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Evaluation of Cardiologic Alterations in Radiographs of Dogs with Bronchopneumonia Before and After Treatment

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ABSTRACT Pneumonia, a common respiratory disease in small animals, causes significant hypoxemia in dogs due to reduced lung capacity and cardiac output. In addition, pneumonia may lead to cardiac complications. This study aimed to evaluate the alterations in cardiac silhouette and main vessel views in dogs that underwent bronchopneumonia treatment, and the alterations were evaluated in radiographs of the dogs with bronchopneumonia before and after treatment. For this purpose, radiographic data from 26 dogs diagnosed with and treated for bronchopneumonia were analyzed. The measurements included left atrial size, long axis, short axis, the fourth thoracic vertebra length, aorta width, caudal vena cava width, and thoracic width. Radiographs obtained before and after treatment indicated no changes in the long and short axes of the vertebral hearth score, the fourth thoracic vertebrae length, aorta and caudal vena cava width, and thoracic width. However, in pre-treatment radiographs, the left atrial size was found to be larger compared to post-treatment radiographs. A strong positive correlation was observed between measurements of LAs and LAs/TV4 in both pre- and post-treatment radiographs, as well as in the measurement differences between pre- and post-treatment radiographs. As a consequence, the radiographs employed to monitor bronchopneumonia treatment may serve as an initial indicator of potential cardiac complications in affected dogs.

Keywords: *Dog, bronchopneumonia, radiograph, cardiac alterations, left atrial size.*

ÖZ

Bronkopnömonili Köpeklerin Tedavi Öncesi ve Sonrası Radyografilerinde Kardiyolojik Değişikliklerin Değerlendirilmesi

Küçük hayvanlarda yaygın bir solunum yolu hastalığı olan pnömoni, akciğer kapasitesinin ve kalp debisinin azalması nedeniyle köpeklerde önemli hipoksemiye neden olur. Ayrıca, pnömoni kardiyak komplikasyonlara da yol açabilir. Bu çalışmada bronkopnömoni tedavisi uygulanan köpeklerde kardiyak siluet ve ana damar görünümlerindeki değişikliklerin değerlendirilmesi amaçlanmış ve bronkopnömonili köpeklerin tedavi öncesi ve sonrası radyografilerindeki değişiklikler değerlendirilmiştir. Bu amaçla, bronkopnömoni teşhisi konulan ve tedavi edilen 26 köpeğe ait radyografik veriler analiz edilmiştir. Ölçümler sol atriyal boyut, uzun eksen, kısa eksen, 4. torasik vertebra uzunluğu, aort genişliği, kaudal vena kava genişliği ve torasik genişliği içeriyordu. Tedavi öncesi ve sonrasında çekilen radyografilerde vertebral kalp skorunun uzun ve kısa eksenlerinde, dördüncü torasik vertebra uzunluğunda, aort ve kaudal vena kava genişliğinde ve torasik genişlikte herhangi bir değişiklik saptanmamıştır. Ancak, tedavi öncesi radyografilerde sol atriyal boyut tedavi sonrası radyografilere kıyasla daha büyük bulunmuştur. Hem tedavi öncesi hem de tedavi sonrası radyografilerde LAs ve LAs/TV4 ölçümleri arasında ve tedavi öncesi ile sonrası radyografiler arasındaki ölçüm farklılıklarında güçlü bir pozitif korelasyon gözlenmiştir. Sonuç olarak, bronkopnömoni tedavisini izlemek için kullanılan radyografiler, etkilenen köpeklerde potansiyel kardiyak komplikasyonların ilk göstergesi olarak hizmet edebilir.

Anahtar Kelimeler: *Köpek, bronkopnömoni, radyografi, kardiyak değişiklikler, sol atriyal boyut.*

INTRODUCTION

In small animals, pneumonia is defined as inflammation of the lower airways and is one of the most commonly diagnosed respiratory diseases (Brady 2004; Ayodhya et al. 2013; Köse et al. 2021). Pneumonia causes variable degrees of ventilation/perfusion mismatch, potentially

