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Assessment of Radiographic Left Atrial Dimension in Maltese Dogs with ACVIM Stage B Myxomatous Mitral Valve Disease

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Abstract Radiographic left atrial dimension (RLAD) is a useful measurement to assess left atrial enlargement in dogs. There are studies on the use of RLAD on various breeds of dogs, but no study on a specific breed with myxomatous mitral valve disease (MMVD). This study was conducted to compare RLAD measurements in Maltese dogs with MMVD ACVIM stage B1 and B2, and also to investigate the correlation of RLAD with the LA:Ao ratio. A total of 29 Maltese dogs were the subjects of this study. Each dog was diagnosed with MMVD ACVIM stage B1 or B2 based on physical examination, thoracic radiography, and echocardiography. The vertebral heart size (VHS), RLAD, LVIDDn, and LA:Ao ratio were measured and compared to evaluate the differences. There were significant differences in the RLAD, LVIDDn, and LA:Ao ratio between dogs with MMVD ACVIM stage B1 and those with stage B2. There was a significant correlation between the LA:Ao ratio and both the RLAD and VHS measurements, but the correlation coefficient was higher for RLAD. The RLAD scores exhibited a significant difference between dogs with ACVIM Stage B1 and with those with B2, and these scores had a higher correlation with the LA:Ao ratio measured by echocardiography than with VHS.

Key words dog, left atrium to aorta ratio, maltese, radiographic left atrial dimension, radiography, vertebral heart size.

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Introduction

Myxomatous mitral valvular disease (MMVD) is one of the most prevalent chronic acquired heart diseases in small breed dogs (4). It is characterized by a progressive myxomatous degeneration of the mitral valve apparatus with subsequent left atrial (LA) and left ventricular (LV) dilation (2). The resulting increase in LA pressure leads to an increase in pulmonary capillary pressure, which triggers pulmonary edema and congestion (3). MMVD is diagnosed and treated according to the American College of Veterinary Internal Medicine (ACVIM) consensus guidelines (7).

LA enlargement is one of the earliest and important indicators of disease severity, and evaluation of LA size should be conducted before the development of clinical signs of congestive heart failure (CHF) (9). Measuring indices such as the left atrial to aortic ratio (LA:Ao) and the left ventricular end diastolic diameter normalized for body weight (LVIDDn) with echocardiography is the gold standard method and provides a direct and accurate evaluation of the CHF condition of dogs (7,9,13). However, measuring indices with echocardiography often requires a skilled examiner and may be difficult to perform due to the patients' condition and time and cost constraints.

Therefore, thoracic radiography, which is a sensitive diagnostic tool for evaluating LA enlargement, can be used as an alternative tool to assess MMVD (3,8). It provides information on the global cardiac size and the presence of pulmonary congestion or edema (3). There are several radiographic methods for assessing LA size in dogs, including vertebral heart size (VHS), vertebral left atrial size (VLAS), and radiographic left atrial dimension (RLAD) (9).

VHS is a tool for measuring heart size on thoracic radiographs (2). This method compares cardiac width and height to the length of the vertebral body starting from the fourth thoracic vertebra (2). There are studies suggesting the usefulness of VHS, but there are limitations in applying it to certain species of dog (6).

RLAD uses the measurements of VHS as a foundation but adds a third line that bisects the intersection of the vertical and horizontal axes of VHS at a 45 degrees angle to the caudal side, extending to the dorsal edge of the LA bulge (13). RLAD with a cutoff value of 1.8 vertebra has a sensitivity of 93.5% and specificity of 96.8% in subjects with an LA:Ao ratio of ≥1.6 (13). In another study, RLAD readings of ≥1.8 vertebra showed a sensitivity of 90.2% and specificity of 79.3% (9). Also, RLAD had a high repeatability and reproducibility with intra-observer variability (9).

Previous studies describing the RLAD method were conducted on a set of dog breeds which might not be representative of the general population with MMVD (9,13). Thus, in this study, we included only Maltese dogs, which have a genetical predisposition for MMVD and are one of the most common breeds in the South Korea (10). The purpose of this study was to compare the VHS and RLAD of subjects with MMVD ACVIM stages B1 and B2 and find both measurements' correlations with the LA:Ao ratio.

