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Research Article

Examination of morphometry of feline thoracic aorta with computed tomography*

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Abstract: This research was performed to specify the morphometry of the adult feline thoracic aorta (AoT) and to obtain reference data for this slice of aorta using computed tomography (CT) as a sensitive indicator for surgical operations and pathological diagnosis in developing veterinary medicine. CT images of the thorax area were used in the study, in which 23 adult short-haired cats (11 male and 12 female) were enrolled. All of the cats were anesthetized with a combination of tiletamine and zolazepam, and then Omnipaque™ was applied. Fifteen transverse slice images of the body of thoracic vertebrae were taken, located between Th6 and Th13 and the area between the vertebrae of cats. After determining the dorsoventral diameter (DVD) and transversal diameter (TD) of these slices, the cross-sectional area (CsA) and total volume of the AoT were determined using the dotted area measuring technique, which is the basis of the Cavalieri principle. It was found that DVD and TD had closer values for male and female cats, and CsA was found to be higher for females, but no significant statistical difference was found. Although AoT volume was measured according to the Cavalieri principle and was found higher in males than in female cats, there was no statistical difference based on sex. When univariate analysis was used, it was revealed that sex was not an important factor in determining the dimensions of the AoT. It was found that the shape of the AoT was not different between sexes, and the general shape was dorsoventral elliptic.

Key words: Thoracic aorta, computed tomography, feline

Introduction

The aorta starts from the sinus aorta and ostium aorticum of the left ventricle. It rises from the right side of the pulmonary artery and slopes to the cranial direction, and is called the ascending aorta. The ascending aorta forms an aorta angle facing the craniodorsal direction. After this arch structure, the aorta rises to a vertebral column on the sixth thoracic vertebral level behind the musculus longus colli and is called the descending aorta. Part of the descending aorta in the chest cavity is the thoracic aorta (AoT). The part that passes to the abdominal cavity from the aortic hiatus is the abdominal aorta (1).

The aorta is a flexible artery carrying highly pressured blood from the heart. Although the heart pumps the blood discontinuously, blood keeps

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flowing continuously within the flexible artery by expanding during the systolic phase of the heart and tightening during the diastolic phase of the heart. The tunica adventitia of the wall of the artery is located on the outside, and a large percentage of this connective tissue includes veins and nerves supporting the arterial wall. Collagen fibers in the tunica media forming the medial layer of the wall of the aorta restrict distention of the vein wall by forming a network of supporting smooth muscle cells. The tunica intima layer, located in the innermost area, is composed of subendothelial connective tissue frequently affected by arteriosclerotic changes, and small quantities of smooth muscle cells, collagen, and flexible fibrils (2–4).

Computed tomography (CT), used frequently in contemporary veterinary medicine, has an important place in both the examination of anatomical structures in the thoracic area and the relations between them, and in the diagnosis of cardiovascular diseases. The abilities to manipulate the contrast of images, to evaluate without superimposition, and to avoid any need to reposition the patient make CT more useful than other radiography techniques (5). High resolution CT images and thin slide thickness are required to interpret images correctly and to obtain fundamental reference data.

Determination of volume and cross-sectional surface areas of the relevant organ or structure in images taken from tomographic scans is possible by using the Cavalieri principle (6,7). Volumes of all types of structures, the lines of which are detected by macroscopic or microscopic research, can be determined by using this principle (8,9). Cross-sectional areas of structures in the images can be determined by developed analysis systems. However, research shows that dotted area measurement techniques give more reliable results than planimetric techniques (10,11).

In another study, the heart structure and topographic relations of the aorta were examined in CT images of cats scanned throughout the length of the thorax (12). Thoracic and cardiac structures of cats were also examined in a different study, and it was suggested there that a slice having a 15-mm thickness is not suitable for adequate determination (13). In the literature, there has been much research focused on thoracic diseases such as aortic stenosis in cats resulting from arterial mineralization (14), aortic thromboembolism characterized generally with heart diseases (15,16), aortic aneurysm (17), aortic dilatation related to atherosclerosis in humans (18), and congenital stenosis of the aorta in humans and cats (19,20), in addition to normal anatomic structures of the thoracic area of cats (12,13,21). On the other hand, research on thoracic diseases of cats and dogs using CT (22–24) showed the importance of CT as a noninvasive diagnosis method for small animal clinics. In addition to research in which diameter measures of the thoracic aorta were determined by using CT in humans (25), CT was used in research on the morphometry of the AoT of German shepherd dogs, and reference values were given for that breed (26). However, there has not been any morphometric research on feline AoT diameters, volume, and reference values for the cross-sectional area.

