			0.74	0.10	

Abbreviations: LL, left lateral: *N*, number of cats; ^{NS}, not significant; RL, right lateral; *SD*, standard deviation;V, length measured in vertebrae.

As the difference between the measurement values between the sexes was not statistically significant due to the lying position in the right and left radiographic measurements, the differences between the sexes were examined by obtaining the averages of the right and left measurement values (Table 2). It was determined that the examined measurement values did not have a statistically significant difference between the sexes.

It was determined in the measurements obtained from the right and left lateral radiographs that the place of the heart in thorax was approximately located in the 2–3 intercostal spaces in male and female Persian cats and the short-axis of heart was at the 3.47

Due to the fact that VHS values obtained from DV and VD images did not have a statically significant difference in terms of both image and sex comparison, the histogram distribution of the VHS was obtained with 28 Persian cats. It was determined that in the histogram distribution chart of VHS, VHS value obtained from DV and VD radiographs was averagely 8.74 ± 0.58 vertebrae (between the range of 7.25 and 9.75 vertebrae) (Figure 5).

As the cardiothoracic ratio, which is another differentiation of cardiomegaly in radiographic diagnoses, did not have a significant difference in terms of both radiographic direction and sex, in the assessment performed with 28 Persian cats, CTR distribution

TABLE 2 Comparison of measurement values obtained from right and left lateral X-ray images in sexes

Measurement	*N*	Sex	Mean (v)	*SD*	*t* value
Long axis (LA)	15	♂	4.71	0.26	0.536^{NS}
	15	♀	4.65	0.23	
Short axis (SA)	15	♂	3.47	0.31	0.771^{NS}
	15	♀	3.50	0.24	
Vertebral heart size (VHS)	15	♂	8.18	0.49	0.870 ^{NS}
	15	♀	8.15	0.39	
Caudal vena cava diameter (CVCd)	15	♂	0.77	0.09	0.238 ^{NS}
	14	♀	0.73	0.20	

Abbreviations: ♀, female; ♂, male; *N*, number of cats; ^{NS}, not significant; *SD*, standard deviation;V, length measured in vertebrae.

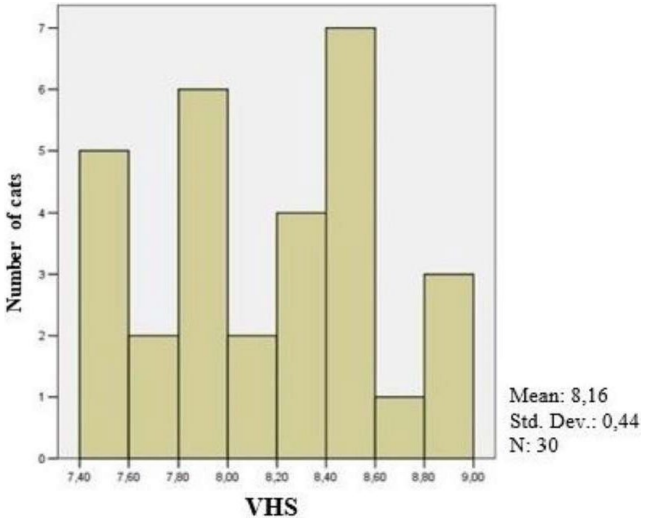

FIGURE 4 Distribution of VHS in lateral radiographs

histogram was present in Figure 6 and the average ratio was determined to be 0.52 ± 0.05.

4 | DISCUSSION

Cardiomegaly is an enlarged heart that is formed as a result of cardiomyopathies, which is the most common form of heart disease in cats (Fox et al., 1999; Kittleson, 2005). Radiographic diagnosis of cardiomegaly in the clinical environment is easy for the experienced observes, but the measurements of heart help as a starting point for the inexperienced observers in assessing cardiomegaly.

Knowing the breed and the sex of an animal is quite important in interpreting the heart size and shape, and the most appropriate result is possible by performing comparisons with the normal radiography of the same breed (Barr, 1999). For example, puppies, the brachycephalic breeds or obese dogs, are examined have a rather wide, round heart silhouette and this situation may be confused with the presence of cardiomegaly (Lamb & Boswood, 2002). Eliminating cardiomegaly is possible only by recognizing this situation.

