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Results of radiographic assessment of cardiac size in dogs with progressing myxomatous mitral valve disease

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Contents

Abstract

Chest radiography for mitral valve endocardiosis (MMVD) is both an independent and an additional method of investigation compared to echocardiography. It allows assessment of lung tissue condition, central airways, degree of vascularization, and changes in the mediastinum and pleural cavities. This study aimed to perform a radiographic examination of dogs with mitral valve endocardiosis at different stages under previously established and new indices and to determine their informativeness. The study was conducted in the private veterinary hospital "Eurovet" and at the Department of Internal Diseases of Animals and Clinical Diagnostics clinic of the Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv. The subjects were 25 dogs with mitral valve endocardiosis. The diagnosis was established based on the American College of Veterinary Medicine criteria. During the study, three experimental groups of animals were formed according to their clinical-functional status and the characteristics of each stage of MMVD development: groups B1, B2, and C. In group B1, 57.1 % of the animals had a slight increase in the RLAD index. With the progression of the disease, we observed a further increase in RLAD (in 80 %), a significant increase in VLAS ($P < 0.01$) for the first time in 40 %, as well as a decrease in RLAD-spine ($P < 0.05$) in 40 % and Bronchus-spine ($P < 0.01$) in 60 % of dogs, which generally indicates both local enlargement of the left atrium and cardiomegaly. The informativeness of the VHS index was noted at stage C (group C), as in 66.7 % of the experimental animals, its value exceeded ($P < 0.001$) the reference values of the norm. At the same time, we observed an increase ($P < 0.05$) in the mean value of RLAD by 1.3 times compared to group B1 and VLAS ($P < 0.001$) by 1.6 times. Between the radiographic indicators, we confirmed the presence of a strong correlation. Thus, in group B2, it was positive ($r = +0.779$) for VHS and RLAD and negative ($r = -0.831$) for VHS and RLAD-spine. In group C, a further increase in the correlation ($r = +0.885$) was found only between VHS and RLAD. Based on the analysis of chest radiography data, it is advisable to use radiographic indices in cases of cardiomegaly, particularly with left atrial enlargement. However, this requires their group determination and mandatory comparison with echocardiographic examination results. In veterinary practice, this has diagnostic significance for establishing the stage of the disease, as well as in the selection or correction of the therapeutic support scheme for the patient.

Keywords: mitral regurgitation; myxomatous mitral valve disease; dog; x-ray examination; cardiomegaly.

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1. Introduction

Radiographic examination of the thoracic cavity is an integral part of the comprehensive evaluation of dogs for cardiovascular pathologies. The application of this method allows for a quick assessment of criteria such as the condition of pulmonary parenchyma, size or shape of the cardiac shadow, pleural cavity, airways, and vascularization (Salguero et al., 2018; Salguero et al., 2019; Fernández et al., 2023). Thus, this non-invasive method, alongside echocardiography, is crucial in the comprehensive and objective assessment of left atrial size, which is a prognostic-diagnostic and therapeutic criterion in the severity of myxomatous mitral valve disease (MMVD) (Salguero et al., 2019; Szatmári et al., 2023).

Initial radiographic methods focused on assessing changes in the heart's overall size (cardiomegaly, microcardia) were subjective and based on the relative determination of anatomical structures: the width of the cardiac silhouette should range from 2.5 to 3.5 intercostal spaces on lateral radiographs, with its height not exceeding 60 % of the total height of the thoracic cavity. Simultaneously, the maximum width on dorsoventral and ventrodorsal projections should be within half the width of the thoracic cavity at the level of the 9th rib. The "clock-face" graphical method was used to identify the enlargement of individual cardiac chambers on dorsoventral projections (Duler et al., 2018). Drawbacks of this approach include limitations regarding variations in the heart axis and its imaging, phase of respiration, rib superimposition, unclear measurement points, and significant breed-related thoracic cage variability (Chhoey et al., 2020;

Wiegel et al., 2022). For the mitigation of these limitations, concepts such as cardiothoracic ratio (CTR ≤ 0.55), sphericity index (CSI ≤ 1), and Buchanan's coefficient (VHS = 8.7 – 10.7) were introduced (Buchanan, 2000; Bagardi et al., 2021). The informativeness of the latter two has been highlighted by numerous studies (Salguero et al., 2018; Chhoey et al., 2020; Levicar et al., 2022; Fernández et al., 2023) (Salguero et al., 2018, Chhoey et al., 2020; Levicar et al., 2022; Fernández et al., 2023), confirming a significant (P = 0.001) and positive correlation (r = +0.812) between them (Salguero et al., 2018).

