pISSN 1598-298X / eISSN 2384-0749
J Vet Clin 37(2) : 82-87 (2020)
http://dx.doi.org/10.17555/jvc.2020.04.37.2.82

Journal of Veterinary Clinics
www.ksvc.or.kr

Evaluation of Azygos Vein to Aorta Ratio using Multi-Detector Computed Tomography in Dogs

Hyunyoung Park, Jungyong Kim, Soochan Kim*, Woochang Jeong*, Jungwoo Lee*, Sooyoung Choi, Hojung Choi and Youngwon Lee[1]**

College of Veterinary Medicine, Chungnam National University, Daejeon 34134, Korea
**Africa Animal Medical Center, Seoul 07590, Korea*
***College of Veterinary Medicine, Kangwon National University, Chuncheon 24341, Korea*

(Received: February 18, 2020 / Accepted: April 01, 2020)

Abstract : The purpose of this study is to evaluate the azygos vein to aorta diameter ratio (AV/AO ratio) in healthy dogs and dogs with diseases that may cause azygos vein dilation. The normal groups included eleven healthy beagle dogs and eleven small breed dogs. The abnormal group included 43 dogs that had diseases with high right atrial pressure (RA group), obstruction of cranial or caudal vena cava (CVC group) and porto-azygos shunt group (PSS group). The diameter of AV and AO were measured at three sites on thoracic CT images; the level of the cranial endplate of 12th thoracic vertebra (TV level), the tracheal bifurcation (TB level) and the insertion to the cranial vena cava (CrVC level). The AV/AO ratio at the CrVC level had significantly higher values than those at the TV and TB levels in the normal groups. The AV/AO ratios of TV and TB levels in the CVC group and the values at all measurement sites of the PSS group were significantly higher than the normal groups. AV/AO ratio will be a useful factor for the evaluation of various clinical conditions that change the AV diameter with respect independent to the body weight in dogs.

***Key words* :** azygos vein, dog, computed tomography, portosystemic shunt, caudal vena cava.

Introduction

The azygos vein (AV) is formed at the third lumbar vertebrae by the union of the third lumbar intervertebral veins (7). It runs cranially through the aortic hiatus into the thorax and empties into the cranial vena cava (7). Right and left veins are present in the embryo, but the pattern is later simplified that the main trunk is the right-sided AV in dogs (6). AV system composes blood flow of lumbar, dorsal costo-abdominal, dorsal intercostal and bronchoesophageal veins (2,7). It carries the blood from the vertebral venous plexus of the thorax and abdomen via the dorsal intercostal and lumbar veins to the right atrium (2,7).

In humans, the enlargement of AV can be seen on the thoracic radiographs or computed tomographic (CT) images in specific clinical status, which are hemodynamic changes including fluid overload and an increase in right atrial pressure and superior or inferior vena cava obstructions (5,14,15). These are most commonly due to right-sided heart failure, tricuspid valvular diseases, pulmonary hypertension and portal hypertension (5,15). Elevation of right atrial pressure makes the venous return to the right atrium from both superior and inferior vena cava difficult (17). Superior or inferior vena cava obstruction can be caused by the tumor, thrombus and lymphadenopathy and development of several collateral vessels has been reported in human and veterinary medicine when the obstruction is chronic (5,14,15,19). These collateral venous pathways provide venous drainage from the caudal site of the obstruction and some empty into the AV resulting in AV dilation (14). The configurations of collateral pathways vary depending on the level of the obstructions of vena cavae (10,15,18).

The multi-detector CT angiography has become a useful diagnostic tool for the non-invasive imaging of vascular anatomy in human and veterinary medicine (16,19,20). CT images provide detailed anatomic information that is able to identify the smaller veins (16,19). In human studies, the diameter of the AV was examined by chest radiography and CT (1,20, 22). Evaluation of the normal diameter of AV might be important to consider the various pathologic process (20). Moreover, the degree of AV dilation is an indicator of both severity and increased risk of mortality associated with acute pulmonary embolism and right heart overload (8,9).

