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RESEARCH ARTICLE

Echocardiographic Characteristics and Main Pulmonary Artery/Aorta Ratio of Dogs with Tracheabronchitis

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ABSTRACT

An acute or chronic inflammation of the trachea and bronchial airways, which can spread to the lungs, is called tracheobronchitis. Monitoring basic echocardiographic parameters in dogs with tracheobronchitis may be useful in detecting early cardiac signs of pulmonary hypertension (PH). Pulmonary artery (PA) dilation is one of the cardiac abnormalities associated with pulmonary hypertension. This study aimed to main pulmonary artery diameter and main pulmonary artery (MPA)/aorta (Ao) ratio in dogs with tracheobronchitis. The animal material of the study consisted of 90 dogs with tracheobronchitis aged 1-14 years (mean 7±3 years), mostly small breeds (Terrier, Pomeranian, Russian Poodle, et al.). Two-dimensional, M-mode and pulse wave Doppler techniques were used in echocardiographic examination. The diameters of the MPA and Ao were measured in the right parasternal short axis view and the MPA/Ao ratio was calculated. The mean MPA diameter, Ao diameter and MPA/Ao ratio of dogs with tracheobronchitis were calculated as 1.20±0.31 cm, 1.37±0.36 cm and 0.90±0.16, respectively. There was a strong positive correlation between body weight and pulmonary artery diameter (r=0.754, P<0.001). As a result, the MPA/Ao ratio in dogs with tracheobronchitis included in the study was within the values reported for healthy dogs. Based on basic echocardiographic findings and pulmonary artery measurements, no signs of pulmonary hypertension were detected in dogs with tracheobronchitis. However, it can be argued that due to the progressive nature of PH and its poor prognosis, a more comprehensive echocardiographic evaluation may be useful to identify dogs with the potential to develop PH.
Keywords: Aorta, Dog, Echocardiography, Main pulmonary artery, Tracheobronchitis

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Trakeabronşitli Köpeklerin Ekokardiyografik Özellikleri ve Ana Pulmoner Arter/Aorta Oranı

ÖZ

Trakeobronşit trakea ve bronşiyal hava yollarının akut veya kronik yangısına denir. Pnömoni, trakeobronşiyal hastalık ve infiltratif pulmoner hastalık gibi birçok solunum yolu hastalığı köpeklerde pulmoner hipertansiyon ile ilişkilendirilmiştir. Trakeobronşitli köpeklerde temel ekokardiyografik parametrelerin izlenmesi, pulmoner hipertansiyonun (PH) erken kardiyak belirtilerinin tespit edilmesinde faydalı olabilir. Pulmoner arter (PA) dilatasyonu, pulmoner hipertansiyon ile ilişkili kardiyak anormalliklerden biridir. Bu çalışmada trakeobronşitli köpeklerde ana pulmoner arter çapı ve ana pulmoner arter (MPA)/aort (Ao) oranının belirlenmesi amaçlanmıştır. Çalışmanın hayvan materyalini Terrier, Pomeranian, Russian Poodle, Pekingese, Pug gibi çoğunlukla küçük ırklardan oluşan 1-14 yaş arası (ortalama 7±3 yaş) toplam 90 trakeobronşitli köpek oluşturdu. Ekokardiyografik muayanede iki boyutlu (2D), M-mod ve PW Doppler inceleme teknikleri kullanıldı. MPA ve Ao çapları sağ parasternal kısa eksen görünümünde ölçüldü ve MPA/Ao oranı hesaplandı. Trakeobronşitli köpeklerin ortalama MPA çapı, Ao çapı ve MPA/Ao oranı sırasıyla 1.20±0.31 cm, 1.37±0.36 cm ve 0.90±0.16 olarak hesaplandı. Canlı ağırlı ile pulmoner arter çapı arasında güçlü bir pozitif korelasyon vardı (r=0.754, P<0.001). Sonuç olarak, çalışmaya dahil edilen trakeobronşitli köpeklerde MPA/Ao oranı sağlıklı köpekler için bildirilen referans değerler arasındaydı. Temel ekokardiyografik bulgulara ve pulmoner arter ölçümlerine dayanarak, trakeobronşitli köpeklerde pulmoner hipertansiyon belirtisi tespit edilmemiştir. Bununla birlikte, PH'nin progresif yapısı ve kötü prognozu nedeniyle, PH gelişme potansiyeli olan köpekleri belirlemek için daha kapsamlı bir ekokardiyografik değerlendirmenin yararlı olabileceği söylenebilir.
Anahtar Kelimeler: Ana pulmoner arter, Aorta, Ekokardiyografi, Köpek, Trakeobronşitis