As of today, due to the increasing prevalence of MMVD (comprising 75 % of all cardiovascular diseases) (Mikawa et al., 2020; Lam et al., 2021; Fernández et al., 2023) and the technical complexity of performing echocardiography, there is a growing need to implement and utilize new radiographic indicators for qualitative and quantitative assessment of atrial dilation. According to recent literature (Keene et al., 2019; Mikawa et al., 2020; Levicar et al., 2022), these include RLAD (radiographic left atrial dimension), Br-spine (bronchus-to-spine), RLAD-spine, and VLAS (vertebral left atrial size) (Vezzosi et al., 2021; An et al., 2023).

However, the evolution of these criteria with the progression of MMVD remains poorly understood, which was the focus of our study.

2. Materials and methods

The study was conducted from 2018 to 2019 at the private veterinary hospital "Eurovet" and the Department of Internal Medicine and Clinical Diagnostics clinic of Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv. The study involved 25 dogs diagnosed with mitral valve endocardiosis. The diagnosis was based on criteria recommended by the American College of Veterinary Medicine (weight <20 kg, left apical murmur, thickening and/or prolapse of the mitral valve leaflets in 2D mode, presence of MR by color Doppler, FS >20 %, EF >40 %) (Keene et al., 2019). According to the ACVIM classification (American College of Veterinary Internal Medicine), considering the clinical-functional status of each stage of MMVD development, three experimental groups of animals were formed – Group B1, Group B2, and Group C.

Group B1 included 14 animals (6 males, 8 females), aged 7 to 14 years (10.2 ± 0.62), weighing 3.3 to 17.5 kg (8.1 ± 1.31). Breeds included English Cocker Spaniel, Chihuahua, mixed breed, Yorkshire Terrier, Dachshund, and Miniature Pinscher. Group B2 consisted of 5 dogs (4 males, 1 female), aged 9 to 14 years (11.0 ± 1.01), weighing 4.7 to 12.3 kg (8.0 ± 1.61), including Dachshund and Pekingese breeds. Group C comprised 6 animals (3 males, 3 females), aged 10 to 15 years (13.2 ± 0.92), weighing 3 to 10.5 kg (5.6 ± 1.22), represented by Yorkshire Terrier, mixed breed, and Miniature Schnauzer.

The radiographic images were obtained from unsedated animals using a digital X-ray system Multimage Maxivet 400 HF DR 400 mA 40 KW. The system's power was 3.5 kW, with a maximum operating voltage of 110 kV, a focus distance of 500 – 1000 mm, and a Toshiba E7239X X-ray tube (5.9–8.1V/7.8 – 10.6V). Image digitization was performed using an EXAMION-X-DR XL digitizer, with a size of 43×43 cm. The animals were positioned in right lateral recumbency with their front limbs extended. Interpretation of the results and measurements was conducted using MicroDicom viewer software.

Radiographic parameters were determined according to established, widely recognized methods. For instance, the VHS (vertebral heart size) coefficient was calculated following Buchanan's description and additionally compared with breed-specific values to enhance the specificity of this criterion (Buchanan, 2000; Salguero et al., 2019) (fig. 1).

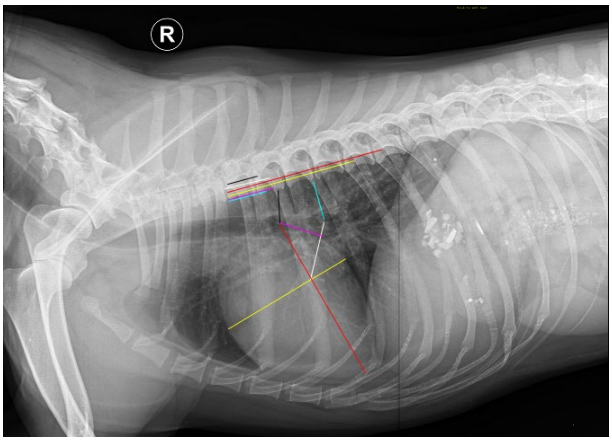

Fig. 1. Right lateral projection of the thoracic cavity of a healthy animal. VHS determination – is indicated by red and yellow lines, RLAD – by a white line, RLAD-spine – by a blue line, Br-spine – by a black line, and VLAS – by a pink line

RLAD was obtained by bisecting the 90-degree angle formed by the intersection of the short and long axes of the heart (Salguero et al., 2018). RLAD to the spine was determined as the perpendicular dropped from the distal end of the RLAD segment to the ventral edge of the thoracic vertebrae (Salguero et al., 2019). Br-Spine is the distance from the ventral edge of the left main bronchus to the thoracic vertebra's ventral edge directly above the heart's base (Salguero et al., 2019; Wiegel et al., 2022). VLAS was obtained using a line drawn from the ventral edge of the carina (the bifurcation point of the two main bronchi) to the dorsal edge of the caudal vena cava at the intersection with the left atrium (Wiegel et al., 2022).