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leading to hypoxemia (Brady 2004). Significant hypoxemia in dogs with pneumonia has been reported in the literature (Wingfield et al. 1997; Brady 2004; Kogan et al. 2008). It is stated that in dogs with pneumonia, total lung capacity and functional residual capacity are severely reduced, and there is also an increase in cardiac output and a decrease in mean systemic arterial pressure and vascular resistance due to hypoxia (Hanly and Light 1987). Respiratory diseases and/or hypoxia (RD/H) are reported as the most common causes of pulmonary hypertension (PH) in dogs (Jaffey et al. 2019). A presumptive diagnosis of RD/H in dogs with PH is typically made entirely on the existence of respiratory symptoms and the exclusion of left-sided heart disease in undiagnosed dogs to determine the underlying cause (Jaffey et al. 2019). The systemic vasculature responds to hypoxia with vasodilation to more effectively perfuse hypoxic tissue, but the pulmonary vasculature responds with pulmonary artery vasoconstriction. Thus, the pulmonary arteries contract in order to take blood away from the diseased lungs while maintaining arterial oxygen concentration (Kellihan and Stepien 2010).

Thoracic radiography is a valuable technique for evaluating both thoracic and systemic illness (Rudorf et al. 2008). So, the pleural space, the mediastinum, the trachea and carina, the bronchi, the cardiac silhouette, the aorta, caudal vena cava, and pulmonary vasculature, and the lung can be easily evaluated thanks to thoracic radiographs (Rudorf et al. 2008; Bradley 2013). Although echocardiography is the gold standard for measuring heart dimensions and internal structures, thoracic radiographs remain the primary clinical diagnostic tool for dogs with suspected cardiac diseases and alterations (Lamb and Boswood 2002; Mostafa and Berry 2017; Mostafa et al. 2020; Tangpakornsak et al. 2023). The most prevalent abnormalities investigated by radiography for the heart are cardiomegaly, pericardial effusion, and chamber enlargements, especially left atrial enlargement (Mostafa et al. 2020).

A vertebral heart score (VHS) is a radiographic procedure to determine the cardiac size by using some measurements and calculations on the cardiac silhouette in the thoracic radiography (Buchanan and Bücheler 1995; Mostafa et al. 2020). However, in the detection of individual cardiac chamber enlargements, this measurement technique is reported as relatively poor (Buchanan and Bücheler 1995; Jojima et al. 2019). So, some researchers have modified the VHS technique to evaluate individual left atrial enlargement and added some new measurements (Sanchez et al. 2013; Jojima et al. 2019). Left atrium size can be measured on lateral radiographs by using a new line drawn at 45 degrees from the intersection of the long axis and short axis of the VHS (Sanchez et al. 2013; Jojima et al. 2019).

Although the heart and lungs are considered individual organs, they are strongly related as a part of the cardiorespiratory system. When abnormalities occur in these organs, they directly affect each other (Corrales-Medina et al. 2013; Restrepo and Reyes 2018). With this insight, in this study, it was aimed to evaluate the alterations in cardiac silhouette and main vessel views in dogs that underwent treatment for bronchopneumonia with the hypothesis that some radiographic alterations in cardiac silhouette and main vessel views (including the aorta and caudal vena cava) might occur in dogs with bronchopneumonia.

MATERIAL AND METHODS

The study was approved by the Hatay Mustafa Kemal University Animal Experiments Local Ethics Committee (Approval number, 2015/10-10; Approval date, 30 Dec 2015).

A total of 116 dogs with respiratory complaints (cough, respiratory distress, nasal discharge, etc.) were evaluated at Hatay Mustafa Kemal University Veterinary Health, Practice, and Research Center Department of Internal Medicine between January 2017 and December 2018. A total of 41 dogs of different breeds, ages, and sexes with signs of lower respiratory tract disease (purulent nasal discharge, intermittent cough, wet rales, crackles, and wheezes on auscultation) were selected within these admissions. These animals underwent radiographic examination with a presumptive diagnosis of bronchopneumonia and were diagnosed and started on their treatment for bronchopneumonia based on their clinical presentations and radiographs. Of these 41 dogs that began treatment for bronchopneumonia, pre- and post-treatment radiographs of 26 dogs were selected according to the inclusion and exclusion criteria and constituted the material for this study.

Inclusion criteria were 1) radiographs in the left lateral and ventrodorsal position to evaluate the diagnosis and treatment outcome in radiographs, and 2) radiographic images of the same treated dog both before and after treatment.