To our knowledge, there are no studies that assess the diameter of normal AV considering the various body weight of dogs on CT examinations. The purpose of this study is to evaluate the size of AV as the AV to aorta ratio (AV/AO ratio) to overcome body weight variation in normal dogs using CT venography and evaluate the changes of the AV/AO ratio in dogs with diseases, which can cause dilation of the AV.

Materials and Methods

The study design was a combination of experimental design

[1]Corresponding author.
E-mail : lywon@cnu.ac.kr

of healthy Beagle dogs with a retrospective study of healthy small breed dogs in the normal groups, and case-control study of dogs with diseases that may cause AV dilation in the abnormal groups. This study was performed under the guidance of Chungnam National University Animal Care and Use Committee.

Subjects

Normal group

Normal group is classified into subgroup B (Beagle) and S (Small breed) according to the dog's breeds. In subgroup B, eleven healthy beagle dogs (8 males and 3 females) between 1.5 to 7 years of age weighing from 7.2 to 14.8 kg were used for the study. Physical examinations, complete blood cell counts, serum chemistry analyses, and thoracic and abdominal radiography were performed to determine the health status of the dogs. Blood pressure measurement, electrocardiography, and echocardiography were also performed for the exclusion of dogs with any other conditions that may cause dilation of AV. Skin turgor test and capillary refill time were performed for evaluation of hydration status. In subgroup S, the dogs underwent abdominal and thoracic CT with various reasons and with any of the following were excluded: tricuspid valve insufficiency, pulmonary hypertension signs including enlargement of the pulmonary artery and hepatomegaly, cranial or caudal vena cava obstruction, and pleural or peritoneal effusion.

Abnormal group

The dogs were selected from image databases of College of Veterinary Medicine of Chungnam National University, Ian Diagnostic Imaging Center, and Africa Animal Medical Center. Forty-three client-owned dogs were prospectively enrolled when they had a diagnosis of increased the right atrial pressure, compression, or invasion into caudal vena cava (CdVC), and porto-azygos portosystemic shunt (PSS) by several imaging modalities. All dogs underwent thoracic or abdominal CT scanning due to various reasons. CT scanning parameters and contrast medium administration varied with institution and the individual status of the dogs.

Computed tomography

In Beagle dogs of the normal group, the dogs were fasted for 12 hours while water was freely fed prior to CT scanning. All dogs were scanned under the general anesthesia and positioned in sternal recumbency. Each dog was hyperventilated before the CT scan, and intermittent positive pressure ventilation (10-15 cmH_2O) was performed during the scanning. All images were obtained using a 32-detector-row CT scanner (Alexion™, Canon, Japan) with the following parameters were used: 120 kVp, 100 mAs, 1 mm slice thickness, 0.75 second rotation time and 0.0938 collimation beam pitch. Intravenous iodinated contrast medium, iohexol (Omnipaque®, GE healthcare, Ireland, Ireland), of 600 mgI/kg was administered with an injection rate of 2 ml/sec using a power injector (Salient™, Imaxeon Pty. Ltd., Australia). In Beagle dogs, the scan field of view was from the caudal endplate of the third lumbar vertebrae to the cranial endplate of the second thoracic vertebrae, which was performed scanning from caudal to cranial. Scanning was started 40-60 seconds after contrast media administration. In small breed dogs of the normal group, scan protocol varied with the institutions and the status of each patient, and post-contrast images were obtained 30-90 seconds after contrast medium administration.

Image analysis

Measurements were performed independently by two clinicians experienced in veterinary medical imaging based on consensus. The diameters of AV and AO were measured at three different sites, which were the level of the cranial endplate of 12^{th} thoracic vertebra (TV level), the tracheal bifurcation (TB level) and the insertion to the cranial vena cava (CrVC level). Electronic calipers were used to obtain the maximum diameter perpendicular to the long axis of the cross-section of the vessels (Fig 1). All values were obtained by average from three repetitive measurements, and the AV/AO ratio was calculated. The origin of AV in the abdomen and the insertion of AV to the cranial vena cava on CT images were also recorded.