All mathematical calculations were performed on a personal computer, and the statistical analysis of the results was conducted using Microsoft Office Excel 2010 software, applying widely accepted methods of variation statistics. This included estimating the mean value (M), its error (m), and the correlation coefficient. The significance was determined using the Student's t-test.

3. Results and discussion

3.1. Results

Based on the history and clinical examination findings, animals in Groups B1 and B2 were included where no visible clinical symptoms of the disease were detected upon examination. Upon auscultation of dogs in Group B1, left-sided apical systolic murmurs were detected in 22.2 % of cases, with intensities ranging from 1/6 to 2/6. In Group B2, the prevalence of this type of murmur was 68.0 %, with intensities increased from 3/6 to 4/6. In contrast, in Group C, 93.2 % of cases exhibited these murmurs with intensities of 4/6 to 5/6.

During clinical examination of animals in Group C, the following findings were observed: mucous membrane pallor

(51.5 %), cyanosis (13.4 %), prolonged capillary refill time (74.6 %), positive tracheal reflex and cough (49.2 %), distended jugular veins (36.2 %), tachypnea (86.9 %), tachycardia, labored breathing (76.9 %), fine crackles on lung auscultation (47.8 %), and abdominal distension (28.5 %) (Trofimiak & Slivinska, 2021).

According to the previously conducted chest radiography results in Group B1, we observed mild tracheal narrowing (collapse) in the thoracic portion in 21.4 % of animals. Conversely, bronchial pattern intensification was noted in 14.3 % of cases. In Group B2, tracheal collapse is recorded in 20 % of dogs, while tracheal elevation (angle less than 45°) was observed in 60 %. Expansion of pulmonary veins was in 20 % of the experimental group, and in an additional 20 %, there is simultaneous bronchial pattern intensification in the caudodorsal part of the lung field.

Significant changes were detected in Group C. Specifically, all dogs in this group exhibit varying degrees of tracheal elevation. Visual dilatation of the caudal vena cava was observed in 33.3 %, along with an alveolar pattern with air bronchograms extending from the center to the periphery in the caudodorsal and cranioventral lung lobes. The diffuse interstitial pattern was found in 66.7 % of cases.

The radiographic (X-ray) cardiometric indicators under study are presented in Table 1.

Table 1

Radiographic indicators in dogs of the experimental groups during the progression of CMVD. Right lateral projection of the thoracic cavity

Radiographic indicator	Biometric indicator	Experimental group of animals		
		B1 (n = 14)	B2 (n = 5)	C (n = 6)
VHS	Lim	9.5–11.1	10.3–11.3	11.2–13.5
	M ± m	10.5 ± 0.12	11.0 ± 0.23°	12.5 ± 0.43***
RLAD	Lim	1.7–2.6	1.8–2.5	2.1–3.7
	M ± m	2.1 ± 0.10	2.2 ± 0.13	2.8 ± 0.29*
RLAD – spine	Lim	1.1–2.8	0.6–1.3	0.6–0.9
	M ± m	1.6 ± 0.13	1.0 ± 0.17°	0.7 ± 0.05***
Bronchus – spine	Lim	1.1–2.0	0.6–1.2	0.5–0.9
	M ± m	1.6 ± 0.09	1.0 ± 0.14°°	0.7 ± 0.08***
VLAS	Lim	1.2–2.9	1.4–3.2	2.5–3.7
	M ± m	2.0 ± 0.13	2.5 ± 0.36°°	3.1 ± 0.17***

*** – P < 0.001 – significant difference compared to the indicators of group B1, * – P < 0.05 – significant difference compared to the indicators of group B1, ° – P < 0.05 – significant difference compared to the indicators of group B1, °° – P < 0.01 – significant difference compared to the indicators of group B1, °°° – P < 0.001 – significant difference compared to the indicators of group B1