Materials and Methods

Animals

The medical records of Maltese dogs treated at the Chungnam National University Veterinary Medicine Teaching Hospital between 2017 and 2021 were examined, and those dogs who had MMVD were selected as candidates for this study. Through physical examination, cardiac auscultation, thoracic radiography, and echocardiography, each patient was diagnosed with MMVD and classified into a stage according to the ACVIM consensus guidelines, and the patients with MMVD ACVIM stage B1 and B2 were chosen for study, resulting in a total of 29 dogs. Stage B1 was defined as asymptomatic patients with mitral regurgitation due to MMVD but without the severity to meet the criteria for Stage B2 (7). Criteria for stage B2 were a cardiac murmur intensity of 3/6 or more, an LA:Ao ratio of 1.6 or more in echocardiography on the right-sided short axis view in early diastole, an LVIDDn

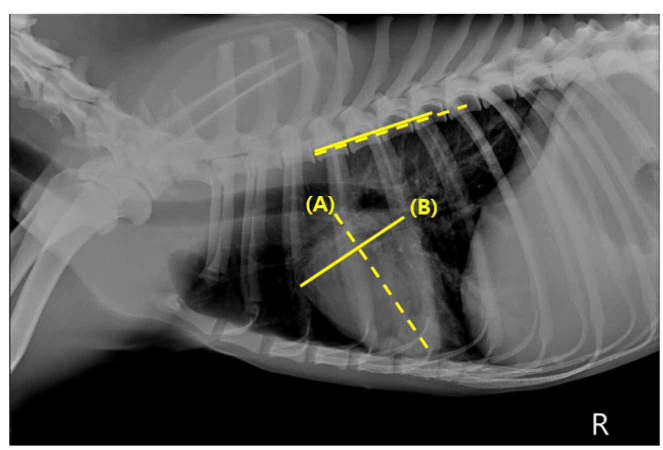

Fig. 1. Radiographic measurement of VHS at right lateral thorax. Long axis of the heart (A) connecting ventral border of the left mainstem bronchus and cardiac apex and short axis of the heart (B) at the widest part of cardiac silhouette, perpendicular to the long axis were drawn. Measurements were converted into the length of vertebrae starting from the cranial edge of fourth thoracic vertebrae. Long axis was 3.6 vertebrae long and short axis was 4.6 vertebrae and both lengths were summed for VHS. VHS was calculated to be 8.2 vertebrae.

of 1.7 or more, and a VHS over 10.5 (7). Patients with congenital heart disease such as patent ductus arteriosus or pulmonic stenosis and medical problems other than MMVD which could have effects on cardiac size were excluded.

Thoracic radiography

Thoracic radiography was used for measuring VHS and RLAD. These measurements were obtained using a digital caliper in the right lateral inspiratory view, according to published methods (2,11). VHS and RLAD were obtained from the same radiograph images (13).

Measurement of VHS started by drawing a line on the long axis of the heart that connects the ventral border of the left mainstem bronchus and the most distant ventral contour of the cardiac apex (2). Also measured was the short axis of the heart at the widest part of the cardiac silhouette, perpendicular to the long axis (2). The long axis and short axis measurement were transferred to the vertebrae, starting at the cranial edge of fourth thoracic vertebrae, and the number of vertebrae intersecting these two measurements were counted and summed (Fig. 1) (2).