Statistics

Statistical analyses were performed using commercially available software (IBM SPSS statistics 22.0, IBM Corp, New York, USA). Descriptive statistics including mean, median, range (from minimum to maximum), standard deviations (SD) and 95% confidence interval (CI) of the mean

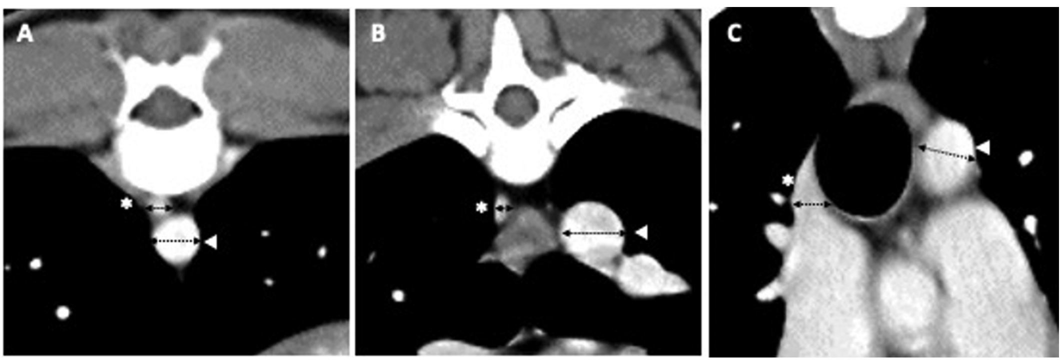

Fig 1. Post-contrast CT images of the azygos vein in a normal dog illustrating where the diameters of AV (asterisk) and aorta (arrowhead) are measured at the level of cranial end plate of the 12th thoracic vertebra (A), tracheal bifurcation (B) and insertion to the cranial vena cava (C).

values were calculated for the diameter of AV and aorta, and the AV/AO ratio. Differences between normal and abnormal groups were evaluated by unpaired t-test. Comparison of the AV/AO ratios among the groups or the measurement sites were tested by one-way ANOVA with Turkey or Scheffe test. Pearson correlation was used to evaluate the relationship of vessel diameter to age or body weight. A probability value ($p < 0.05$) was considered statistically significant.

Results

Subjects

The eleven small breed dogs in the normal group were composed of four malteses, two poodles, two Shih-tzu dogs, and each of Spitz, Yorkshire terrier, and Chihuahua weighing from 2.0 to 7.2 kg and aged between 8 to 13 years.

In the abnormal group, a total of forty-three dogs was included and categorized into three subgroups: high RA pressure (RA), obstruction of CdVC (CVC), and porto-azygos PSS groups (PSS). Yorkshire terrier (21%) was the most common breed followed by Maltese (19%), Shih-tzu (17%), cocker spaniel (13%), Pekingese (7%), poodle (7%) and mongrel (7%). Each of Schnauzer, Beagle and pointer were also included. Thirteen dogs were in RA group, where tricuspid valve insufficiency was diagnosed in nine dogs, right atrial mass in two, intracardiac thrombosis and pulmonary thromboembolism in each one. In the CVC group, sixteen dogs were included and diagnosed with adrenal masses in 8, renal masses in 3, hepatic masses in 2, each one of the abdominal, ovarian, and caudal mediastinal masses. Fourteen dogs were included in the PSS group.