This research was performed to specify the morphometry of the adult feline AoT, and to obtain reference data for this slice of aorta using CT as a sensitive indicator for surgical operations and pathological diagnosis in developing veterinary medicine.

Materials and methods

Twelve female cats with an average weight of 3.5 kg and 11 male cats with an average weight of 3.8 kg, for a total of 23 adult domestic cats (*Felis silvestris catus*) who were healthy upon physical examination, were subjected to the research. Before anesthesia, 0.1 mg/kg atropine sulfate (Atropine®; Vetaş, İstanbul, Turkey) was given preoperatively and subcutaneously, and a combination of tiletamine and zolazepam (Zoletil®50; Virbac) was applied intramuscularly for anesthesia at 5 mg/kg.

CT images were scanned after application of Omnipaque™ (Opakim, İstanbul, Turkey) at 300 mgI/mL and 3 mL/kg intravenously (cephalic vein) to provide resolution of the AoT.

Cats were placed on the CT table in the sternal position, and CT images in high resolution were taken from thoracic area.

For each cat, a dorsoventral explanatory image was taken initially, and then a total of 15 transversal slices were captured from the middle points of each thoracic vertebra located between Th_6 and Th_{13} and between vertebrae (Figure 1). Tomographic slices taken transversally were scanned at 1.5 s of scanning duration, 5 mm of thickness, 125 mA, and 130 kV of filtration (PICKER CT Scanner).

The dorsoventral diameter (DVD) and transversal diameter (TD) values of the AoT were measured from slices taken from the thorax area (Figure 2). The cross-sectional areas (CsAs) of 15 transversal slices taken from the AoT were evaluated by using a stereological technique, and volumes of the AoTs were determined by using the point-counting principle for each cat. After CT scanning, cats were cared for until they recovered from the anesthesia.

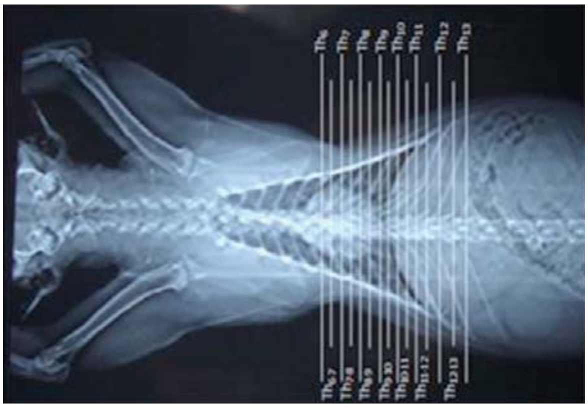

Figure 1. CT slices taken between Th_6 and Th_{13} from cats in dorsoventral direction.

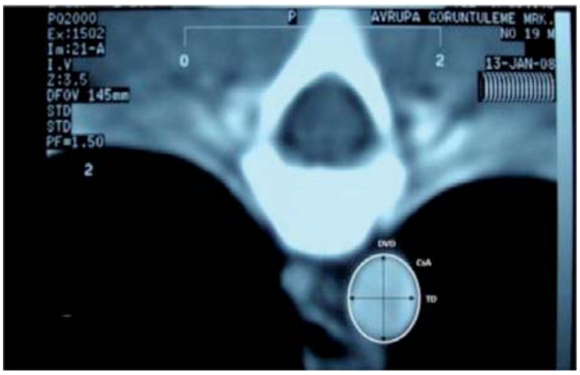

Figure 2. Dorsoventral diameter (DVD) taken from transversal slice of thoracic aorta; transversal diameter (TD) and cross-sectional surface area (CsA) of thoracic aorta.

Volume determination

According to the point-counting principle using the Cavalieri method, the following formula was used to calculate the total area of the AoT between Th_6 and Th_{13} using 0.4-cm style gapped grids (Figure 3):

$$V = t \times a(p) \times \Sigma P,$$

where t is the section thickness (5 mm), $a(p)$ is the area represented by a point in the grid, and ΣP is the total point number placed on the surface area of the slice.

The following formula was used to determine calculations for tomographic images (6):

$$V = t \times [((SU) \times d) / SL]^2 \times \Sigma P,$$

where t is the section thickness (5 mm), SU is the length of the scale that shows the enlarged image, d is the distance between 2 points that are on the test points of the grid, SL is the length of the scale of the image measured with ruler or caliper, and ΣP is the total number of points hitting the surface area of the sections.

The coefficient of error (CE) was determined, and thus the effectiveness of the sample and the density of grid points were measured according to the description from the literature (27–29).

Area determination

In the determination of area using the Cavalieri principle, image enlargement was used as in the determination of volume; the length of the scale that shows the enlarged image (SU) and the measured length of the scale of the image with ruler or caliper (SL) were also considered in the formula.