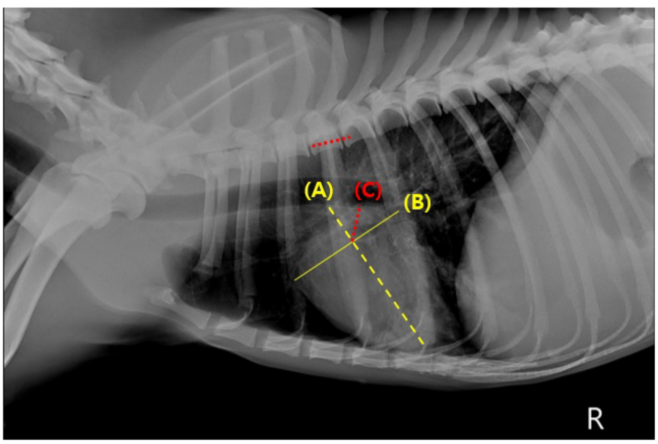

Fig. 2. Radiographic measurement of RLAD at right lateral thorax. After long axis (A) and short axis (B) of the heart were drawn for calculating VHS, line equally dividing angle of the long and short axes (C) was drawn extending to the dorsal edge of the left atrium. The measurement was converted into the length of vertebrae starting from the cranial edge of fourth thoracic vertebrae for RLAD calculation. RLAD was 1.2 vertebrae.

For measurement of RLAD, a line equally dividing the 90 degree angle of the VHS long and short axes was drawn and extended to the dorsal edge of the left atrium (13). The length of the line was then normalized to vertebrae, starting at the edge of the fourth thoracic vertebra (13). Using a digital protractor computer program, the angle between this line and the VHS long and short axes was ensured to be 45 degrees (Fig. 2) (13).

Echocardiography

A complete transthoracic echocardiographic examination (TTE) was performed on all dogs. Diagnosis of MMVD was based on characteristic valvular lesions of the mitral valve apparatus and mitral valve regurgitation by color doppler examination.

The LA:Ao ratio was the ratio between the LA and cross-sectional aortic (Ao) diameters from the 2D right parasternal short axis view. The normalized LV internal dimension at end-diastole (LVIDDn) was calculated from the LV M-mode of the right parasternal short axis view (Figs. 3, 4).

Fig. 3. Echocardiographic measurement of LA:Ao from right parasternal short axis view on aortic root level.

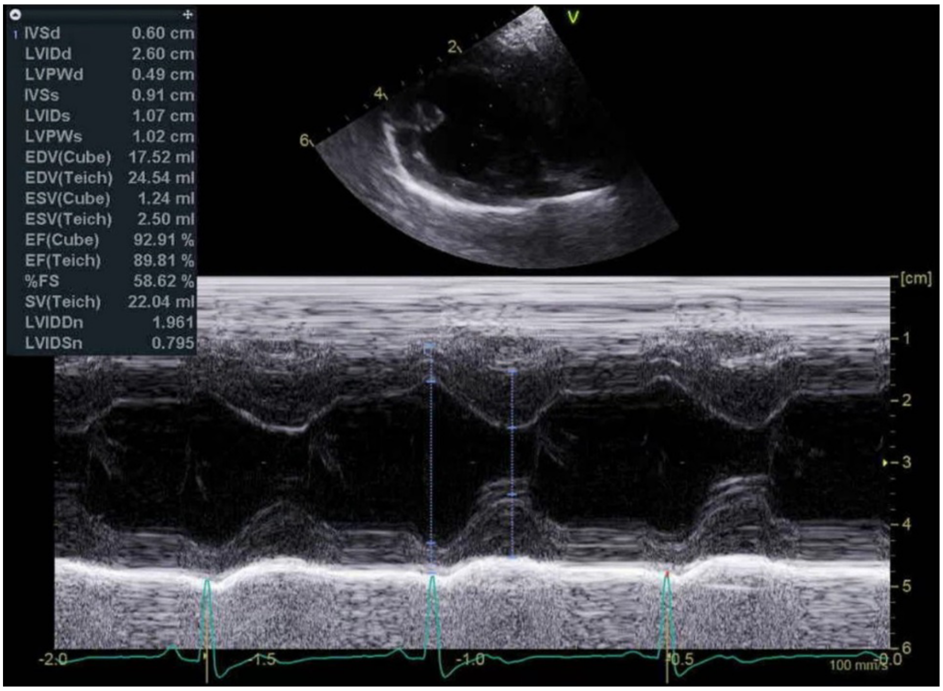

Fig. 4. M-mode echocardiographic measurement of LVIDD from right parasternal short axis view on papillary muscle level.