Vascular evaluation

The AV was originated at the first lumbar vertebra level in

Table 1. The AV and AO diameters, and AV/AO ratio in normal group

		Group B			Group S		
		TV	TB	CrVC	TV	TB	CrVC
AV	Mean ± SD	$2.73 \pm 0.18^{b,c}$	$3.34 \pm 0.41^{a,c}$	$4.62 \pm 0.56^{a,b}$	$1.99 \pm 0.47^{b,c}$	$2.67 \pm 0.55^{a,c}$	$3.91 \pm 0.60^{a,b}$
	95% CI	2.60-2.85	3.06-3.61	4.24-5.00	1.67-2.31	2.30-3.04	3.51-4.31
	Range	2.5-3.0	2.8-4.3	4.0-5.7	1.4-2.7	1.9-3.9	3.2-4.9
AO	Mean ± SD	$6.76 \pm 0.60^{b,c}$	$8.25 \pm 0.88^{a,c}$	$9.02 \pm 0.99^{a,b}$	$4.93 \pm 0.93^{b,c}$	6.41 ± 0.96	7.88 ± 0.92
	95% CI	6.36-7.17	7.66-8.83	8.35-9.69	4.30-5.55	5.77-7.05	7.17-8.67
	Range	6.0-7.9	6.8-9.6	7.9-11.0	3.8-6.4	4.5-7.7	6.2-9.1
Ratio	Mean ± SD	0.40 ± 0.03	0.41 ± 0.04	$0.53 \pm 0.09^{a,b}$	0.40 ± 0.03	0.42 ± 0.04	$0.50 \pm 0.04^{a,b}$
	95% CI	0.38-0.43	0.37-0.44	0.46-0.58	0.38-0.42	0.39-0.45	0.47-0.52
	Range	0.34-0.47	0.32-0.50	0.38-.066	0.34-0.44	0.35-0.51	0.43-0.57

[a)]Significant difference with respect to TV level. [b)]Significant difference with respect to TB level. [c)]Significant difference with respect to CrVC level; CI, confidence interval.

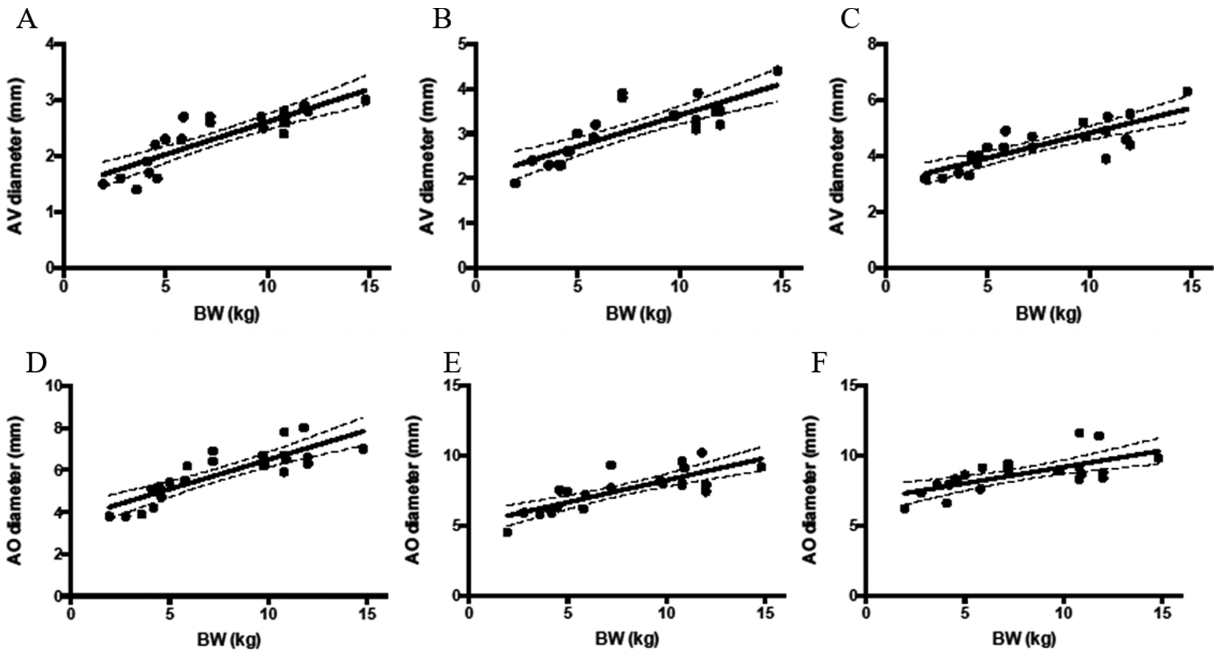

Fig 2. Correlation with AV diameter and body weight (BW) (A, B, C), and AO diameter and BW at all levels (D, E, F). Pearson' correlation coefficient is 0.856 (A), 0.814 (B), 0.822 (C), 0.841 (D), 0.805 (E), and 0.684 (F) respectively, with a P value of <0.001.

