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Evaluation of caudal vena cava size using computed tomography in dogs under general anesthesia

Kiwamu HANAZONO[1)]*, Mako NAKAMOTO[1)], Ai HORI[1)], Kenjiro MIYOSHI[1)], Tetsuya NAKADE[1)], Takaharu ITAMI[1)], Tadashi SANO[1)], Keiko KATO[1)], Akifumi ITO[1)], Kakeru TANAKA[1)], Kazuto YAMASHITA[1)], Daiji ENDOH[1)]

[1)]School of Veterinary Medicine, Rakuno Gakuen University, Hokkaido, Japan

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ABSTRACT. This study investigated the association between caudal vena cava (CVC) size and circulatory dynamics in dogs using computed tomography (CT) under general anesthesia. The subjects were 104 dogs who had undergone CT under general anesthesia in the past. The ratio of short diameter of the CVC to aortic diameter (CVC_S/Ao) and the ratio of long to short diameter of the CVC (CVC_L/CVC_S) in the thorax and abdomen, respectively, were calculated using factors such as mean blood pressure (MBP), shock index (SI), anemia, hypoproteinemia, presence of intra-abdominal mass, and cardiac disease. There was a significant but negligible negative correlation between CVC_S/Ao and MBP. In contrast, no significant correlation was found between CVC size and SI. The low MBP group had significantly higher CVC_S/Ao of the thorax than the normal MBP group. The group with intra-abdominal mass had significantly lower CVC_S/Ao of the abdomen than the group without intra-abdominal mass. The group with cardiac disease had significantly lower CVC_L/CVC_S of the thorax than the group without cardiac disease. In multiple regression analysis, low MBP, cardiac disease, intra-abdominal mass, and anemia were significant factors for CVC_S/Ao of the thorax, CVC_L/CVC_S of the thorax, CVC_S/Ao of the abdomen, and CVC_L/CVC_S of the abdomen, respectively. In conclusion, CVC size assessment using CT in dogs under general anesthesia is influenced by various factors.

KEYWORDS: caudal vena cava, computed tomography, dog, general anesthesia, hypovolemia

The venous system accommodates approximately 70% of the circulating blood volume and serves as a reservoir to return blood from the periphery to the heart and maintains cardiac hyperemia. The venous wall is significantly thinner than the diameter of the blood vessel and is easily stretched, making it 30 times more compliant than the arterial wall [15, 34]. In contrast, during hypovolemia due to bleeding or other causes, sympathetic tone causes peripheral veins to constrict and pump blood to the central veins, the vena cava, which perfuse the heart, increasing central venous pressure [36, 37]. The increase in central venous pressure increases right ventricular end-diastolic pressure, which increases the ventricular volume and cardiac output per cycle [20]. Because of these functions, the venous system is often used as an important indicator of circulatory dynamics. However, because of the high compliance of venous vessels, their volume is easily influenced by external factors such as cardiac disease, airway pressure, and intra-abdominal pressure [6, 18, 33].

In recent years, there have been multiple reports in human medicine on the usefulness of ultrasonography and computed tomography (CT) to assess the size of the inferior vena cava (IVC) in detecting decreased circulating blood volume. Patients with flattened IVC, i.e., a reduction in the minimum IVC diameter, have decreased circulating blood volume, which is a prognostic indicator in patients with high-energy trauma [1, 4, 10, 16, 21, 23, 40, 42]. In veterinary medicine, the usefulness of assessing caudal vena cava (CVC) size using radiography and ultrasonography has been studied. An increased CVC diameter in dogs on thorax radiographs suggests right heart failure, and a decreased CVC diameter suggests decreased circulating blood volume [18, 24]. More recently, attempts have been made in ultrasonography to evaluate the circulatory dynamics of dogs by assessing CVC size, and in particular, the CVC diameter/aorta diameter ratio (CVC/Ao) determined using ultrasonography has been suggested to be related to circulating blood volume [8, 17, 25, 32].