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INTRODUCTION

An acute or chronic inflammation of the trachea and bronchial airways, which can spread to the lungs, is called tracheobronchitis. It frequently manifests in dogs already afflicted by respiratory diseases or disorders of the lungs or airways (Rozanski et al. 2020). Infectious tracheobronchitis frequently accompanies a viral infection of the respiratory system (Maden et al. 2000; Reagan and Sykes 2020). Other causes of tracheobronchitis in dogs include parasites, oral and pharyngeal disorders, chronic coughing due to heart or lung disease, smoke inhalation, and chemical fume exposure (Kumrow and Rozanski 2012). Chronic bronchitis most commonly affects small breed dogs, but it can also occur in large breeds. Chronic bronchitis in middle-aged and older dogs may worsen in response to rapid weather changes or other environmental pressures (MSD Vet Manuel). Chronic bronchitis is defined as a cough that lasts at least two months and is not caused by another respiratory disease. The most noticeable symptom is coughing spasms. The acute stage of bronchitis lasts two to three days, although the cough might last for weeks. The disease is diagnosed based on a history, physical examination, clinical symptoms, and the exclusion of alternative causes of coughing (Kumrow and Rozanski 2012). Dogs with tracheobronchitis usually have a loud cough that sounds like a 'goose honk'. Other signs of tracheobronchitis include coughing when the dog's throat is rubbed, coughing during or after exercise, gagging, spitting up frothy saliva, runny eyes and nose, swollen tonsils, wheezing, loss of appetite, depressed or lethargic behavior (Day et al. 2020). In mild cases or those with recent start of symptoms, supportive care may be useful; nevertheless, treatment of the underlying disease (if present) is also required. Rest, warmth, and good hygiene are all crucial. Corticosteroids are commonly used to reduce airway inflammation in dogs with chronic bronchitis. If a bacterial infection exists, antibiotics may be provided (Vieson et al. 2012).

In small animal practice, echocardiography is the most effective diagnostic tool for assessing heart anatomy, function, and cardiovascular illness (Bonagura and Miller 1989, Vurucu et al. 2021; Terzi, 2022). The pulmonary artery (PA) is a key site for assessing pulmonary hypertension (PH) in dogs using echocardiography, as recommended by the American College of Veterinary Internal Medicine (ACVIM) guidelines (Reinero et al. 2020). Echocardiographic assessment of pulmonary hypertension (PH) is primarily based on typical cardiac alterations (i.e., echocardiographic signs of PH) and the estimation of pulmonary arterial pressure (PAP) from spectral Doppler tracings. Because right cardiac catheterization is rarely used for definitive diagnosis of pulmonary hypertension in dogs, veterinarians rely on echocardiography to diagnose, classify, and manage dogs with PH (Reinero et al. 2020). Parameters such as pulmonary artery (PA) diameter (PA/Ao>1.017), pulmonary artery pressure (PAP ≥25 mm Hg), right ventricle/left ventricle basal diameter ratio, peak early diastolic pulmonary regurgitation velocity (>2.5 m/s), flattening of the interventricular septum are used to help grade the probability of pulmonary hypertension (Augustine et al. 2018; Reinero et al. 2020; Grosso et al. 2023). Estimated systolic pulmonary artery pressure is most frequently used to classify the pulmonary hypertension as mild (30-55 mm Hg), moderate (55-80 mm Hg), or severe (>80 mm Hg) (Pyle et al., 2004; Campbell 2007).

Chronic obstructive pulmonary disease is the most common cause of pulmonary hypertension in humans (Olsson et al. 2023). Pneumonia, tracheobronchial disease, infiltrative pulmonary disease, laryngeal paralysis, pulmonary thromboembolism, *Angiostrongylus vasorum* infestation, interstitial pulmonary fibrosis of West Highland White Terriers, neoplasia, and *Dirofilaria immitis* have all been linked to pulmonary hypertension (Nicolle et al. 2006; Schober et al. 2006; Reinero et al. 2020). Pulmonary hypertension is a serious complication of pulmonary diseases, and severe hypertension has a poor prognosis (Campbell 2007). PA diameter, Ao diameter and PA/Ao ratio are basic parameters that can be measured quickly in echocardiographic examination. Dogs with tracheabronchitis may have increased main pulmonary artery (MPA) diameter and main pulmonary artery (MPA)-to-aorta (Ao) ratio. Dilatation of the MPA in dogs may be a normal anatomical variant or a sign of underlying cardiac or pulmonary disease. Chronic pressure increase in the pulmonary circulation causes dilatation of the MPA. It can be caused by left heart disease (mitral valve disease), pulmonary thromboembolism, chronic lung disease or heartworm disease. There are not many studies determining the ranges of these parameters in dogs with tracheobronchitis. Monitoring basic echocardiographic parameters (MPA diameter, Ao diameter, MPA/Ao ratio) may allow early diagnosis of these diseases or predisposition to them. This study aimed to define basic echocardiographic measurements, primarily pulmonary artery (PA) diameter and main pulmonary artery MPA/Ao ratio in dogs with tracheobronchitis.

MATERIALS and METHODS

Animals

The animal material of the study consisted of 90 dogs aged 1-14 years (median 4), mostly small breeds such as Terrier, Pomerian, Russian Poodle, Pekingese and Pug, which were brought to Erciyes University, Faculty of Veterinary Medicine, Veterinary Teaching Hospital, Small Animal Clinic.

Physical Examination

Each dog included in the study had a comprehensive physical assessment. These examinations were performed by a single individual. The dogs included in the study were subjected to a complete physical examination including examination of the mucous membranes, determination of capillary refill time, estimation of the degree of dehydration, palpation of the lymph nodes, body temperature (°C), pulse frequency (bpm), respiratory rate, auscultation of the lungs and heart (presence of murmurs, arrhythmias, etc.). Skin elasticity, capillary refill time, and mucous membrane dryness were used to evaluate dehydration levels (<5% [subclinical], 5% [mild], 6%-8% [moderate], 8%-10% [severe], and ~12% [hypovolemia]) (Tello et al. 2017).

Diagnosis of Tracheobronchitis, Inclusion and Exclusion Criteria

The diagnosis of tracheobronchitis in dogs was based on anamnesis, physical examination findings, diagnostic imaging (thoracic radiography) and laboratory (CBC) findings.