80% of the normal dogs and at second lumbar vertebra level in 20%. The insertion level of the AV into the cranial vena cava was between the fourth and fifth thoracic vertebrae as 65% and 35%, respectively.

The AV and AO diameter values in the normal groups are shown in Table 1. There were significant differences in AV diameter of both subgroup B and S among the three different measurement sites ($p < 0.05$). In this study, AV diameters on all three measurement sites were strongly related to body weight (Fig 2). Aorta diameter obtained from the three measurement sites gradually increased with the cranial direction. In group B, a significant difference in aorta diameter was detected among the three measurement sites ($p < 0.001$). However, in group S, it was only significantly lower at the TV level compared to the values from two other sites ($p < 0.001$). Aorta diameter was also significantly correlated with the body weights (Fig 2).

The AV/AO ratio in the normal groups are shown in Table 1. The AV/AO ratio at the CrVC level was higher than those measured on the other sites ($p < 0.001$). There were no significant differences in the AV/AO ratios between group B and S, and ages of the dogs did not affect the AV/AO ratio.

In the abnormal groups, the descriptive data related to the AV/AO ratio on each of the measurement sites are shown in Table 2. The AV/AO ratio of the RA group measured at the CrVC level had significantly higher values than at the TV and TB level ($p = 0.013$). Compared to the normal groups, AV/AO ratio at the three measurement sites in the RA group represented the trend of increase, but the difference was not statistically significant. The AV/AO ratios of TV and TB levels of the CVC group were significantly higher than those measured in the normal groups. The AV/AO ratios in the PSS group were significantly increased at all measurement sites than the normal groups, and it was especially higher at the TV level ($p < 0.001$) (Fig 3).

Discussion

The evaluation of anatomical variations of the normal AV was previously studied using CT angiography in humans (2,13,15,20,21). Based on these studies, numerous variations in the origin of the AV were outlined in humans, but studies related to AV were rarely reported in dogs. The origin of AV was described where the third lumbar intervertebral veins were merged at the third lumbar vertebrae level in an anatomic study (7). However, the AV was visible at the level of the first lumbar vertebrae on CT images (23). In the present study, we could observe two locations of origins of AV, which were the first and second lumbar vertebrae levels. The discrepancy between anatomical and imaging studies was considered that the AV is too small to be identified on CT images at the real site of origin.

In this study, the mean AV diameters of the beagle and small breed dogs at the insertion into the CrVC were measured 4.62 and 3.91 mm, respectively. According to the previous report, the AV diameter is approximately 8 mm at its junction with the CrVC (7). The difference from the previous study may result from wide variation of body weights in dogs. Therefore, the absolute AV diameters cannot be used alone as a criterion of AV dilation. There was a significant correlation between AV and body weight, whereas AV diameter had no correlation with age in this study. Similarly, the AV does not increase proportionately in size with age in a human report (1). However, the relation between AV and body weight has not been studied in humans. In this study, the measurement values of AV were gradually increased from the TV level to the CrVC level, and the mean of the

Table 2. The AV/AO ratio in the abnormal groups

	RA group			CVC group			PSS group		
	TV	TB	CrVC	TV	TB	CrVC	TV	TB	CrVC
Median	0.40	0.44	0.54	0.54	0.47	0.48	0.90	0.64	0.76
Mean ± SD	0.41 ± 0.11	0.48 ± 0.14	0.62 ± 0.24*	0.54 ± 0.17	0.49 ± 0.12	0.51 ± 0.12	0.82 ± 0.37	0.65 ± 0.17	0.72 ± 0.22
Range	0.31-0.71	0.30-0.84	0.44-1.26	0.29-0.86	0.32-0.81	0.31-0.74	0.37-1.62	0.32-1.00	0.40-1.03

*Significantly difference from other measurement sites in the RA group ($p < 0.05$).