Although we sometimes encounter CVC size changes and flattened CVC on CT images when performing CT examinations of dogs under general anesthesia, there have been no reports on the evaluation of CVC size by CT examination under general anesthesia,

*Correspondence to: Hanazono K: k-hanazono@rakuno.ac.jp, School of Veterinary Medicine, Rakuno Gakuen University, 582 Bunkyodai-Midorimachi, Ebetsu, Hokkaido 069-8501, Japan

which is commonly performed in veterinary medicine. Therefore, we hypothesized that the CVC size on CT examination under general anesthesia in dogs reflects circulatory dynamics and aimed to investigate factors affecting CVC size. Furthermore, we focused on low mean blood pressure (MBP) and high shock index (SI), which are indicators of hypovolemia [3, 9, 31, 41]; hypoproteinemia and anemia [39], which are indicators of blood loss; intra-abdominal masses, which can increase intra-abdominal pressure [6, 19]; cardiac disease [18]; and airway pressure [33], which can affect venous volume, as candidate factors affecting CVC size.

MATERIALS AND METHODS

Animals

Dogs that underwent CT examination of the thorax and abdomen under general anesthesia at the Rakuno Gakuen University Animal Medical Center between April 2017 and March 2018 were included in this study. Informed consent was obtained from the dog owners for all examinations.

CT imaging and general anesthesia

The CT images used in this study were obtained using a 16-row multi-slice CT system (Bright Speed elite SD, GE Healthcare Japan, Tokyo, Japan). At the time of examination, all dogs were administered general anesthesia and imaged in the supine position. All dogs were intubated and ventilated with intermittent positive pressure ventilation, which was stopped during expiration at the time of imaging. The imaging parameters were as follows: tube voltage, 100–120 kV; tube current, automatically adjusted by automatic exposure control; and slice thickness, 0.625–2.5 mm. Pre-contrast images were selected to avoid the effect of increased intravascular volume due to contrast administration. During anesthesia induction, heart rate (HR) and respiratory rate were recorded using a biological monitoring device (BP-88v, Omron Healthcare, Kyoto, Japan), and non-invasive blood pressure was measured using the oscillometric method. Cylinder pressures measured with a pressure gauge attached to the anesthetic apparatus (Fancy 80M, K (cmH_2O) IMURA MEDICAL INSTRUMENT, Tokyo, Japan) were recorded as airway pressures. Based on these anesthesia records, HR, MBP, systolic blood pressure (SBP), and airway pressure were measured just before the CT scan. In addition, the SI (SI=HR/SBP) was calculated [31, 41].

The images were evaluated by a student (M.N) who had only been trained on how to measure CVC size and had no prior knowledge, using an image viewer (XTREC, J-MAC SYSTEM, Sapporo, Japan) and with information on the subject animals concealed. The site of CVC size measurement was selected midway between the confluence level of the CVC and heart and the cephalic level of the diaphragm in the thorax. In the abdomen, the site was selected midway between the level of the porta hepatis and the cephalic level of the confluence of the right renal vein. The long diameter [maximum diameter (CVC_L)] and short diameter [minimum diameter (CVC_S)] of the CVC on transverse images were recorded in the thorax and abdomen, respectively. In addition, the aortic diameter (Ao) was recorded at the same level (Fig. 1). CVC size was assessed by the ratio of CVC_S to Ao (CVC_S/Ao) and the ratio of CVC_L to CVC_s (CVC_L/CVC_S).

Patient information

Information on breed, sex, age, weight, blood pressure at CT examination, HR, hypoproteinemia (total protein <5.4 g/dL), anemia (packed cell volume <35%), presence of intra-abdominal mass, cardiac disease, and anesthetic method was collected for the subject animals. The presence of intra-abdominal mass was confirmed by CT images. For cardiac disease, all cases in which cardiac disease was noted in the electronic medical record or an abnormal echocardiogram were designated as "cardiac disease".