Exclusion criteria for the study were 1) the dog's treatment was not completed for any reason (such as death, inability to reach the owner, or not brought in by the owner), 2) one of the lateral and/or ventrodorsal radiographs is missing, 3) the presence of additional radiographic findings such as cardiac-noncardiac pulmonary edema, pleural effusion, or pericardial effusion that may affect the cardiac silhouette and main vessel appearance on radiography, and 4) that the quality of the radiographic images was poor to measure the heart silhouette, main vessel views, and thoracic width.

Radiographic Evaluations

Thoracic radiographs in DICOM format were obtained from the patient database. The left lateral (LL) and ventrodorsal (VD) radiographs (60-80 kV and 5-20 mAs, Regius ∑II, Konica Minolta, Tokyo, Japan) were used to evaluate the cardiological views. The same expert veterinary surgeon evaluated all radiographs by using PDI DICOM Viewer V2.20, Konica Minolta, Inc. The cardiological views in radiographs of dogs with bronchopneumonia were evaluated before and after treatment. Left Atrial Size (LAs), Long Axis (LA), Short Axis (SA), 4th Thoracic Vertebra Length (TV4), Aorta Width (Aw), Caudal Vena Cava Width (CVCw), Thoracic Width (Tw), and the ratios of Left Atrial Size to Aorta Width (LAs/Aw), Left Atrial Size to Caudal Vena Cava Width (LAs/CVCw), and Left Atrial Size to 4th Thoracic Vertebra Length (LAs/TV4) were measured and calculated in the radiographs as the cardiological views. Left Atrial Size, LA, SA, 4TV, Aw, and CVCw were measured in the LL radiographs (Figure 1), and Tw was measured in the ventrodorsal radiographs (Buchanan and Bücheler 1995; Estrada and Fox-Alvarez 2016) (Figure 2). All measurements were performed as described by Buchanan and Bücheler (1995), Hansson et al. (2005), and Jojima et al. (2019).

Statistical Analysis

For categorical variables, descriptive statistics were presented as frequencies and percentages, and for continuous variables, as arithmetic means and standard errors. The normality assumption was checked with the Shapiro-Wilk Test. Comparison of the data of radiographical views in pre- and post-treatment radiographs was performed with a paired t-test if the data held the normality assumption or a Wilcoxon rank test if the data did not hold the normality assumption. The relationships between data of radiographical views were specified with Spearman's rank correlation coefficient due to the normality assumption not holding. The association was classified as weak, moderate, strong, or perfect when the correlation coefficient value was .1-.3, .4-.6, .7-.9, or 1, respectively (Bagardi et al. 2021). A p value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS Statistics for Windows, Version 26.0.

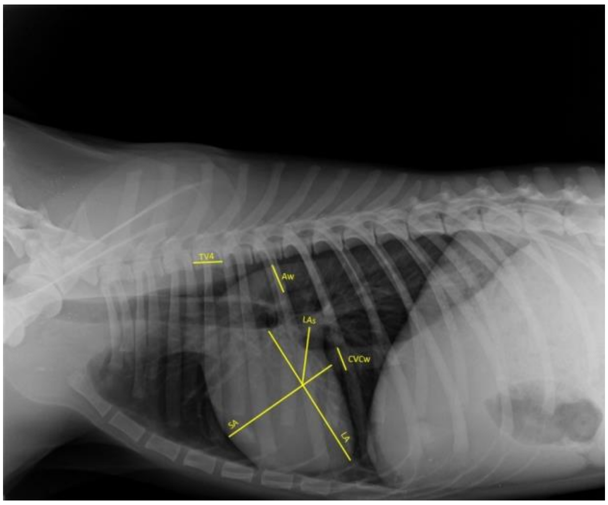

Figure 1: Measured cardiac views in L/L radiograph.

LAs: Left Atrial Size, LA: Long Axis, SA: Short Axis, TV4: 4th Thoracic Vertebra, Aw: Aorta Width, CVCw: Caudal Vena Cava Width