According to the obtained data, in group B1, 57.1% of the animals show only a slight increase in the RLAD indicator. In contrast to the previous experimental group, in group B2, against the background of increased RLAD in 80% of the animals, we simultaneously observe an increase in VLAS (P < 0.01) in 40 % and a decrease in RLAD-spine (P < 0.05) and Bronchus-spine (P < 0.01) in 40 % and 60 % of the dogs, respectively. The diagnostic significance of VHS in stages B1 and B2 is quite debatable due to significant fluctuations (10.5–11.5) in the upper limit of the norm between breeds. With the progression of mitral valve endocardiosis, we observe significant changes in the radiographs. Thus, in group C, 66.7 % of the experimental animals have VHS values exceeding (P < 0.001) the reference typical values (Buchanan, 2000). At the same time, we observe an increase (P < 0.05) in the mean RLAD value by 1.33 times compared to group B1, and VLAS (P < 0.001) by 1.6 times. It should be noted that this coincides with a decrease in the mean RLAD-spine (P < 0.001) and Bronchus-spine (P < 0.001) values by 2.3 times compared to the corresponding indicators in group B1 (fig. 2).

We established correlation relationships between parameters within each experimental group. Thus, in group B1, a moderate positive correlation (r = +0.550) was found between the VHS and RLAD indicators (fig. 3) and a moderate negative correlation (r = -0.500) between VHS and RLAD-spine (fig. 4).

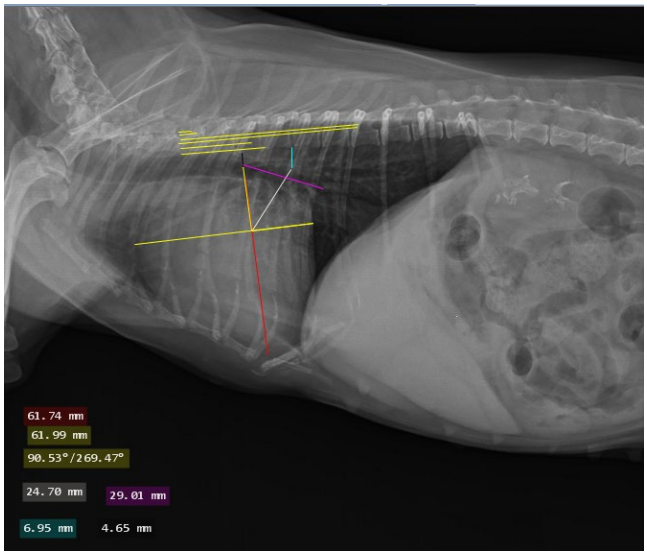

Fig. 2. Right lateral projection of the thoracic cavity in a dog with CMVD, group/stage C. Findings: VHS – 12.3v, RLAD – 2.6v, RLAD-spine – 0.6v, Br-spine – 0.5v, VLAS – 3.2v

With the disease progression in dogs of group B2, we observe a strong positive correlation (r = +0.779) between VHS and RLAD. In contrast, a strong negative correlation (r = -0.831) is noted between VHS and RLAD-spine. In group C, a further increase in the correlation (r = +0.885) is found only between VHS and RLAD (fig. 5).