In the radiographic examination of the Persian cats used in the study, the location of heart in thorax was generally determined in the 4.-7., 4.-6. and 5.-7. intercostal spaces. These results of heart corresponding to the 2–3 intercostal spaces are compatible with the results of the study conducted on the cardiac radiographs of healthy Van cats (Kılıçalp & Çınar, 2003).

Cat heart is more parallel to the sternum and has a more caudal placement compared with dogs. The mentioned parallelism may increase as age increases. In the present study, the fact that the angle of the long-axis of the heart with sternum was approximately 40 degrees in the Persian cats and the mentioned angle is about 45 degrees in dogs (Dyce et al., 2016) supports the idea that heart is more parallel to sternum in cats compared with dogs. The fact that the angle between the long-axis of the heart and sternum was less in females in this study was possibly due to the fact that most of the female cats were older than the male cats.

The use of the VHS method is more effective compared with dogs as cats have a uniform thorax. Also, it has been reported that heart size does not change with the age and developmental stage

TABLE 3 Measurement values obtained from dorsoventral and ventrodorsal lateral X-ray images in male and female cats

			Male			Female		
Measurement	Side	*N*	Mean	*SD*	*t* value	Mean	*SD*	*t* value
Long axis (LA) (v)	DV	14	4.77	0.31	0.611^{NS}	4.93	0.38	0.273^{NS}
	VD		4.84	0.35		5.07	0.29	
Short axis (SA) (v)	DV	14	3.80	0.35	0.385^{NS}	3.77	0.33	0.531^{NS}
	VD		3.93	0.41		3.85	0.32	
Vertebral heart size (VHS) (v)	DV	14	8.57	0.60	0.440^{NS}	8.70	0.67	0.343^{NS}
	VD		8.76	0.70		8.92	0.54	
Cardiothoracic ratio (CTR)	DV	14	0.52	0.05	0.342^{NS}	0.53	0.05	0.772^{NS}
	VD		0.50	0.48		0.52	0.06	

Abbreviations: DV, dorsoventral; *N*, number of cats; ^{NS}, not significant; *SD*, standard deviation;v, length measured in vertebrae; VD, ventrolateral.

TABLE 4 Comparison of the average of the measurements between sexes obtained from dorsoventral and ventrodorsal X-ray images

Measurement	*N*	Sex	Mean	*SD*	t value
Long axis (LA) (v)	14	♂	4.80	0.28	0.090^{NS}
	14	♀	5.00	0.31	
Short axis (SA) (v)	14	♂	3.86	0.36	0.674^{NS}
	14	♀	3.81	0.30	
Vertebral heart size (VHS) (v)	14	♂	8.67	0.60	0.523^{NS}
	14	♀	8.81	0.56	
Cardiothoracic ratio (CTR)	14	♂	0.51	0.04	0.327^{NS}
	14	♀	0.53	0.05	

Abbreviations: ♀, female; ♂, male; *N*, number of cats; ^{NS}, not significant; *SD*, standard deviation; v, length measured in vertebrae.