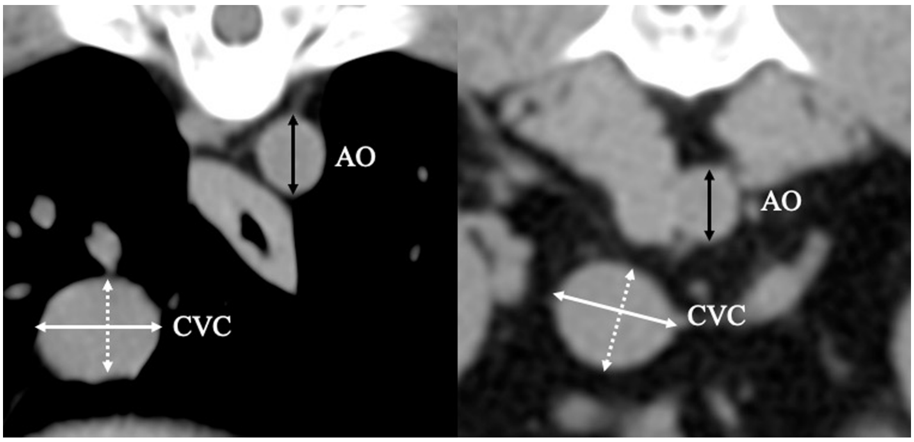

Fig. 1. Method of measuring the diameter of caudal vena cava and aorta. **A**: Thorax. **B**: Abdomen. The caudal vena cava (CVC) was measured for long diameter (CVC_L, white solid double arrow) and short diameter (CVC_S, white dotted double arrow). The aorta (AO) had the largest diameter (Ao, solid black double arrow).

Statistical analyses

Statistical analyses were performed using a commercial statistical software (BellCurve for Excel, Social Survey Research Information, Tokyo, Japan). To examine the correlation of the indicators (MBP and SI), Pearson's product rate correlation coefficient was used for those that follow a normal distribution and Spearman's rank correlation coefficient for those that do not.

Correlation coefficients (r) of 0 to 0.3 (0 to −0.3), 0.31 to 0.5 (−0.31 to −0.5), 0.51 to 0.7 (−0.51 to −0.7), 0.71 to 0.9 (−0.71 to −0.9), and >0.9 (< −0.9) were considered negligible, weak, moderate, strong, and very strong correlation, respectively [27]. The patients were classified into a low MBP group (MBP <60 mmHg just before the CT scan) and a normal MBP group (MBP ≥60 mmHg just before the CT scan) [36]. They were also classified into a high SI group (SI ≥1.0) and a normal SI group (SI <1.0), indicating shock [31, 41]. Patients were further classified into two groups according to the presence of hypoproteinemia, anemia, intra-abdominal mass, and cardiac disease. CVC size was compared using Student's *t*-test for those following a normal distribution and Mann–Whitney *U* test for those that did not. Cases with any of these conditions (hypoproteinemia, anemia, intra-abdominal mass, and cardiac disease) were included.

In addition, multiple regression analysis of CVC size was performed using low MBP, high SI, hypoproteinemia, anemia, presence of intra-abdominal mass, cardiac disease, and airway pressure as possible influencing factors on CVC size. The significance level was set at $P<0.05$ for all statistical analyses.

RESULTS

There were 104 dogs in this study, including 11 males, 45 neutered males, 4 females, and 44 neutered females. The included dogs were of the following breeds: 14 Miniature Dachshunds; 8 Chihuahuas; 7 Shibas; 6 Shih Tzus, Jack Russell Terriers, Miniature Schnauzers, and mixed breed dogs; 5 Toy Poodles and Beagles; 4 Papillons and Labrador Retrievers; 3 Pembroke Welsh Corgis, Border Collies, Maltese dogs, and Yorkshire Terriers; 2 Akitas, Golden Retrievers, French Bulldogs, and Bernese Mountain dogs; and 1 American Cocker Spaniel, Cavalier King Charles Spaniel, Kooikerhondje, Shetland Sheepdog, St. Bernard, Pug, Basenji, Bichon Frise, Bulldog, Pekinese, Boston Terrier, Pomeranian, and Whippet. The median age of the dogs was 137 (range, 5–208) months, and the median weight was 7.4 (range, 2.1–53.0) kg.

Among the 104 dogs, 9 had hypoproteinemia, 18 had anemia, 45 had intra-abdominal masses, and 24 had single or multiple cardiac disease. Abnormalities found on ultrasound included mitral and tricuspid regurgitation in 16 dogs each, aortic regurgitation in 3, ventricular septal defect in 2, pulmonary valve regurgitation in 1, myocardial hypertrophy in 1, and cardiac tumor in 1 (the number of dogs with multiple cardiac disease overlap). The present study did not include any patients with high-energy trauma immediately after the injury.