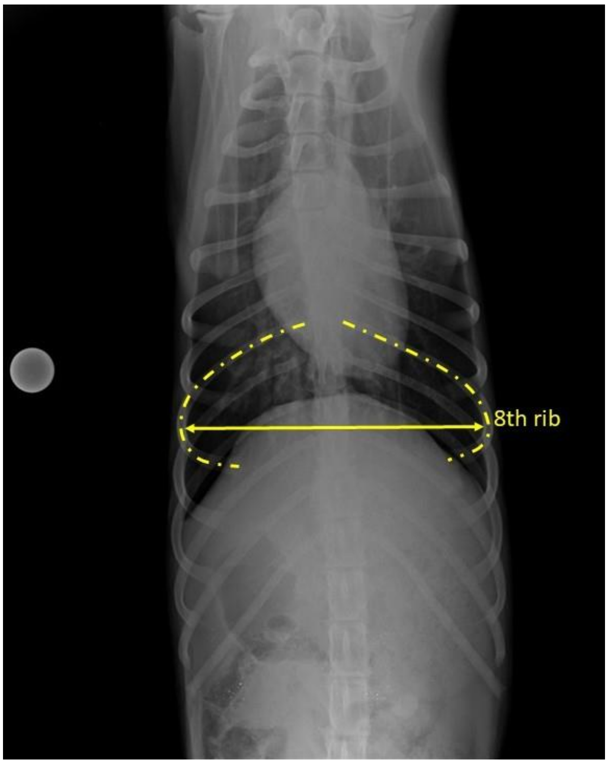

Figure 2: Measuring of thoracic width in V/D radiograph.

RESULTS

The radiographic data from 26 dogs that underwent bronchopneumonia treatment were retrospectively analyzed. No difference between pre-treatment and post-treatment radiographs was detected in the long and short axes of VHS, 4th Thoracic Vertebra, the aorta and caudal vena cava width, and thoracic width (Table 1). On the other hand, the left atrial size was observed as approximately nine percent larger in pre-treatment radiographs than in post-treatment radiographs (Table 1). Pre-treatment radiographs showed higher ratios of left atrium size to aorta width, caudal vena cava width, and the fourth thoracic vertebra than post-treatment ones (Table 1). Correlations between measured parameters both in pre-treatment and post-treatment radiographs were given in Tables 2 and 3. The difference in measurement of left atrial size between pre- and post-treatment radiographs had a strong positive correlation with the ratio of fourth vertebrae and aortic width, but a moderate positive correlation with the ratio of caudal vena cava width (Table 4).

DISCUSSION AND CONCLUSION

As explained above, pneumonia may lead to cardiovascular complications by various pathways. In this study, some changes were observed in pre- and post-treatment radiographs from the dogs with bronchopneumonia, suggesting that pneumonia may cause cardiac changes, especially left atrial size. In this study, changes in the silhouette of the heart and the appearance of the main blood vessels were assessed in the radiographs of dogs treated for bronchopneumonia before and after treatment. The left atrial size was found to be larger in the pre-treatment radiographs than in the post-treatment radiographs. A strong positive correlation was identified between the measurement differences performed in the pre- and post-treatment radiographs for LAs and LAs/Aw, as well as LAs/TV4.

Whereas the heart and lungs are separate organs, they are inextricably linked as part of the cardiorespiratory system (Corrales-Medina et al. 2013; Restrepo and Reyes 2018). So, pneumonia and cardiovascular diseases are reported as causes of morbidity and mortality in veterinary medicine as well as in human medicine (Ilten et al. 2003; Kogan et al. 2008; Corrales-Medina et al. 2013; Jaffey et al. 2019; Restrepo and Reyes 2018). The occurrence of functional alterations in the cardiovascular system in the process of respiratory diseases, especially pneumonia, is supported by various studies that have been done with both humans and animals (Hanly and Light 1987; Ilten et al. 2003; Jaffey et al. 2019). These alterations are explained by the effects of pneumonia-related myocardial microorganism invasion, hypoxemia-related myocardial ischemia or infarction, deterioration in the hemostatic functions of the vascular endothelium, and renal dysfunction (Corrales-Medina et al. 2013).

Many respiratory disorders in dogs, such as pneumonia, infiltrative pulmonary disease, and tracheobronchial disease, have been linked to pulmonary hypertension (PHT) (Campbell 2007; Morita et al. 2018). PHT is a multifactorial disorder characterized by increased pulmonary vascular resistance due to vasoconstriction and vascular remodeling, triggered by hypoxemia, and the release of endogenous vasoactive mediators and mitogens from diseased pulmonary cells, activated platelets, and inflammatory cells (Voelkel and Tuder 1995; Campbell

2007). In dogs with severe respiratory disease, compensatory polycythemia develops in response to hypoxemia, increasing red blood cell concentration. This causes an exponential increase in blood viscosity, resulting in increased pulmonary vascular resistance and exacerbation of PHT (Campbell 2007). On the other hand, it is obvious that an increase in proteolysis, formation of thrombus, and generation of reactive oxygen species, all of which may raise the risk of significant cardiac events, occur in pneumonia in both animals and humans (Stotts et al. 2023).