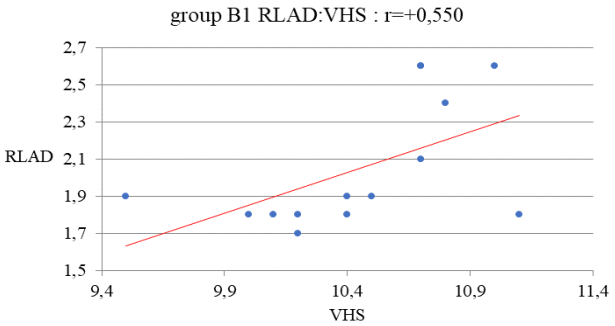

Fig. 3. Correlation relationship between RLAD and VHS in group B1

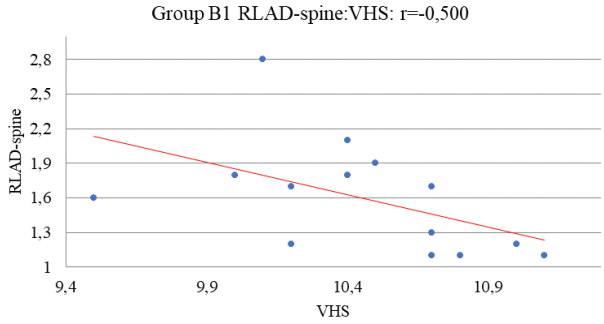

Fig. 4. Correlation relationship between RLAD-spine and VHS in group B1

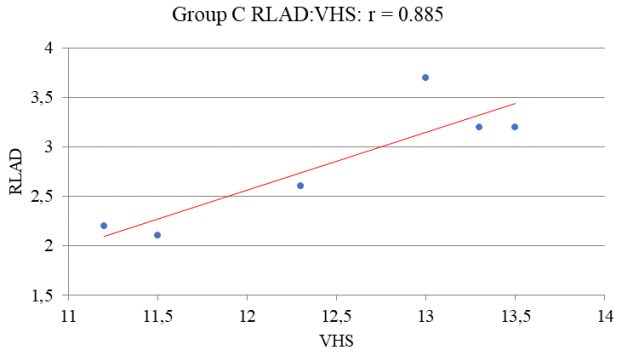

Fig. 5. Correlation relationship between RLAD and VHS in group C

3.2. Discussion

Cardiovascular disease involves complex changes in both the organs' structure and their neuro-humoral regulation. The nature of cardiac remodeling depends on the type and degree of stress experienced by the organ. Development of mitral valve endocardiosis (Vezzosi et al., 2021; An et al., 2023) results in volume overload of the chambers, causing ventricular dilatation due to increased blood flow and left atrial dilatation from retrograde flow induced by progressive mitral valve insufficiency. As a result, eccentric hypertrophy or dilatation develops.

We evaluated five radiographic indicators at various stages of MMVD. According to the ACVIM classification, stage B1 (group B1) is characterized by hemodynamically insignificant regurgitation. This explains the radiographic indicators remaining within normal limits and the weak to moderate correlations observed between them. The slight increase in RLAD in this group is attributed to breed-specific chest configuration, with occasional difficulty in identifying the dorsal edge of the left atrium on radiographs due to overlap from the bronchial tree and proximity of pulmonary veins (Salguero et al., 2018; Wiegel et al., 2022).

In group B2, the elevation of VHS and RLAD is explained by the increasing volume overload of the chambers and subsequent cavity dilatation. The strong positive correlation between them indicates their interdependence, with the intersection point of the long and short axes of the heart at VHS serving as the center for RLAD measurement. Notably, VHS and RLAD also show a strong positive correlation with the echocardiographic parameter LA/AO – r = +0.802 and r = +0.844, respectively, confirming the diagnostic significance of these measures (Salguero et al., 2018).

Decreases in RLAD-spine and Bronchus-spine values are observed due to left atrial dilatation and dorsal displacement of the heart border. It's important to note that RLAD-spine and Bronchus-spine exhibit a lower correlation with LA/AO compared to the previous parameters – r = -0.762 and r = -0.662, respectively. However, their diagnostic value increases in cases where it is challenging to visualize the dorsal edge of the left ventricle on radiographs (Salguero et al., 2019; Levicar et al., 2022).

In group B2, an increase in the VLAS index is also noted, resulting from atrial enlargement in various planes as a three-dimensional structure (Duler et al., 2018). According to the literature (Mikawa et al., 2020), this index demonstrates high sensitivity (95 %) and specificity (84 %) at stage B2. Alongside VHS, it has been included in the 2019 ACVIM guidelines for diagnosing and treating dogs with MMVD (Keene et al., 2019). Interestingly, in group B2, VLAS's likelihood ratio is higher than VHS's, attributed to the anatomical nuances of calculating these parameters. The former directly reflects the radiographic size of the left atrium, while the latter represents the short and long axes projecting more toward the right half of the heart (Duler et al., 2018).

4. Conclusions

Mitral valve endocardiosis in dogs is characterized by left-sided atrial dilation, which progresses with the stages of the disease. The use of the investigated radiographic parameters VHS, RLAD, Br-spine, RLAD-spine, and VLAS allows for the assessment of the relative size of the heart and detection of deviations in its position within the thoracic cavity compared to breed-stable structures (thoracic vertebral bodies). Equally important is monitoring the dynamic changes in these parameters, which indicate disease progression and can predict the increase or emergence of new clinical symptoms. Additionally, conducting radiographic studies at stage B1 helps differentiate cardiac from non-cardiac causes of respiratory system disorders (cough, dyspnea, etc.).

Conflict of interest

The authors declare no conflict of interest.

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