Inclusion criteria were clinical signs (presence of a harsh, dry, unproductive cough, usually worsened by tracheal palpation) of tracheobronchitis, cough lasting at least 2-3 days, runny nose, sneezing or gagging after coughing, noisy breathing or mild inspiratory stridor, normal or mild abnormalities on chest X-ray (to rule out pneumonia).

Dogs with pneumonia (productive cough, fever, significant radiographic lung involvement), tracheal collapse, concurrent systemic disease (e.g., severe cardiac disease, immunosuppression, or neoplasia), recent antibiotic, steroid, or immunosuppressive therapy were excluded.

Blood Pressure Measuring

Non-invasive blood pressure measures were taken with the PetTrust oscillometer (BioCARE, Taiwan). To reduce stress during blood pressure measures in dogs and help them adjust to unfamiliar persons, a 5-10 minute waiting interval was used. During the blood pressure readings, the animal owner, assistance staff, and the veterinarian doing the assessment were all present. The cuff size was determined using the measuring tape provided by PetTrust. To determine the proper cuff size, the circumference of the dog's right forelimb (proximal) was measured using a flexible measuring tape. The suitable cuff size was determined by measuring approximately 30% of the circumference of the right forelimb. To measure blood pressure in the proximal region of the right forelimb, the bladder of the cuff was put over the arteria radialis at the center of the antebrachium, making sure it wasn't too tight or too loose. When the device was activated, the cuff inflated automatically. Mean arterial pressure (MAP), diastolic blood pressure (DBP) and systolic blood pressure (SBP) were measured. The data was then recorded. All measurements were taken by an experienced veterinarian. The first blood pressure readings were dismissed. Following that, three measures were collected, with a 15-second delay between each reading. Data analysis was performed using the arithmetic average of these three readings.

Blood Sampling and Complete Blood Count Analysis

Blood samples were taken from the dogs' cephalic veins for hematological exams to detect infection status and leukocyte counts in accordance with clinic standard methods. Blood samples were inserted into BD Vacutainer® K_2 EDTA tubes (Becton Dickinson, USA) for hematological analysis. Hematological analyses were performed using a complete blood count device (Exigo EosVet, Boule Medical AB, Stockholm, Sweden).

Echocardiographic Examination

M-mode and 2D measurements were recorded according to the recommendations of American Society of Echocardiography and methodology published in the veterinary literature (Thomas et al. 1993). Echocardiographic examinations were performed using a multifrequency (3-11 MHz) Doppler ultrasound device (Mindray DC-N3, Shenzhen Mindray Bio-Medical Electronics Co. Ltd, China). All examinations were performed without sedation. Depending on the size of the patient, 5-11 MHz multifrequency probes were used. Two-dimensional (2D), M-mode (or motion mode) and pulse wave (PW) Doppler examination techniques were used in echocardiographic examination. The right 4-6 intercostal spaces were shaved. After the area was cleaned with alcohol, ultrasound gel was applied and waited for 1 minute for better conductivity. Then, right parasternal short axis (PSAX) and right parasternal long axis (PLAX) were taken and the heart was examined. M-mode measurements were made using the Teichholz method (Teicholz et al. 1976). To obtain left ventricular images, the cursor was positioned perpendicular to the interventricular septum (IVS) and left ventricular posterior wall (LVPW) at the level just posterior to the chordae tendineae. The following parameters were recorded: Left ventricular internal diameter in diastole (LVIDd) and systole (LVIDs), IVS thickness in diastole (IVSd) and IVS thickness in systole (IVSs), LVPW thickness in diastole (LVPWd) and LVPW thickness in systole (LVPWs). Directing the transducer slightly anteriorly and towards the spine allowed the aorta and left atrium to be visualized. The following measurements were recorded: left atrium (LA) diameter, aorta (Ao) diameter.

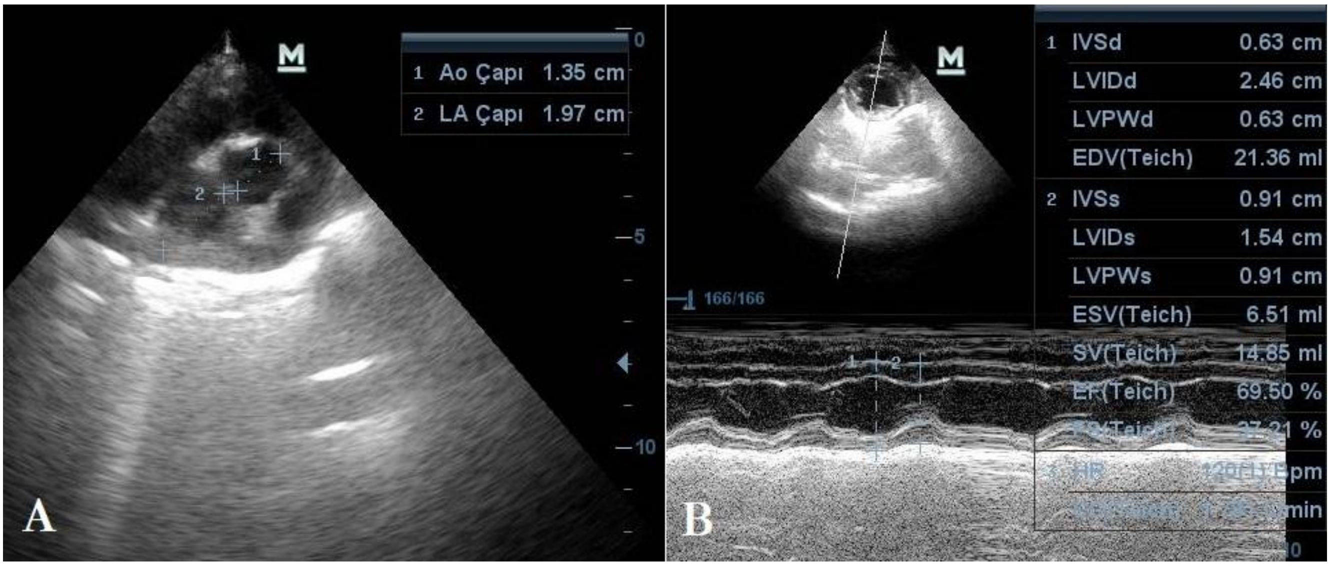
Ultrasonographic measurement of main pulmoner arter/aorta ratios