The vertebral heart scale system (or vertebral heart size) is designed to objectively evaluate the size of the heart both in dogs of various breeds and thoracic conformations and in cats (Estrada and Fox-Alvarez 2016) by measuring and calculating the cardiac appearance in thoracic radiography (Buchanan and Bücheler 1995; Mostafa et al. 2020). On a lateral radiograph, the line drawn from the carina to the most ventral aspect of the heart is the long axis. The line drawn perpendicular to the long axis at the widest point of the heart and extending to the craniocaudal limits is the short axis (Figure 1) (Buchanan and Bücheler 1995; Hansson et al. 2005; Estrada and Fox-Alvarez 2016; Jojima et al. 2019). In addition to research showing that there is no change in VHS measurements in the lateral radiographic position (Buchanan and Bücheler 1995), researches have shown that the measurements are greater (approximately 0.3 vertebrae) in the right lateral radiographic position (Greco et al 2008; Jojima et al. 2019). The published range for a normal VHS on a lateral radiograph is 9.2 to 10.9 (Buchanan and Bücheler 1995; Gülanber et al 2005; Estrada and Fox-Alvarez 2016). In a study, VHS in dogs without cardiac disease is reported as 10.5±0.7 on the right lateral radiographs (Mostafa et al. 2020). Birks et al. (2017) report that the left lateral VHS was detected as 10.1 vertebrae. In the presented study, similar to previous studies (Buchanan and Bücheler 1995; Gülanber et al. 2005; Estrada and Fox-Alvarez 2016; Birks et al. 2019; Mostafa et al. 2020), pre- and post-treatment VHS on radiographs were detected as 10.22±0.13 and 10.32±0.12 vertebrae, respectively. Therefore, there was no statistical difference (p=0.191) between the pre- and post-treatment radiographs for VHS. The fact that there was no difference in the vertebral heart scale in the pre- and post-treatment radiographs confirms that there was no difference in the vertebral heart scale parameters: long axis (p=0.959), short axis (p=0.07), and length of the fourth thoracic vertebra (p=0.574) (Table 1).

Table 1: Comparison of pre-treatment and post-treatment X-Ray measurements and ratio calculations of cardiac views (mean±SEM).

	LAs	LA	SA	TV4	Aw	CVCw	Tw	LAs/Aw	LAs /CVCw	LAs/TV4
PreT	35.877 ±0.913	114.904 ±2.428	96.438 ±1.844	20.719 ±0.380	19.358 ±0.543	17.935 ±0.524	165.281 ±3.816	1.876 ±0.055	2.025 ±0.057	1.738 ±0.043
PostT	32.800 ±0.860	114.973 ±2.180	98.423 ±1.953	20.715 ±0.380	19.831 ±0.653	18.204 ±0.573	167.558 ±3.814	1.685 ±0.055	1.829 ±0.054	1.592 ±0.043
P value	***0.003***[1]	0.959	0.070	0.574	0.236	0.488	0.195	***0.002***[1]	***0.003***[1]	***0.005***[2]

[1]Paired t-test; [2]Wilcoxon test
PreT: Pre-treatment, PostT: Post-treatment, LAs: Left Atrial Size, LA: Long Axis, SA: Short Axis, TV4: 4th Thoracic Vertebra, Aw: Aorta Width, CVCw: Caudal Vena Cava Width, Tw: Thoracic Width

Table 2: Correlations in Pre-treatment X-Ray measurements and ratio calculations.

Parameters	LAs	LA	SA	TV4	Aw	CVCw	Tw	LAs/Aw	LAs /CVCw	LAs/TV4
LAs	1	**.576****	**.636****	**.429***	**.409***	**.529****	.057	**.482***	.373	**.730****
LA		1	**.622****	**.811****	**.726****	**.537****	.298	-.187	-.033	.000
SA			1	**.529****	**.693****	**.465***	.126	-.087	.131	.282
TV4				1	**.793****	**.578****	**.611****	-.373	-.212	-.302
Aw					1	**.714****	**.488***	**-.589****	-.360	-.170
CVCw						1	.356	-.213	**-.584****	.109
Tw							1	**-.414***	-.354	**-.405***
LAs/Aw								1	**.664****	**.795****
LAs /CVCw									1	**.568****
LAs/TV4										1

**Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

LAs: Left Atrial Size, LA: Long Axis, SA: Short Axis, TV4: 4th Thoracic Vertebra, Aw: Aorta Width, CVCw: Caudal Vena Cava Width, Tw: Thoracic Width

Table 3: Correlations in Post-treatment X-Ray measurements and ratio calculations.