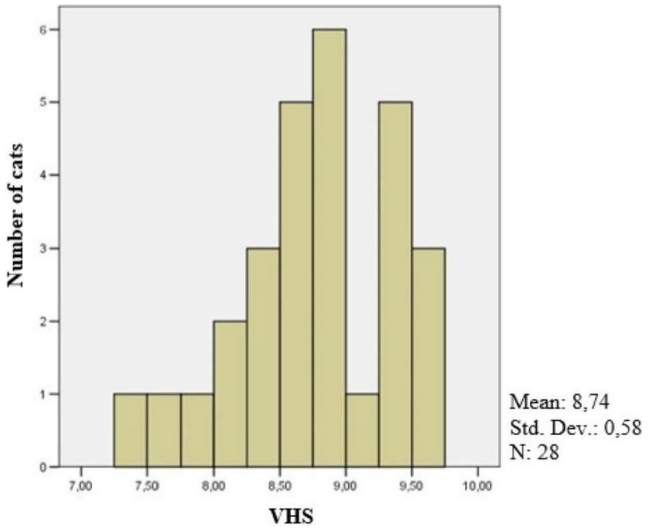

FIGURE 5 Distribution of VHS in dorsoventral and ventrodorsal radiographs

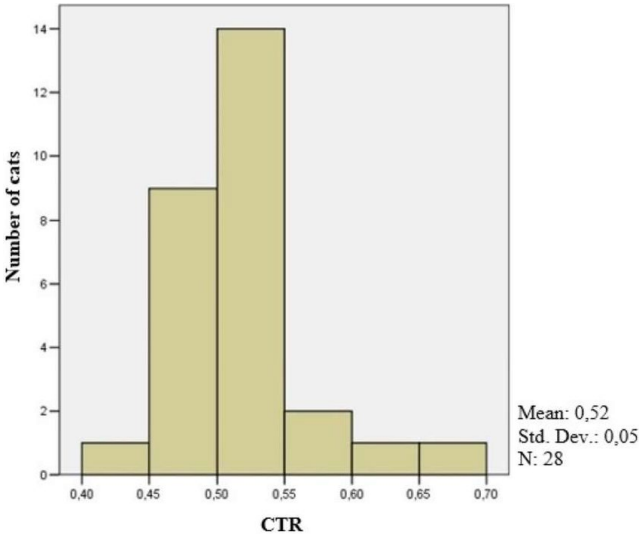

FIGURE 6 Distribution of CTR in dorsoventral and ventrodorsal radiographs

of dogs (Sleeper & Buchanan, 2001). On the other hand, it has been stated that the cardiac measurements in cats decrease to normal levels in the 6. and 12. months and VHS values are over the normal level in the younger cats (Gaschen et al., 1999). The Persian cats were preferred between the ages of 10 months and 10 years to have effective and reliable reference data.

It was determined that the VHS values we obtained from the thorax radiograph in this study conducted with the Persian cats were at 8.18 and 8.15 (8.16 ± 0.44 on average for 30 cats) vertebral level, respectively, in lateral radiograph and they were 8.67 and 8.81 in DV and VD radiographs for the male and female cat (8.74 ± 0.58 on average for 28 cats) vertebral level, respectively, and it was observed that they were higher than the VHS values of the other cat breeds specified in the literature (Litster & Buchanan, 2000a, 2000b; Ghadiri et al., 2008; Guglielmini et al., 2014; Oliveira et al., 2014; Bîrsan et al., 2016). Similarly, it has been emphasized in the study conducted on the vertebral heart size of pug, Boston terrier and bulldog breed dogs (Jepsen-Grant et al., 2013) that the reason behind why VHS values of these breeds were higher than the VHS values reported by Buchanan and Bücheler (1995) for dogs (9.7 ± 0.5) may be due to the fact that these breeds were brachycephalic breeds. In parallel with this study conducted with dogs, the fact that the VHS value we obtained from both lateral and dorsoventral and ventrodorsal images in the Persian cats was higher compared with the studies conducted on other cats may be since the Persian cats are brachycephalic breeds.

Litster and Buchanan (2000a) used the cats from different breeds in their studies, but we only included the Persian cats, which is a specific breed. In the interpretation of the cardiac measurements, the differences between the sex and the species have importance as well as breed. In some studies conducted with dogs, it has been emphasized that the VHS values of female dogs are lower compared with male dogs and the layer of fat in the obese animals increases the heart size in radiography (Lamb & Boswood, 2002). In the present study, it was determined that although the VHS values obtained from the lateral radiographic images were found to be higher in the male cats compared with the female cats, as in dogs, this was not statistically significant. As a result, we observed in the present study that the sex did not affect statistically the VHS values obtained from the radiographic images taken after lateral and supine lying and lying over sternum. This result

is in parallel with the idea that the lying position, dog size and sex did not have an effect on the VHS value determined by Greco et al. (2008) and Gugjoo et al. (2013) in various dog breeds.