The diameter of the main pulmonary artery (MPA) (below the pulmonary valve) was measured at the level of the pulmonary valve in the right parasternal short axis view. The aortic (Ao) diameter was then measured.

The MPA diameter was divided by the Ao diameter (Figure 1).

Statistical analysis

Statistical analyses were performed with SPSS 25.0 (Chicago, IL, USA). Descriptive statistics were expressed as frequency and percentage. The conformity of the data to normal distribution was evaluated by Shapiro-Wilk test, histogram and Q-Q graphs. Data were expressed as median (25th and 75th percentile) or mean±standard deviation (SD). One-way ANOVA test (alternative, Kruskal Wallis) test was used for comparisons between groups. Tukey and Bonferroni tests were used for multiple comparisons. The relationship between pulmonary artery and body weight and age variables were evaluated using Pearson and Spearman rho correlation test. Statistical significance level was accepted as $P<0.05$.



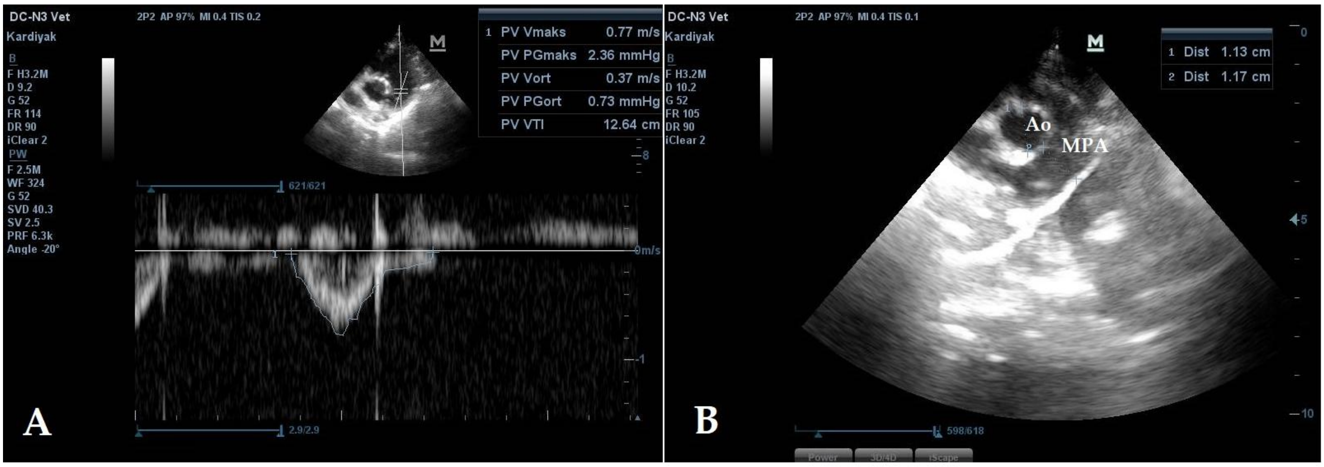


Figure 1. This sonogram was obtained from right parasternal short axis view. (**A**) Pulmonary valve PW Doppler and (**B**) pulmonary artery 2D echocardiograpic measurements **Ao**: Aorta; **MPA**: main pulmonary artery. **Vmaks**: Pulmonary valve maximum velocity, **PGmaks**: Maximum systolic pressure gradient, **Vort**: Mean velocity, **PGort**: Mean pressure gradient of pulmonic valve, **VTI**: Velocity time integral

RESULTS

Of the ninety dogs, 48 (53.3%) were female and 42 (46.7%) were male. Median body weight was 6.20 (4.80-9.80) kg. The most common dog breeds were Terrier (25.6%, 23/90), followed by Pomerian (18.9%, 17/90), Russian Poodle (13.3%, 12/90), crossbreed (7.8%, 7/90), Pekingese (6.7%, 6/90), Pug (6.7%, 6/90) and other dog breeds (number of animals less than 3).

Physical Examination Findings

Physical examination of dogs with tracheobronchitis revealed cough (100%, 90/90), tracheal tenderness (100%, 90/90), dyspnea (100%, 90/90), tachypnea (68.9%, 62/90), anorexia (60%, 54/90), and weakness

(40%, 36/90). When the degree of dehydration was examined, it was estimated that 73.3% were normal 66/90), 18.9% were mild (17/90), 4.4% were (moderate (4/90), and 2.2% were severely dehydrated (2/90). Enlargement of prescapular lymph nodes was detected in 70% (63/90) of dogs with tracheobronchitis. When the color of the mucous membranes was examined, it was determined that 66.7% were normal, 17.8% were pale, and 15.6% were hyperemic. It was determined that the mean/median pulse and respiratory rate of dogs with tracheobronchitis were higher than the reference values specified for dogs (Table 1) (Cugmas et al. 2020; MSD Veterinary Manual).