Parameters	LAs	LA	SA	TV4	Aw	CVCw	Tw	LAs/Aw	LAs /CVCw	LAs/TV4
LAs	1	**.468***	**.654****	.279	**.472***	**.520****	-.105	.303	.292	**.757****
LA		1	**.757****	**.746****	**.704****	**.544****	**.492***	-.350	-.165	-.067
SA			1	**.677****	**.800****	**.647****	.266	-.322	-.130	.160
TV4				1	**.666****	**.439***	**.654****	**-.457***	-.160	**-.413***
Aw					1	**.780****	.324	**-.673****	**-.433***	-.013
CVCw						1	.137	-.357	**-.647****	.196
Tw							1	**-.418***	-.151	**-.529****
LAs/Aw								1	**.646****	**.616****
LAs /CVCw									1	.386
LAs/TV4										1

**Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

LAs: Left Atrial Size, LA: Long Axis, SA: Short Axis, TV4: 4th Thoracic Vertebra, Aw: Aorta Width, CVCw: Caudal Vena Cava Width, Tw: Thoracic Width

Table 4: Correlations in difference of Pre-treatment and Post-treatment X-Ray measurements and ratio calculations.

Parameters	LAs	LA	SA	TV4	Aw	CVCw	Tw	LAs/Aw	LAs /CVCw	LAs/TV4
LAs	1	.113	.260	-.224	.156	.311	-.017	**.725****	**.624****	**.996****
LA		1	-.172	-.002	.113	-.044	-.057	.015	.107	.128
SA			1	.000	.145	.165	.347	.107	.166	.272
TV4				1	-.025	-.056	.114	-.178	-.141	-.237
Aw					1	**.486***	-.003	**-.553****	-.256	.149
CVCw						1	.094	-.049	**-.525****	.302
Tw							1	.025	-.007	-.007
LAs/Aw								1	**.683****	**.735****
LAs /CVCw									1	**.637****
LAs/TV4										1

**Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

LAs: Left Atrial Size, LA: Long Axis, SA: Short Axis, TV4: 4th Thoracic Vertebra, Aw: Aorta Width, CVCw: Caudal Vena Cava Width, Tw: Thoracic Width

The absence of a difference in these parameters may be attributed to the utilization of left-sided radiographs. Furthermore, in consideration of the p-value approaching the significance level for the short axis of VHS, the small sample size may also be responsible for the absence of a difference in VHS.

In addition to mechanical function, the left atrium performs endocrine and regulatory roles (Boudoulas et al. 2014). Cardiopulmonary baroreceptors situated in the atria, pulmonary veins, and systemic vena cava help to regulate cardiac output by controlling venous return, pulmonary arterial and venous pressure, and pulmonary capillary blood flow (Aviado and Guevera Aviado 2001; Boudoulas et al. 2014). The aging process, neurohumoral stimulation, and chronic atrial stretch engage several signaling pathways, resulting in histological alterations in the atria (Boudoulas et al. 2014). Atrial remodeling refers to histologic changes such as myocyte hypertrophy, fibroblast proliferation, and complex alterations of the extracellular matrix, which may affect LA function (Nattel et al. 2008; Boudoulas et al. 2014). As a consequence of atrial remodeling, LA dilation, LA hypocontractility, and atrial fibrillation are likely to occur (Boudoulas et al. 2014). In dogs, some studies evaluate the vertebral left atrial size in radiographs to determine reference intervals for the evaluation of atrial enlargement (Malcolm et al. 2018; Sánchez Salguero et al. 2018; Vezzosi et al. 2020). In healthy dogs, Bagardi et al. (2022) report that the radiographic left atrial dimension on left lateral radiographs was determined to be 1.37±0.20 vertebrae, as well as 1.20±0.34 vertebrae on the right side. On the other hand, while it ranges between 2.1 and 2.8 vertebrae, the cut-off value has been reported to be ≥2.3 vertebrae for dogs with left atrial enlargement (Malcolm et al. 2018; Vezzosi et al. 2020). In this study, there was no difference between pre- and post-treatment cardiac and vascular views in radiographs, except for the left atrial size (Table 1). Even though the left atrium size in the pre-treatment radiograph seems larger (Z: -2.831, p=0.005) than in the post-treatment radiograph, the left atrium size in both radiographs (pre-treatment=1.74±0.04 vertebrae; post-treatment=1.59±0.04 vertebrae) (Table 1) remained below the reference value (Malcolm et al. 2018; Vezzosi et al. 2020). Therefore, explaining this condition as a compensatory response of the heart to PHT triggered by hypoxemia that is likely to develop as a result of bronchopneumonia may be a more accurate approach than atrial enlargement.