General anesthesia was determined by the American Society of Anesthesiologists (ASA) classification and the dog's general condition and disease. No dog in the current study was classified as ASA classification categories IV and V with severe hypovolemia [13]. Pre-anesthetic drugs were administered in 24 cases, with midazolam and butorphanol in 8; midazolam and tramadol in 13; midazolam, ketamine, fentanyl, and morphine in 1; midazolam in 1, and a combination of atropine, midazolam, ketamine, and fentanyl in 1. Propofol and alfaxalone were used as anesthetic induction drugs in 92 and 12 patients, respectively. Sevoflurane was used for anesthesia maintenance in 103 patients, and only 1 patient received continuous infusion of propofol. As a result, there were 15 different combinations of pre-anesthetic drugs and anesthetics. The median airway pressure was 8 cmH_2O (range, 6–13 cmH_2O).

There was a significant but negligible negative correlation between CVC_S/Ao of the thorax and MBP (r= −0.289, P=0.003). The correlation between CVC_S/Ao of the abdomen and MBP was also significant, but it was negligible and negative (r= −0.207, P=0.036). In contrast, no significant correlation was found between all CVC sizes and SIs (Table 1).

The low MBP group had a significantly higher CVC_S/Ao of the thorax than the normal MBP group (P=0.015). The group with intra-abdominal masses had significantly lower CVC_S/Ao of the abdomen than the group without intra-abdominal masses (P=0.01). The group with cardiac disease had significantly lower CVC_L/CVC_S of the thorax than the group without cardiac disease (Table 2). In multiple regression analysis, low MBP (β=0.248, P=0.019), cardiac disease (β= −0.204, P=0.049), presence of intra-abdominal mass (β= −0.228, P=0.031), and anemia (β=0.299, P=0.006) were significant factors for CVC_S/Ao of the thorax, CVC_L/CVC_S of the thorax, CVC_S/Ao of the abdomen, and CVC_L/CVC_S of the abdomen, respectively (Table 3 and Fig. 2).

Table 1. Correlation between caudal vena cava size and circulatory parameters

Variables		CVC_S/Ao		CVC_L/CVC_S	
		r	*P*	r	*P*
MBP	Thorax	−0.289	**0.003****	0.123	0.189
	Abdiomen	−0.207	**0.036***	0.029	0.772
SI	Thorax	−0.075	0.449	0.033	0.737
	Abdiomen	−0.018	0.854	0.106	0.283

**P*<0.05, ***P*<0.01. MBP, mean blood pressure; SI, shock index.

Table 2. Comparison of caudal vena cava size for each classification

CVC size		Normal MBP (n=70)				Low MBP (n=34)				*P*
		Mean	SD	Median	Range	Mean	SD	Median	Range	
Thorax	CVC_S/Ao	1.09	0.223	1.095	0.615–1.6	1.199	0.208	1.2	0.7–1.75	**0.015***
	CVC_L/CVC_S	1.273	0.209	1.25	1–2	1.273	0.209	1.211	1–1.75	0.423
Abdomen	CVC_S/Ao	0.756	0.223	0.727	0.143–1.5	0.819	0.274	0.789	0.375–1.6	0.397
	CVC_L/CVC_S	1.408	0.305	1.354	1–5	1.408	0.305	1.343	1–2.167	0.958

CVC size		Normal SI (n=42)				High SI (n=62)				*P*
		Mean	SD	Median	Range	Mean	SD	Median	Range	
Thorax	CVC_S/Ao	1.139	0.207	1.143	0.667–1.6	1.114	0.234	1.101	0.615–1.75	0.484
	CVC_L/CVC_S	1.297	0.233	1.268	1–2	1.306	0.238	1.231	1–2	0.868
Abdomen	CVC_S/Ao	0.748	0.246	0.721	0.143–1.5	0.796	0.239	0.778	0.375–1.6	0.424
	CVC_L/CVC_S	1.482	0.628	1.388	1–5	1.401	0.257	1.333	1–2.167	0.855

CVC size		No Hypoproteinemia (n=95)				Hypoproteinemia (n=9)				*P*
		Mean	SD	Median	Range	Mean	SD	Median	Range	
Thorax	CVC_S/Ao	1.123	0.232	1.125	0.615–1.75	1.172	0.101	1.146	1.083–1.375	0.774
	CVC_L/CVC_S	1.314	0.242	1.25	1–2	1.191	0.102	1.177	1.083–1.385	0.146
Abdomen	CVC_S/Ao	0.783	0.249	0.778	0.143–1.6	0.65	0.13	0.636	0.455–0.875	0.411
	CVC_L/CVC_S	1.437	0.465	1.375	1–5	1.457	0.173	1.429	1.25–1.75	0.759