Complete Blood Count Findings

Complete blood count values of dogs with tracheobronchitis were within the reference values (Moritz et al. 2004; López and Mesa 2021) specified for dogs (Table 2).

Table 1. Physical examination findings of dogs with tracheobronchitis

Variables	Mean±SD	Median (25th-75th percentile)	Reference Range (Cugmas et al. 2020; MSD Veterinary Manual)
T (°C)	38.9±0.63	39.0 (38.6-39.3)	37.5-39.2
RR (min)	63.85±33.22	56 (40-72)	18.0-34.0
HR (bpm)	133.81±28.28	130 (120-150)	70.0-120.0
CRT (sec)	2.39±0.66	2.00 (2.00-3.00)	<3.0 sec

Data were expressed mean and standard deviation (SD) and median (25th–75th percentile). **CRT;** Capillary refill time, **HR;** heart rate, **T:** body temperature, **RT:** Respiration rate.

Table 2. Complete blood count results of dogs with tracheabronchitis

Variables	Mean±SD	Median (25th-75th percentile)	Reference Range (Moritz et al. 2004; López and Mesa 2021)
WBC (10^9/L)	12.87±5.44	11.20 (8.75-15.50)	6.00-17.00
Lymph (10^9/L)	2.36±0.93	2.30 (1.70-2.75)	0.90-5.00
Mono (10^9/L)	0.94±0.46	0.80 (0.60-1.20)	0.30-1.50
Neut (10^9/L)	9.48±5.05	8.20 (5.95-11.50)	3.50-12.00
Lymp (%)	20.40±8.36	20.10 (14.30-25.05)	9.00-47.00
Mono (%)	6.99±2.06	7.00 (5.45-7.95)	2.00-12.00
Neut (%)	72.55±9.15	73.30 (67.30-78.95)	42.00-84.00
Eos (%)#	0.05±0.01	0.00 (0.00-0.00)	1.00-18.00
RBC (10^{12}/L)	6.87±1.04	6.94 (6.14-7.46)	5.50-8.50
Hgb (g/dL)	15.94±2.51	16.00 (14.35-17.75)	12.00-18.00
Hct (%)	46.28±8.00	47.60 (40.35-52.10)	37.00-55.00
MCV (fL)	67.30±5.30	68.90 (65.40-70.75)	60.00-72.00
MCH (pg)	23.25±1.73	23.50 (21.90-24.50)	19.50-25.50
MCHC (g/dL)	34.41±2.30	34.10 (33.40-35.50)	32.00-38.50
RDWa (fL)	50.31±2.90	50.10 (48.30-52.35)	35.00-65.00
RDW (%)#	14.62±1.53	14.30 (13.55-15.60)	12.00-17.50
PLT (10^9/L)	321.08±119.56	296.00 (248.50-385.50)	200.00-500.00
MPV (fL)	6.61±0.90	6.50 (6.05-7.10)	5.50-10.50

Data were expressed mean and standard deviation (SD) and median (25th–75th percentile). **RBC**; Red Blood Cell, **Hct**; hematocrit, **Hgb**; hemoglobin concentration, **Lymph**; lymphocyte, **Neut**; Neutrophil, **Mono**; monocyte, **Eos**; Eosinophil, **MCV**; mean corpuscular volume, **MCH**; mean corpuscular hemoglobin volume, **MCHC**; mean corpuscular hemoglobin concentration, **WBC**; White Blood Cell, **PLT**; platelet, **RDW**; Red cell distribution, **RDWa**; absolute value of the width of the distribution of red blood cells, **MPV**; mean platelet volume.

Blood Pressure Findings

Mean SBP (148.74±21.34 mmHg), mean DBP (104.96±27.84 mmHg) and mean MAP (121.26±23.97 mmHg) values of the dogs with tracheobronchitis were slightly higher than the reference values specified for dogs (Acierno et al. 2018) (Table 3).

Echocardiographic Findings

The mean MPA diameter, Ao diameter and MPA/Ao ratio of dogs with tracheobronchitis were calculated as 1.20±0.31 cm, 1.37±0.36 cm and 0.90±0.16, respectively. PW Doppler measurements are presented in Table 4. There was a strong positive correlation between body weight and pulmonary artery diameter (r=0.754, P<0.001). The mean LA diameter, Ao diameter and LA/Ao ratio of dogs with tracheobronchitis were calculated as 1.90±0.56 cm, 1.37±0.46 cm and 1.42±0.25, respectively. M-mode and 2D echocardiographic measurements are presented in Table 5.

In the present study, no statistically significant difference was found between dog breeds in terms of MPA/Ao ratios. However, the mean Ao diameter of Pomeranian (1.03±0.14 cm) was lower than that of Terrier (1.30±0.26 cm), Russian Poodle (1.29±0.18 cm) and crossbreed (1.57±0.39 cm) (P=0.005, P=0.018, P=0.001, respectively). PW Doppler and 2D measurements according to dog breeds is presented in Table 6.

Table 3. Blood pressure values obtained from the right forelimbs of dogs with tracheobronchitis

Variables	Mean±SD	Median (25^{th}-75^{th} percentile)	Reference Ranges (Acierno et al. 2018)
SBP (mmHg)	148.74±21.34	144.00 (134.00-167.00)	90-140 mmHg
DBP (mmHg)	104.96±27.84	109.00 (83.00-119.00)	50-80 mmHg
MAP (mmHg)	121.26±23.97	122.00 (103-141.00)	60-100 mmHg

Data were expressed mean and standard deviation (SD) and median (25^{th}-75^{th} percentile). **SBP:** Systolic blood pressure, **DBP:** Diastolic blood pressure, **MAP**: Mean arterial pressure.