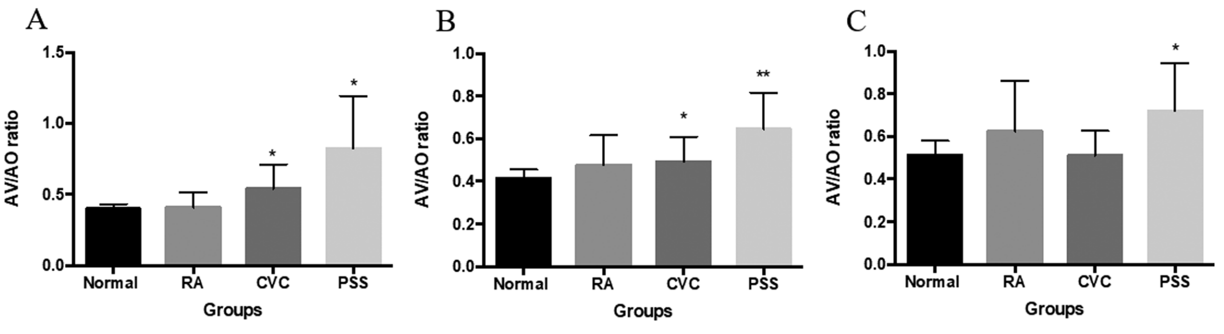

Fig 3. The AV/AO ratio of the normal and abnormal groups. The AV/AO ratios measured on the level of the TV (A), TB (B), and CrVC (C). The AV/AO ratios on the TV and TB level are significantly increased in the CVC group compared with normal group. The AV/AO ratios on all sites are significantly increased in the PSS group compared to normal group. *$P < 0.05$, **$P < 0.001$.

diameter at the CrVC level was significantly higher compared to those from other sites.

In human reports, it is thought that the degree of AV dilation could be affected by pulmonary diseases (11,21). Acquired abnormalities causing enlargement of AV have been reported fluid overload, an increase of mean right atrial pressure, superior vena cava obstruction, and inferior vena cava obstruction in humans (3,4,12,15). The high right atrial pressure is the main reason for the AV dilation and correlates significantly with the AV diameter (15). When the compensation for obstruction of the superior vena cava or inferior vena cava is exceeded, collateral vessels are developed. In this case, the AV system is the most important pathway for decompression of obstruction (4,15).

In this study, the AV/AO ratio in the abnormal group represented the tendency of increase compared with the normal group. The AV/AO ratios of the CVC group and the PSS group were especially significant different from the normal group. The change of the AV/AO ratios in the PSS group was similar to the results of the previous report, where the AV/AO ratios in the PSS group were about twice than the normal group (24). The AV/AO ratios of the CVC group at the level of TV and TB were significantly different from the normal group, except only the ratio at the CrVC level. It seems that the level of obstruction affects the degree of the AV dilation. In previous human literature, as the lesion of the obstruction is positioned whether above or below the AV, the flow direction will be retrograde or antegrade (15). However, the AV/AO ratio of the RA group was not significantly increased than the normal group. It is thought that the RA pressure increase enough to cause the AV dilation does not occur due to the chronic disease process.

A major limitation of this study was that the results from a number of experimental animals and breeds were small in the normal group, and further investigation is required in a larger population, including various breeds. Other limitations in the CVC group, we did not consider the location and duration of the CVC obstruction.

In conclusion, contrast CT angiography is a useful method for the identification and assessment of the AV. The AV/AO ratio obtained from CT images is thought to be a useful factor for evaluating the AV dilation caused by increase of the right heart pressure, caudal vena cava obstruction, and porto-azygos shunt independent to body weight variations.

Acknowledgment

This work was supported by research fund of Chungnam National University.