CVC size		No Anemia (n=86)				Anemia (n=18)				*P*
		Mean	SD	Median	Range	Mean	SD	Median	Range	
Thorax	CVC_S/Ao	1.119	0.234	1.118	0.615–1.75	1.145	0.167	1.162	0.857–1.5	0.584
	CVC_L/CVC_S	1.31	0.249	1.25	1–2	1.264	0.153	1.24	1–1.5	0.84
Abdomen	CVC_S/Ao	0.792	0.236	0.764	0.444–1.6	0.703	0.261	0.739	0.143–1.286	0.284
	CVC_L/CVC_S	1.377	0.263	1.333	1–2.167	1.705	0.859	1.4	1.143–5	0.08

CVC size		No Intra-abdominal mass (n=59)				Intra-abdominal mass (n=45)				*P*
		Mean	SD	Median	Range	Mean	SD	Median	Range	
Thorax	CVC_S/Ao	1.091	0.227	1.091	0.615–1.625	1.167	0.213	1.2	0.75–1.75	0.068
	CVC_L/CVC_S	1.319	0.262	1.25	1–2	1.28	0.194	1.25	1–1.8	0.76
Abdomen	CVC_S/Ao	0.832	0.244	0.8	0.444–1.6	0.705	0.222	0.667	0.143–1.286	**0.01***
	CVC_L/CVC_S	1.381	0.258	1.333	1–2.15	1.503	0.606	1.4	1–5	0.541

CVC size		No Cardiac disease (n=80)				Cardiac disease (n=24)				*P*
		Mean	SD	Median	Range	Mean	SD	Median	Range	
Thorax	CVC_S/Ao	1.106	0.206	1.118	0.615–1.6	1.183	0.269	1.171	0.7–1.75	0.321
	CVC_L/CVC_S	1.33	0.240	1.279	1–2	1.216	0.198	1.143	1–1.75	**0.022***
Abdomen	CVC_S/Ao	0.794	0.258	0.778	0.143–1.6	0.718	0.169	0.667	0.455–1	0.209
	CVC_L/CVC_S	1.442	0.494	1.354	1–5	1.405	0.233	1.354	1–2.125	0.685

**P*<0.05, ***P*<0.01. MBP, mean blood pressure; SI, shock index.

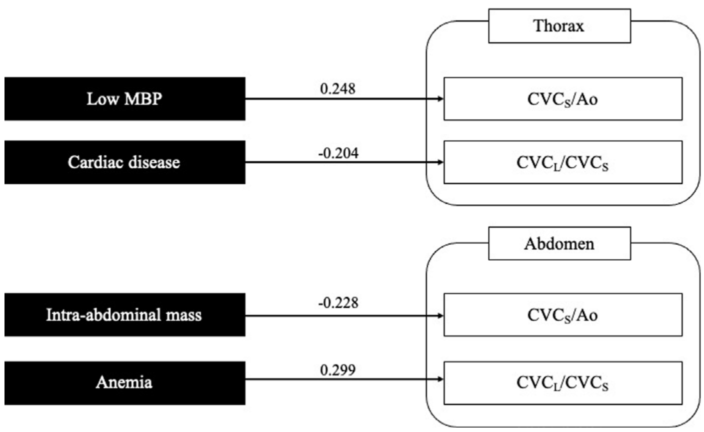

Fig. 2. Path analysis to identify significant factors influencing caudal vena cava size. Results of multiple regression analysis revealed that low MBP, cardiac disease, presence of intra-abdominal mass, and anemia were significant factors for CVC_S/Ao of the thorax, CVC_L/CVC_S of the thorax, CVC_S/Ao of the abdomen, and CVC_L/CVC_S of the abdomen, respectively.