Table 4. Pulsed wave (PW) Doppler and two-dimensional (2D) echocardiographic measurements obtained from right parasternal short axis (PSAX) views in dogs with tracheobronchitis

Variables	Mean±SD	Median (25^{th}-75^{th} percentile)	Reference Ranges (Esser et al. 2016; Vurucu et al., 2021; Romito et. al., 2023)
MPA (cm)	1.20±0.31	1.12 (1.00-1.38)	0.8-1.5 cm
Ao (cm)	1.37±0.36	1.30 (1.13-1.53)	1.2-1.8 cm
MPA/Ao	0.90±0.16	0.88 (0.79-0.95)	≤1.0
Vmax (m/s)	0.88±0.20	0.83 (0.73-0.99)	0.6-1.0 m/s
PGmax (mmHg)	3.25±1.56	2.77 (2.12-3.90)	<20 mmHg
Vmean (m/s)	0.43±0.12	0.41 (0.35-0.48)	0.6-1.3 m/s
PGmean (mmHg)	1.05±0.63	0.89 (0.64-1.23)	<15 mmHg
VTI (cm)	15.71±8.54	14.53 (12.31-17.27)	8-15 cm

Data were expressed mean and standard deviation (**SD**) and median (25th–75th percentile). **Ao**: Aorta diameter, **MPA**: Main pulmonary artery, **MPA/Ao:** Main pulmonary artery/Aorta ratio, **Vmax**: Pulmonary valve maximum velocity, **PGmax**: Maximum systolic pressure gradient, **Vmean**: Mean velocity, **PGort**: Mean pressure gradient of pulmonic valve, **VTI**: Velocity time integral.

Table 5. M-mode and 2D echocardiographic measurements obtained from right parasternal long and short axis views in dogs with tracheobronchitis

Variables	Mean±SD	Median (25th-75th percentile)
LA (cm)	1.90±0.56	1.82 (1.51-2.11)
Ao (cm)	1.37±0.46	1.24 (1.07-1.53)
LA/Ao (No unit)	1.42±0.25	1.39 (1.28-1.52)
IVSd (cm)	0.75±0.21	0.74 (0.56-0.80)
LVIDd (cm)	2.62±0.67	2.40 (2.11-3.02)
LVPWd (cm)	0.70±0.20	0.69 (0.51-0.86)
EDV (mL)	27.77±18.38	20.14 (14.64-35.69)
IVSs (cm)	1.04±0.21	0.97 (0.86-1.26)
LVIDs (cm)	1.47±0.46	1.22 (1.09-1.83)
LVPWs (cm)	1.02±0.25	0.97 (0.89-1.09)
ESV (mL)	6.81±5.91	3.53 (2.57-10.11)
SV (mL)	20.96±12.95	16.61 (11.28-25.12)
EF (%)	77.25±7.24	78.97 (71.48-82.16)
SI (No unit)	40.36±12.13	41.15 (29.56-51.29)
FS (%)	43.95±6.68	43.15 (38.71-48.65)
CO (L/min)	2.91±1.73	2.40 (1.56-4.07)
CI (No unit)	5.33±1.92	5.37 (3.72-6.06)

Data were expressed mean and standard deviation (SD) and median (25th-75th percentile). **BSA**: Body surface area, **LA**: Left Atrium Diameter, **Ao**: Aorta Diameter, **LA/Ao**: Left atrium diameter/Aorta diameter, **IVSd**: Interventricular septal thickness at end diastole, **LVIDd**: Left ventricular internal diameter at end diastole, **LVPWd**: Left ventricular posterior wall thickness at end diastole, **EDV**: End-diastolic left ventricular volume, **IVSs**: Interventricular Septal thickness at end-systole, **LVIDs**: Left ventricular internal diameter at end systole, **LVPWs**: Left ventricular posterior wall thickness at end systole, **ESV**: End-systolic left ventricular volume, **SV**: Stroke volume, **EF**: Ejection fraction, **SI**: SV Index (SI = SV/BSA), **FS**: Fractional shortening [FS (No unit)= (LVIDd (cm)-LVIDs (cm)/LVIDd (cm)], **CO**: Cardiac output (CO= SV×HR), **CI**: CO index (CI= CO/BSA)

Table 6. Comparison of MPA diameter and pulmonary valve PW Doppler measurements between dog breeds