References

1. Berdon WE, Baker DH. Azygos vein dilatation in acquired obstruction of the inferior vena cava. Pediat Radiol 1974; 2: 221-224.
2. Bowsher D. A comparative study of the azygos venous system in man, monkey, dog, cat, rat and rabbit. J Anat 1954; 88: 400-406.
3. Chait A. Interstitial pulmonary edema. Circulation 1973; 45: 1223-1330.
4. Dahan H, Arrive L, Monnier-Cholley L, Le Hir P, Zins M, Tubiana JM. Cavoportal collateral pathways in vena cava obstruction: imaging features. Am J Rentgenol 1998; 171: 1405-1411.
5. Dudiak CM, Olson MC, Posniak HV. CT evaluation of congenital and acquired abnormalities of the azygos system. Radiographics 1991; 11: 233-246.
6. Dyce KM, Sack WO, Wensing CJG. In: Textbook of Veterinary Anatomy. London: Saunders, 2002.
7. Evans HE, de Lahunta A. Miller's Anatomy of the Dog. Elsevier Health Sciences, 2013.
8. Ghaye B, Ghuysen A, Willems V, Lambermont B, Gerard P, D'Orio V, Dondelinger RF. Severe pulmonary embolism: pulmonary artery clot load scores and cardiovascular parameters as predictors of mortality 1. Radiology 2006; 239: 884-891.
9. Ghuysen A, Ghaye B, Willems V, Lambermont B, Gerard P, Dondelinger RF, D'Orio V. Computed tomographic pulmonary angiography and prognostic significance in patients with acute pulmonary embolism. Thorax 2005; 60: 956-961.
10. Kapur S, Paik E, Rezaei A, Vu ND. Where there is blood there is a way: unusual collateral vessels in superior and inferior vena cava obstruction. Radiographics 2010; 30: 67-78.
11. Keats TE, Lipscomb GE, Betts III CS. Mensuration of the arch of the azygos vein and its application to the study of cardiopulmonary disease 1. Radiology 1968; 90: 990-994.
12. Kim HJ, Kim HS, Chung SH. CT diagnosis of superior vena cava syndrome: importance of collateral vessels. Am J Roentgenol 1993; 161: 539-542.
13. Lawler LP, Corl FM, Fishman EK. Multi-detector row and volume-rendered CT of the normal and accessory flow pathways of the thoracic systemic and pulmonary veins. Radiographics 2002; 22: S45-60.
14. Paoletti F, Pellegrino V, Antonelli M, Ripani U, Mosca S, Durì D, Galzerano A. Compensatory dilatation of the azygos venous system secondary to superior vena cava occlusion. J Radiol Case Rep 2009; 3: 49-55.
15. Piciucchi S, Barone D, Sanna S, Dubini A, Goodman LR, Oboldi D, Bertocco M, Ciccotosto C, Gavelli G, Carloni A, Poletti V. The azygos vein pathway: an overview from anatomical variations to pathological changes. Insights Imaging 2014; 5: 619-628.
16. Rivero MA, Ramirez JA, Vazquez JM, Gil F, Ramirez G, Arencibia A. Normal anatomical imaging of the thorax in three dogs: computed tomography and macroscopic cross sections with vascular injection. Anat Histol Embryol 2005; 34: 215-219.
17. Shin MS, Ho KJ. Clinical significance of azygos vein enlargement: radiographic recognition and etiologic analysis. Clinical Imaging 1999; 23: 236-241.
18. Sonin AH, Mazer MF, Powers TA. Obstruction of the inferior vena cava: a multiple-modality demonstration of causes, manifestations, and collateral pathway. Radiographic 1992; 12: 309-322.
19. Specchi S, d'Anjou MA, Carmel EN, Bertolini G. Computed tomographic characteristics of collateral venous pathways in dogs with caudal vena cava obstruction. Vet Radiol Ultrasound 2014; 55: 531-538.
20. Tatar I, Denk CC, Celik HH, Oto A, Karaosmanoglu DA, Ozdemir BM, Surucu SH. Anatomy of the azygos vein examined by computerized tomography imaging. Saudi Med J 2008; 29: 1585-1588.
21. Trigaux JP, Jamart J, Van Beers B, Goncette L, Pringot J. Pulmonary sequestration: visualization of an enlarged azygos

system by CT. Acta Radiol 1995; 36: 265-269.
22. Wishart DL. Normal Azygos Vein Width in Children 1. Radiology 1972; 104: 115-118.
23. Zwingenberger AL, Schwarz T. Dual-phase CT Angiography of the Normal Canine Portal and Hepatic Vasculature. Vet Radiol Ultrasound 2004; 45: 117-124.
24. Zwingenberger AL, Schwarz T. Saunders HM. Helical computed tomographic angiography of canine portosystemic shunts. Vet Radiol Ultrasound 2005; 46: 27-32.