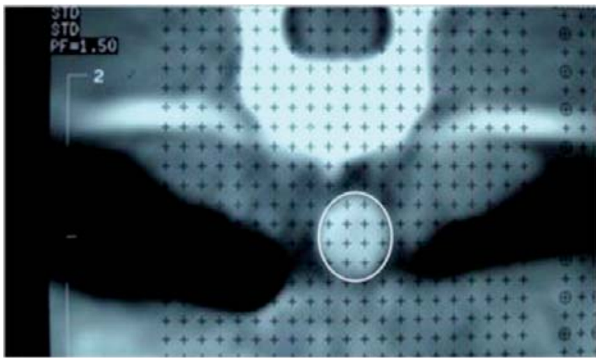

Figure 3. Estimating of CsA and volume of thoracic aorta by using transparent grids with 0.4-cm probability intervals.

The surface area of each of the 15 slices taken from the AoT between Th_6 and Th_{13} with CT were determined according to the following formula (30):

$A_i = [((SU) \times d) / SL]^2 \times \Sigma P.$

Statistical analysis

The general linear analysis model univariate analysis procedure was used to analyze the data set. *Sex*, *area* (Th_6, Th_{6-7}, ...,Th_{13}), and *area* × *sex* interactions were included in the model as fixed factors. The weights of the cats were included in the model as covariates.

Pearson's correlation test was used to define relations between parameters. SPSS 13.0 was used for analysis.

Results

In this research, DVDs and TDs of slices were taken from the body of vertebrae between Th_6 and Th_{13} and the area between vertebrae. Statistical data of surfaces of CsAs were determined by the dotted-area measuring technique, and the average value of the volume of the AoT was gathered from tomographic images of female and male cats.

CT findings of localization of the thoracic aorta

The AoT was observed ventrolateral to the body of Th_6 within 5-mm CT slices taken from the thorax area of the cats. It was found that the AoT was located ventromedial of the vertebral column in its caudal direction.

Volume determination

The average volume of the AoT was found to be 1.19 ± 0.043 mm^3 (mean ± SE) for female cats and 1.23 ± 0.084 mm^3 (mean ± SE) for male cats.

Statistical analysis of DVD, TD, and CsA

It was observed that the differences between parameters of CsAs (DVD, TD, and CsA) had significance ($P < 0.001$) (Table 1). Differences for *sex* and *area* × *sex* interaction parameters were not significant ($P > 0.05$). DVD was the highest at the Th_6 area and the lowest at Th_{12-13}. It was found that the differences in the area between slices of Th_{9-10} and Th_{13} were not significant. The DVD values of areas showed a trend of decreasing from Th_6 caudally.

The highest value for TD was again found in the Th_6 area. However, the difference between areas Th_6 and Th_{7-8} was not significant. The lowest value for TD was found in Th_{11-12}. The difference between the Th_9 and Th_{13} areas was not significant. TD values between the Th_6 and Th_{10} areas had a decreasing trend toward the caudal direction.

The highest value was observed in Th_6 slices and the lowest was found in Th_{11-12} slices for CsA. The differences for the slices from Th_9 were not significant.

Although the sex factor was statistically not significant for DVD, TD, and CsA, females had higher values for area determination.

Based on the performed measurements, it was observed that the AoT was generally elliptical in shape for both male and females.

Correlations at important levels were found between 3 parameters (DVD, TD, and CsA) for all of the cats ($P < 0.01$). In addition, higher correlation constants for these 3 parameters were found in male cats (Table 2–4).

Discussion

Normal morphometric values of feline AoTs must be known to diagnose aortic thromboembolism characterized with heart diseases (15,16), aortic aneurysm (17), and aortic stenosis, which are often seen with congenital heart diseases (31) for these animals. CT, as the most sensitive method known to detect pathological structures and to choose surgical operations, was used to obtain the concerned reference data in this study. Three-dimensional properties of examined structures can be deduced from 2-dimensional slice images scanned with CT. CsAs, and thus the total volume of the structures, can be determined using these types of analysis systems with special software. However, many researchers have shown that the dotted-area measuring technique gives more effective and reliable results (10,11).

In a study in which localization and topographical relations of the AoT of cats were examined with CT, it was reported that the descending aorta was located ventrally to the Th_6 body and the left side (21). In our study, we also found from CT images of 5-mm slices that the AoT was likewise located ventrolaterally to the center of the Th_6 body.

Table 1. Analysis results for dorsoventral diameter (DVD), transversal diameter (TD), and cross-sectional area (CsA) of thoracic aorta.