Variables	Terrier (n=23)	Pomeranian (n=17)	Russian Poodle (n=12)	Pekingese (n=6)	Pug (n=6)	Crossbreed (n=7)	P Values
LA (cm)	1.82±0.45	1.55±0.35	1.82±0.28	1.58±0.28	1.90±0.39	2.12±0.77	0.088
Ao (cm)	1.30±0.26^{b}	1.03±0.14^{a}	1.29±0.18^{b}	1.11±0.13^{ab}	1.23±0.19^{ab}	1.57±0.39^{b}	**<0.001**
LA/Ao	1.40±0.21	1.51±0.30	1.40±0.09	1.42±0.13	1.59±0.41	1.34±0.27	0.424
MPA (cm)	1.16±0.19	1.01±0.23	1.09±0.25	1.07±0.08	1.25±0.22	1.39±0.40	0.085
MPA/Ao	0.88±0.07	0.95±0.23	0.81±0.14	0.97±0.21	0.94±0.16	0.87±0.09	0.469
Vmax (m/s)	0.81±0.08^{ab}	0.88±0.25^{ab}	1.00±0.21^{a}	0.83±0.23^{ab}	0.69±0.20^{b}	0.68±0.16^{ab}	**0.024**
PGmax (mmHg)	2.68±0.53^{ab}	3.35±2.09^{ab}	4.17±1.76^{a}	2.93±1.66^{ab}	2.03±1.28^{b}	1.91±0.92^{ab}	**0.027**
Vmean (m/s)	0.40±0.07	0.46±0.17	0.47±0.10	0.39±0.08	0.37±0.12	0.35±0.07	0.091
PGmean (mmHg)	0.82±0.28	1.21±0.98	1.28±0.52	0.81±0.35	0.75±0.58	0.64±0.31	0.056
VTI (cm)	14.00±2.76	16.86±4.25	15.69±4.39	14.84±5.05	11.31±2.41	14.43±5.25	0.871

Data were expressed mean and standard deviation (SD) and median (25th–75th percentile). **LA**: Left Atrium Diameter, **Ao**: Aorta Diameter, **LA/Ao**: Left atrium diameter/Aorta diameter, **MPA**: Main pulmonary artery, **MPA/Ao:** Main pulmonary artery/Aorta ratio, **Vmax**: Pulmonary valve maximum velocity, **PGmax**: Maximum systolic pressure gradient, **Vmean**: Mean velocity, **PGort**: Mean pressure gradient of pulmonic valve, **VTI**: Velocity time integral. ^{a,b}Values within a row with different superscripts differ significantly at P<0.05. Other dog breeds were not included in the comparison due to their small numbers.

DISCUSSION

In this study, echocardiographic characteristics and MPA/Ao ratio were determined in dogs with tracheobronchitis, mostly small breed dogs brought to the clinic with respiratory difficulties. In our study, no abnormalities were observed in right and left ventricular functional indicators based on m-mode, 2D and PW Doppler measurements in dogs with tracheobronchitis. In the present study, the MPA/Ao ratio was found to be between the values reported for healthy dogs.

Tracheobronchitis is an inflammation of the trachea and bronchi (Rozanski et al. 2020). It typically affects the conducting airways, which are responsible for air transport, rather than directly influencing the blood vessels or the pulmonary vasculature (Rozanski et al. 2020). The MPA/Ao is presently the sole echocardiographic metric of pulmonary artery size recognized by the ACVIM recommendations for the noninvasive identification of pulmonary hypertension in canines (Reinero et al. 2020). In veterinary medicine, echocardiographic objective assessment of the MPA has been evaluated in dogs with healthy (Serres et al. 2007; Grosso et al. 2023) and pulmonary hypertension (PH) (Visser et al. 2016; Reinero et al. 2020). Echocardiography (Reinero et al. 2020), computed tomography (Truong et al. 2012) and cardiac magnetic resonance imaging (Burman et al. 2016) have linked PH severity to proximal MPA enlargement, stiffness, and impaired distensibility (Campbell 2007; Augustine et al. 2018; Reinero et al. 2020). In a study, the MPA/Ao ratio increased in proportion to the severity of pulmonary hypertension in dogs diagnosed with mild [1.05 (0.99-1.15)], moderate [1.1 (1.04-1.17)] and severe [1.24 (1.13-1.35)] PH compared to the control group [0.92 (0.89-0.98)] (Grosso et al., 2025). Serres et al. (2007) conducted an echocardiographic assessment of MPA in 45 healthy dogs utilizing 2D imaging from the right parasternal short axis. According to their findings, the MPA/Ao reference intervals ranged from 0.80 to 1.15 (Serres et al. 2007). In another study, MPA/Ao reference ranges of 22 healthy dogs were reported as 0.80 to 1.08 (Visser et al. 2016). Grosso et al. (2023) reported a range of 0.78 to 1.01 for 269 healthy dogs. In the present study, the MPA/Ao ratio of dogs with tracheobronchitis (0.90±0.16) was within the reference values specified for healthy dogs (Serres et al. 2007; Visser et al. 2016; Grosso et al., 2023; Grosso et al., 2025). In a study investigating echocardiographic characteristics in dogs with and without PH secondary to respiratory diseases, PA diameter and PA/Ao ratio were defined (Yuchi et al. 2023). PA/Ao ratio was calculated as 0.8 (0.8-0.9) in healthy dogs, 0.8 (0.8-0.8) in no or low PH probability, 1.0 (0.9-1.0) in without PH signs, 1.0 (1.0-1.0) in with PH signs (Yuchi et al. 2023). The MPA/Ao ratio of dogs with tracheobronchitis in our study (mean 0.90±0.16) was closer to dogs no or low PH probability (median 0.8 [0.8-0.8]) and healthy dogs (median 0.8 [0.8-0.9]) (Yuchi et al. 2023). The findings from this study indicate that tracheobronchitis does not cause vascular changes that could affect pulmonary pressure.

Gentile-Solomon et al. (2016) found that the MPA showed a positive linear relationship to body weight (R^2= 0.795). In another study, the MPA showed a positive linear relationship to body weight (R^2=0.859) (Grosso et al. 2023). In the present study, a strong positive correlation (r=0.754, P<0.001) was observed between the MPA and the body weight in dogs with tracheobronchitis.