Table 3. Multiple regression analysis of factors influencing caudal vena cava size

CVC size		Variables	SE	β	95%CI	F	t	*P*
Thorax	CVC_S/Ao	Low MBP	0.049	0.248	0.02–0.217	5.704	2.388	**0.019***
		High SI	0.048	−0.112	−0.145–0.044	1.146	−1.071	0.287
		Anemia	0.063	−0.025	−0.14–0.111	0.054	−0.232	0.817
		Hypoproteinemia	0.078	0.001	−0.154–0.155	0.0001	0.01	0.992
		Intra-abdominal mass	0.047	0.134	−0.033–0.154	1.653	1.286	0.202
		Cardiac disease	0.053	0.169	−0.015–0.196	2.883	1.698	0.093
		Airway pressure	0.018	−0.063	−0.047–0.024	0.387	−0.618	0.538
	CVC_L/CVC_S	Low MBP	0.054	−0.104	−0.159–0.054	0.96	−0.98	0.33
		High SI	0.051	0.071	−0.068–0.136	0.439	0.662	0.509
		Anemia	0.068	0.007	−0.131–0.14	0.004	0.067	0.947
		Hypoproteinemia	0.084	−0.076	−0.228–0.106	0.525	−0.724	0.47
		Intra-abdominal mass	0.051	−0.057	−0.128–0.074	0.287	−0.536	0.594
		Cardiac disease	0.057	−0.204	−0.228–0	3.942	−1.986	**0.049***
		Airway pressure	0.019	0.026	−0.034–0.043	0.062	0.248	0.805
Abdomen	CVC_S/Ao	Low MBP	0.054	0.117	−0.046–0.167	1.268	1.126	0.263
		High SI	0.051	0.065	−0.07–0.134	0.38	0.617	0.539
		Anemia	0.068	−0.012	−0.143–0.128	0.012	−0.112	0.911
		Hypoproteinemia	0.084	−0.113	−0.26–0.074	1.216	−1.103	0.273
		Intra-abdominal mass	0.051	−0.228	−0.213–0.011	4.803	−2.192	**0.031***
		Cardiac disease	0.058	−0.111	−0.178–0.05	1.233	−1.11	0.269
		Airway pressure	0.019	0.046	−0.029–0.047	0.203	0.451	0.653
	CVC_L/CVC_S	Low MBP	0.099	−0.021	−0.216–0.176	0.041	−0.204	0.839
		High SI	0.095	−0.053	−0.236–0.141	0.252	−0.502	0.617
		Anemia	0.126	0.299	0.103–0.604	7.849	2.802	**0.006****
		Hypoproteinemia	0.155	−0.042	−0.373–0.244	0.172	−0.415	0.679
		Intra-abdominal mass	0.094	0.019	−0.169–0.204	0.033	0.183	0.856
		Cardiac disease	0.106	−0.093	−0.309–0.112	0.869	−0.933	0.353
		Airway pressure	0.036	−0.124	−0.114–0.027	1.486	−1.219	0.226

*$P<0.05$, **$P<0.01$. MBP, mean blood pressure; SI, shock index; SE, standard error; 95%CI, 95% confidence interval.

DISCUSSION

In veterinary medicine, several studies evaluating circulatory dynamics using CVC/Ao by ultrasonography have been reported [17, 25]. In human medicine, imaging studies have shown that evaluation methods based on the long diameter/short diameter ratio of the IVC and the IVC/aorta ratio are less affected by body size [14, 35]. This suggests that these methods may be applicable to animals, but no useful index for evaluating CVC size on CT images in dogs has been proposed. Based on these reports, the present study used CVC_S/Ao and CVC_L/CVC_S of the thorax and abdomen, respectively, as indices for determining CVC size on CT images.

In a previous report, the CVC/Ao of experimentally dehydrated Beagles was evaluated by ultrasonography, and it decreased as the dehydration became more severe [17]. Another report showed that a decrease in the CVC/Ao in dogs is an indicator of infusion responsiveness [32]. Furthermore, in traumatized dogs, the CVC/Ao showed a good positive correlation with SBP and respiratory variability, an indicator of hypovolemia [25]. Human medical reports have suggested that trauma patients with a higher long diameter/short diameter ratio on CT images have a poor prognosis [1, 16, 23]. However, contrary to our hypothesis that CVC size on CT images of dogs can be used to determine its association with MBP and SI, the present study found no strong correlation among CVC size, MBP, and SI just before the CT scan. Moreover, CVC_S/Ao was paradoxically and significantly higher in the hypotensive group. There are four possible reasons for why CVC size and circulating dynamics did not correlate. The first is the absence of dogs with severe shock, such as immediately after high-energy trauma injuries. Previous reports on dogs used a pronounced hypovolemia model [17, 25], but this study included dogs with a variety of diseases. Reports in human medicine have also focused mainly on severely injured patients due to high-energy trauma [1, 16], but in this study, no dogs were in shock immediately after severe trauma, such as those in ASA classification category IV or V. Therefore, because this study was not a comparative study of dogs with pronounced hypovolemia, the hypothesized results were not obtained.