In veterinary medicine, the most often used technique for assessing left atrial size is the left atrial-to-aortic root ratio, which gives a body weight-independent measurement of left atrial size (Wesselowski et al. 2014). In the recent studies (Sanchez et al. 2013; Mostafa and Berry 2017; Mostafa et al. 2020; Tangpakornsak et al. 2023), the fourth thoracic vertebra length is used for the evaluation of cardiac alterations in radiographs, especially for left atrial enlargement. With this approach, in this study, the left atrial size measurement was ratioed to aorta width, caudal vena cava width, and fourth thoracic vertebra length, which were obtained on the thoracic radiograph. The difference was detected for LAs/Aw, LAs/CVCw, and LAs/TV4 ratios between pre- and post-treatment radiographs. All ratios were observed to be higher in the pre-treatment radiographs than the post-treatment radiographs (Table 1). Authors have reported that the left atrial size in the left lateral radiographs was weakly correlated (r=0.60) with the left atrium to aorta ratio detected by using echocardiographic measurement (Jojima et al. 2019). In a similar methodology to that employed by Jojima et al. (2019), Bagardi et al. (2021) report a moderate correlation (r=0.591) between the left atrial dimension as observed in right lateral radiographs and the left atrium to aorta ratio. In this study, contrary to Jojima et al. (2019) and Bagardi et al. (2021), a strong positive correlation (r=0.725) was identified between the LAs and the LAs/Aw ratio in measurement differences between pre- and post-treatment radiographs (Table 4). The dissimilarity in findings may be attributable to a discrepancy in methodology, whereby Jojima et al. (2019) and Bagardi et al. (2021) employed a comparison of radiographic measurements (LAs) with echocardiographic measurements (LA/Ao), in contrast to the approach taken in our study.

A strong positive correlation was detected between LAs and LAs/TV4 in pre- and post-treatment measurements (Tables 2 and 3), as well as for measurement differences between pre- and post-treatment radiographs (Table 4). The strong correlation between the differences in LAs and LAs/TV4 ratio measurements in pre-treatment and post-treatment radiographs (Table 4) may be related to the changes that are likely to occur in the aforementioned left atrium (Aviado and Guevera Aviado 2001; Boudoulas et al. 2014) rather than the length of the 4th thoracic vertebra, which showed almost no difference in both measurements (Table 1). In fact, the difference in the size of the left atrium pre- and post-treatment radiographs may also support this idea (Table 1). Therefore, the 4th thoracic vertebra length ratio may be usable to assess changes in the left atrial silhouette.

The main limitation of this study designed as a retrospective study may be the lack of echo or Doppler ultrasonographic examination that would allow comparison of changes in cardiac and vascular silhouettes in radiographs. Another limitation of this study may be the lack of etiology, symptom duration and blood gas data.

Finally, in dogs with bronchopneumonia, it is thought that the radiographs used to monitor the treatment process may provide an early warning of dogs with cardiac complications. In addition, it is also thought that further comprehensive studies consisting of echo and Doppler ultrasound examinations, right lateral thoracic radiographs, and laboratory analyses (blood gases analyses, canine troponin I, NT-proBNP etc.) should be performed for the evidence of internal and functional cardiac alterations in dogs with pneumonia.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Idea / Concept: SİK
Supervision / Consultancy: SİK, RG
Data Collection and / or Processing: SİK
Analysis and / or Interpretation: SİK, RG
Writing the Article: SİK, RG
Critical Review: RG

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