In dogs with tracheobronchitis, basic laboratory tests, including a complete blood count, are useful in determining general health and would be expected to be largely normal in a dog with tracheobronchitis or chronic bronchitis (Kumrow and Rozanski 2012). In a study, no significant difference was reported between dogs with infectious tracheabronchitis and healthy dogs in terms of WBC and granulocyte counts (Koçhan et al. 2017). In the present study, WBC and differentials (lymph, neut, etc..) in dogs with tracheobronchitis were found to be within the reference ranges (Moritz et al. 2004; López and Mesa 2021) for healthy dogs. A possible explanation for our findings may be related to the fact that most cases of tracheobronchitis are localized, chronic and with a mild infection. Tracheal bronchitis usually involves localized inflammation of the upper respiratory tract without systemic involvement. Because the infection is confined to the trachea and bronchi, it does not always trigger a systemic immune response to alter leukocyte levels (Rozanski et al. 2020). In chronic or long-term cases, the immune system can adapt to ongoing low-level inflammation and prevent significant changes in leukocyte levels. Most cases of tracheal bronchitis result from mild infections (especially those caused by canine parainfluenza or *Bordetella bronchiseptica*). Mild infections usually do not trigger an immune response strong enough to increase WBC counts (Rozanski et al. 2020). In addition, in immunocompetent dogs, the immune system can effectively control the infection locally without the need to mobilize large numbers of circulating white blood cells (Kumrow and Rozanski 2012; Reagan and Sykes 2020).

Blood pressure (BP) is an important parameter to measure to assess cardiovascular system function (Sierra and Savino 2015ab). Measuring blood pressure in dogs (Ekinci et al. 2024), cats (Güneş et al. 2021) and calves (Deniz et al. 2022) using the oscillometric method is a practical method. In the present study, mean blood pressure values (SBP, DBP, MAP) of dogs with tracheobronchitis were found to be slightly higher than the reference values reported by Acierno et al. (2018) for healthy dogs. Stress and anxiety in the clinic setting, combined with stress from handling to take a blood pressure measurement, can result in increased readings and a false diagnosis of hypertension (Sierra and Savino 2015ab).

In the present study, the mean pulse frequency and respiratory rate obtained from dogs with tracheabronchitis were higher than the values reported for healthy dogs (Cugmas et al. 2020; MSD Veterinary Manual). Other vital parameters (body temperature, capillary refilling time) were within the normal range. Body temperature and white blood cell counts usually remain normal in dogs with tracheobronchitis (MSD Veterinary Manual).

In the present study, the mean maximum velocity of blood flow (Vmax) and maximum pressure gradient (PGmax) values of Pugs were lower than those of Russian poodles. Pugs suffer from Brachycephalic Obstructive Airway Syndrome, which often leads to upper airway obstruction (Wiegel et al. 2022). There are also slight differences in heart size and positioning within the chest cavity in Pugs (Romito et al. 2023). The altered geometry of the heart valves (especially the tricuspid and pulmonary valves) can lead to breed-specific variations in flow velocity and pressure gradients. Due to the Pug's compact chest and short neck, echocardiographic angles may be suboptimal, which may affect the accuracy of measured Vmax and PG max values (Kavitha et al. 2020; Wiegel et al. 2022). These factors may explain the difference in echocardiographic measurements obtained from Pugs in the current study.

In the present study, no statistically significant difference was found between dog breeds in terms of PA and MPA/Ao ratios. However, the mean Ao dia (cm) of Pomeranian dog breed was lower than that of Terrier and Russian Poodle dogs. Reference values from breed-specific echocardiographic studies have been found to differ significantly from the overall population of healthy dog breeds (Jacobson et al. 2013; Vurucu et al. 2021). As a result, breed-specific echocardiographic reference ranges may be more useful in preventing misunderstanding of echocardiographic findings (Kayar et al. 2006). The difference in mean Ao diameters among the dog breeds included in the study can be explained by differences in body size and somatotype (Jacobs et al. 1988; Morrison et al. 1992).

The main limitation of the present study is that echocardiographic measurements obtained from the dog breeds included in the study could not be compared with healthy control groups. Another limitation is that nasoparigeal swabs, transtracheal and bronchoalveolar lavage fluids could not be obtained from the dogs included in the study. Therefore, common pathogens causing respiratory tract infections in dogs (canine parainfluenza, Bordetella bronchiseptica, etc.) could not be identified. The diagnosis of tracheabronchitis was based only on anamnesis, physical examination findings, diagnostic imaging (thoracic radiography) and laboratory (complete blood count) findings. Furthermore, the study lacked assessment of intra- and inter-observer variability.

CONCLUSION

In conclusion, the MPA/Ao ratio in dogs with tracheobronchitis included in the study was between the values reported for healthy dogs. Based on basic echocardiographic findings and pulmonary artery measurements, no signs of pulmonary hypertension were detected in dogs with tracheobronchitis. However, it can be argued that due to the progressive nature of PH and its poor prognosis, a more comprehensive echocardiographic evaluation may be useful to identify dogs with the potential to develop PH.

Conflict of interest: The authors have no conflicts of interest to report.

Authors' Contributions: GE contributed to the project idea, design and execution of the study. CB and GE contributed to the acquisition of data. CB and GE analysed the data. CB and GE drafted and wrote the manuscript. CB and GE reviewed the manuscript critically. All authors have read and approved the finalized manuscript.

Ethical approval: "This study is not subject to the permission of HADYEK in accordance with the "Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees" 8 (k1). The data, information and documents presented in this article were obtained within the framework of academic and ethical rules."

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