The second is the effect of anesthesia. Previous studies on dogs were conducted with a uniform anesthetic method [25] or without anesthesia [17, 32]. In the present study, alfaxalone administration in some dogs resulted in a higher HR compared to propofol [13, 29]. It cannot be ruled out that this difference in action may have affected the circulatory dynamics just before the CT scan. However, it is a matter of conjecture because there were 15 different combinations of pre-anesthetic and anesthetic medications in this study, making it difficult to compare the effects of the various agents.

The venous system has a compensatory mechanism wherein, when blood volume in the venous lumen decreases due to hypovolemia, sympathetic tone causes its lumen to progressively narrow, increasing the stressed blood volume and venous return [12, 37, 38].

However, sevoflurane, an inhaled anesthetic used in 99% of the subject dogs, suppresses sympathetic nerves and induces vasodilation [2, 22], which may increase the unstressed blood volume in venodilation and suppress the aforementioned compensatory mechanism [12]. These anesthetic effects may not be reflected in the actual circulatory dynamics of the dog. In any case, a pilot study using consistent anesthetic methods is needed to elucidate the true effects of anesthetics on CVC size.

The third issue concerns the index of circulatory dynamics. In this study, MBP and SI were used as indices of circulatory dynamics, but they are ineffective at detecting imbalances between cellular oxygen supply and demand in emergency patients [30]. Although inadequate oxygen supply to tissues increases blood lactate levels, occult shock, in which serum lactate levels increase without hypotension, has been associated with a poor prognosis in emergency patients [7, 26]. Thus, grouping by blood pressure and SI may not have been absolute. In contrast, in human medicine, occult shock can be predicted by determining the high long diameter/short diameter ratio of IVC on CT images [28]. Since lactate monitoring was not performed just before the CT scan in this study and therefore could not be evaluated, the possibility of occult shock cannot be ruled out. Therefore, it may be necessary to investigate the relationship between CVC size on CT images of dogs and serum lactate levels that detect occult shock.

The fourth is the influence of underlying disease. In this study, the results of multiple regression analysis showed that, in addition to low MBP, cardiac disease, presence of intra-abdominal mass, and anemia were factors affecting CVC size. A high CVC/Ao on thorax radiography in dogs can help detect right heart disease, and there have been reports of a high CVC/Ao and low short diameter/long diameter ratio of CVC on ultrasound examination in dogs with right heart disease [11, 18]. Although the present study utilized a retrospective study design and the severity of right heart failure in the cardiac disease group could not be evaluated, cases of tricuspid and pulmonary valve regurgitation were included, and the impaired beating due to right heart failure may have led to hypotension, resulting in the present paradoxical results [5]. In addition, although CVC_S/Ao of the abdomen was significantly lower in the intra-abdominal mass group in the present study, a decrease in cross-sectional area and flattening of the IVC on ultrasound images occur in humans with intra-abdominal hypertension [6]. Thus, the presence of an intra-abdominal mass increases the abdominal pressure [19], which significantly affects the CVC size assessment in the abdomen. As mentioned above, it is highly likely that various underlying diseases influenced the evaluation in this study.

In addition to these four reasons, this study also has the following limitations: this was a retrospective study, the anesthesia method used in this study was not standardized, and the detailed cardiac function of the dogs was unknown. Thus, the true clinical significance of CVC size on CT examination under anesthesia in dogs must be assessed under conditions in which serum lactate levels are measured, cardiac disease and intra-abdominal masses are excluded, and a uniform anesthetic method is used. In conclusion, in this study, CVC size evaluation using CT in dogs under general anesthesia is influenced by a variety of factors.

CONFLICT OF INTEREST. The authors declare that there are no conflicts of interest.

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