Area	DVD (mm)	TD (mm)	CsA (mm^2)
	***	***	***
Th_6	5.54 ± 0.100^{a}	5.18 ± 0.099^{a}	21.10 ± 0.628^{a}
Th_{6-7}	5.05 ± 0.100^{b}	$4.99 \pm 0.099^{a,b}$	18.87 ± 0.628^{b}
Th_7	$4.91 \pm 0.100^{b,c}$	$4.98 \pm 0.099^{a,b,c}$	$17.81 \pm 0.628^{b,c}$
Th_{7-8}	$4.96 \pm 0.100^{b,c}$	$4.97 \pm 0.099^{a,b,c}$	$17.74 \pm 0.628^{b,c}$
Th_8	$4.84 \pm 0.100^{b,c,d}$	$4.84 \pm 0.099^{b,c,d}$	$17.03 \pm 0.628^{c,d}$
Th_{8-9}	$4.78 \pm 0.100^{b,c,d}$	$4.71 \pm 0.099^{c,d,e}$	$16.17 \pm 0.628^{c,d,e}$
Th_9	$4.69 \pm 0.100^{c,d,e}$	$4.58 \pm 0.099^{d,e,f}$	$15.38 \pm 0.628^{d,e,f}$
Th_{9-10}	$4.57 \pm 0.100^{d,e,f}$	$4.57 \pm 0.099^{d,e,f}$	$15.26 \pm 0.628^{e,f}$
Th_{10}	$4.60 \pm 0.100^{d,e,f}$	$4.47 \pm 0.099^{e,f}$	$15.18 \pm 0.628^{e,f}$
Th_{10-11}	$4.58 \pm 0.100^{d,e,f}$	$4.50 \pm 0.099^{e,f}$	$14.71 \pm 0.628^{e,f}$
Th_{11}	$4.49 \pm 0.100^{e,f}$	$4.46 \pm 0.099^{e,f}$	$14.79 \pm 0.628^{e,f}$
Th_{11-12}	$4.50 \pm 0.100^{e,f}$	4.37 ± 0.099^{f}	14.34 ± 0.628^{f}
Th_{12}	$4.46 \pm 0.100^{e,f}$	$4.46 \pm 0.099^{e,f}$	$14.48 \pm 0.628^{e,f}$
Th_{12-13}	4.41 ± 0.100^{f}	$4.45 \pm 0.099^{e,f}$	$14.46 \pm 0.628^{e,f}$
Th_{13}	$4.46 \pm 0.100^{e,f}$	4.41 ± 0.099^{f}	$14.71 \pm 0.628^{e,f}$
Sex	NS	NS	NS
Male (n = 11)	4.72 ± 0.037	4.67 ± 0.037	16.05 ± 0.236
Female (n = 12)	4.72 ± 0.036	4.66 ± 0.036	16.22 ± 0.226
Area × sex	NS	NS	NS
Grand mean	4.72 ± 0.026	4.66 ± 0.026	16.14 ± 0.162

^{NS}: Not significant. Different letters used as a subscript in the same column express statistical differences.

Table 2. Correlation analysis between measured parameters of thoracic aorta of the cats.

	DVD	TD	CsA
DVD		0.886**	0.921**
TD			0.909**
CsA			

**P < 0.01.

Table 3. Correlation analysis between measured parameters of thoracic aorta of the male cats.

	DVD	TD	CsA
DVD		0.896**	0.933**
TD			0.922**
CsA			

**P < 0.01.

Table 4. Correlation analysis between measured parameters of thoracic aorta of the female cats.

	DVD	TD	CsA
DVD		0.868**	0.900**
TD			0.887**
CsA			

**P < 0.01.

In stereological methods, determination of the CE is important in deciding the density of grid dots and the adequate number of slices (32). For research, CE values less than 5% are acceptable ranges (8,28,29). In this research, finding a CE value of 4% for male and female cats showed that a 0.4-cm grid was an acceptable choice.

In using diameters and CsAs for the measuring of the AoT of German shepherd dogs with CT, it was found that the highest value was at the starting point of the AoT (26). In the same research, it was reported that the shape of the AoT was dorsoventrally elliptical for male dogs in general and transversally elliptical for female dogs. In our research on cats, we found that the diameter and CsA measurements of the AoT were high at the starting point of the AoT (Th_6), which showed parallelism with the results of the research on German shepherd dogs. However, the shape of the AoT was dorsoventrally elliptical for both male and female cats in general.

In this research, in which univariate analysis was used, it was observed that sex is not a significant factor in determining the dimensions of the AoT. Using the same analysis, it was shown that sex is a significant factor in humans (18).

By evaluating the statistical analysis of parameters of 15 parts of the AoT with CT, it is expected that this study may constitute a reference for surgical operations of cats having importance in veterinary medicine and also enable easy detection of clinical and pathological changes of the AoT.

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