In the study conducted by Litster and Buchanan (2000b) on cats, it was stated that the boundaries of the heart silhouette in DV imaging of the obese cats cannot be clear due to fat accumulation and the VD imaging is superior than the DV imaging. It has also been stated that the most common radiographic change observed in cats is the left atrial enlargement and its early diagnosis can be best observed in ventrodorsal radiograph (Buchanan, 2000). In another study conducted with cats, it was stated that the left atrium size was generally assessed better in lateral and ventrodorsal imaging (Schober et al., 2007). Carlisle and Thrall (1982) stated that the differences in the DV and VD thorax radiographs of 11 healthy cats were at minimum level and they did not have statistical significance. In this study, we conducted with healthy Persian cats, no statistical difference was found in male and female cats between the VHS and CTR values obtained from DV and VD imaging. Also, for the imaging of these two laying positions, the differences between the VHS values were insignificant reflecting the results in the studies of Ghadiri et al. (2008) and Litster and Buchanan (2000a). As a result, it was observed that the lying on the left and right sides and back and sternum did not affect VHS value. But, in the comparison of the average VHS values of the lateral radiograph and DV-VD radiograph, it was determined that there was a statistical difference at $p < .05$ level in the male cats between these two images and this difference was at the level of $p < .01$ in the female cats. As it is seen, the VHS values obtained from the right and left lateral and DV-VD radiographs did not have a statistical difference, but there was a statistical difference when the VHS values of the lateral and DV-VD images were compared. Also, one side is enough in the lateral measurements and there is a need for both lateral and DV-VD radiographs to determine the vertebral length in DV-VD VHS calculations and it is understood that this may cause an extra workload and cost.

In a radiographic study conducted with the cats and dogs infected with dirofilaria, a significant increase was observed in the diameter of caudal vena cava in vertebra compared with the reference group in accordance with the increase in the right heart filling pressure (Litster et al., 2005). This demonstrated the need to know the diameter of caudal vena cava in order to be a reference for the clinical examination of the healthy Persian cats.

Referring to all of the studies reviewed, VHS method is observed to be a more suitable method in the species such as cats which have a uniform body size compared to dog breeds with various body conformations.

Another method applied easily and objectively in the radiographic assessment of cardiac size is the cardiothoracic ratio. As in the vertebral heart size, the cardiothoracic ratio is a method, that can be applied only through the radiography without the need for any advanced hardware in the clinical environment, can determine the difference between the normal heart silhouette and the enlarged silhouette and, therefore, has a role in the diagnosis of heart disease (Bîrsan et al., 2016). It has been reported that CTR more commonly used in medicine obtained by proportioning the short-axis, where heart has its widest form, to the distance, where thorax has its widest form, in dorsoventral and ventrodorsal radiographs in animals and posterio-anterior radiographs in human beings have increased the death risk of the cardiac patients for whom CTR exceeds 0.50 (Giamouzis et al., 2008). In the study conducted by Dimopoulos et al. (2013) also with human beings, they stated that CTR of >0.55 indicated cardiomegaly. In the assessment of CTR and the increase in cardiac size, the use of VD images has been recommended rather than DV radiograph and it has been reported that animals have a normal heart silhouette only in the supine position (Van Den Broek & Darke, 1987). In the CTR studies conducted with monkeys and dogs, references values have been provided for these animal species and it has been reported that this ratio has not had statistical differences between sexes (Rocha-Neto et al., 2015; Azevedo et al., 2016). In the present study, we determined the cardiothoracic ratio through both DV and VD images in the Persian cats. There was no statistical difference between the results obtained from these images, and it was observed that there was no difference in the examination between sexes. However, since the VHS method is based on unchanged skeletal structures, it can be thought that it describes changes in heart size better than CTR.

With the present study, the reference values related to the vertebral heart size and cardiothoracic ratio effective in the assessment of thorax diseases, especially cardiomegaly, of the brachycephalic breed cats such as the Persian cats were determined and the data we believed to be useful for the clinician veterinary practitioners were obtained.

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CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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