Table 1. Descriptive data for 29 Maltese dogs with myxomatous mitral valve disease

Stage	No. of dogs	Sex (M/F)	Age (year)	Body weight (kg)
Stage B1	14	10/4	14.00 ± 3.11	3.81 ± 1.49
Stage B2	15	7/8	11.67 ± 3.58	3.74 ± 1.68

Table 2. The Mean VHS, LA:Ao ratio, LVIDDn and RLAD

Index	Stage B1	Stage B2	p-value
VHS	10.40 ± 0.49	11.61 ± 1.02	0.103
LA:Ao ratio	1.45 ± 0.14	2.32 ± 0.39	0.000
LVIDDn	1.356 ± 0.10	1.896 ± 0.28	0.018
RLAD	1.58 ± 0.23	2.01 ± 0.16	0.042

Statistical analysis

Statistical analysis was performed using a commercial computer-based software program (IBM SPSS statistics 26.0, SPSS Inc., USA).

The mean, standard deviation, and other statistics were calculated to identify age, body weight, VHS, LA:Ao ratio, LVIDDn, and RLAD according to the MMVD ACVIM stages. Independent t-tests were conducted to compare the difference in VHS, LA:Ao ratio, LVIDDn, and RLAD between dogs with MMVD ACVIM stage B1 and with stage B2. Pearson's correlation coefficient was evaluated to determine the correlation between the LA:Ao ratio, VHS, LVIDDn, and RLAD. A p value of <0.05 was considered to have statistical significance.

Results

A total of 29 Maltese dogs were included in this study. The clinical data for age, sex, and body weight were summarized in Table 1. The dogs were divided into two groups according to the MMVD ACVIM guidelines as follows: 14 dogs in stage B1; 15 dogs in stage B2.

Descriptive data on the radiographic and echocardiographic data for each group are summarized in Table 2. The VHS, LA:Ao ratio, LVIDDn and RLAD in stage B2 were larger than those in the stage B1. The mean VHS of the stage B1 group was 10.40 ± 0.49, and that of stage B2 was 11.61 ± 1.02; the average value was larger in stage B2, but there was no significant difference between the two groups.

The mean value of the LA:Ao ratio was 1.45 ± 0.14 for stage B1 and 2.32 ± 0.39 for stage B2, showing a significant difference ($p < 0.01$). The means for LVIDDn were 1.356 ± 0.10 for stage B1 and 1.896 ± 0.28 for stage B2, and that of B2 was significantly larger ($p < 0.05$).

RLAD also showed a significant difference between stages B1 and B2, and the mean value was 1.58 ± 0.23 for stage B1 and 2.01 ± 0.16 for stage B2 ($p < 0.05$).

It shows the Pearson correlation coefficient values compar-

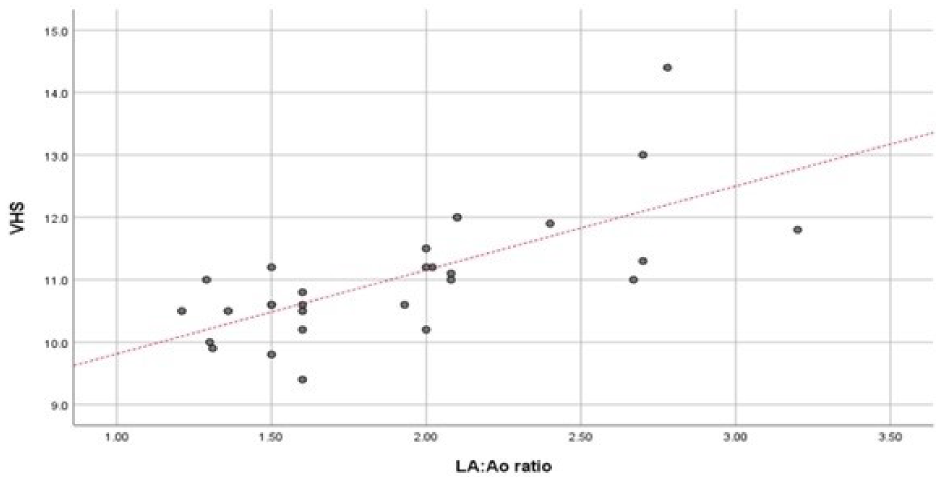

Fig. 5. Correlation analysis of LA:Ao ratio and VHS ($r = 0.701$, $p < 0.01$).

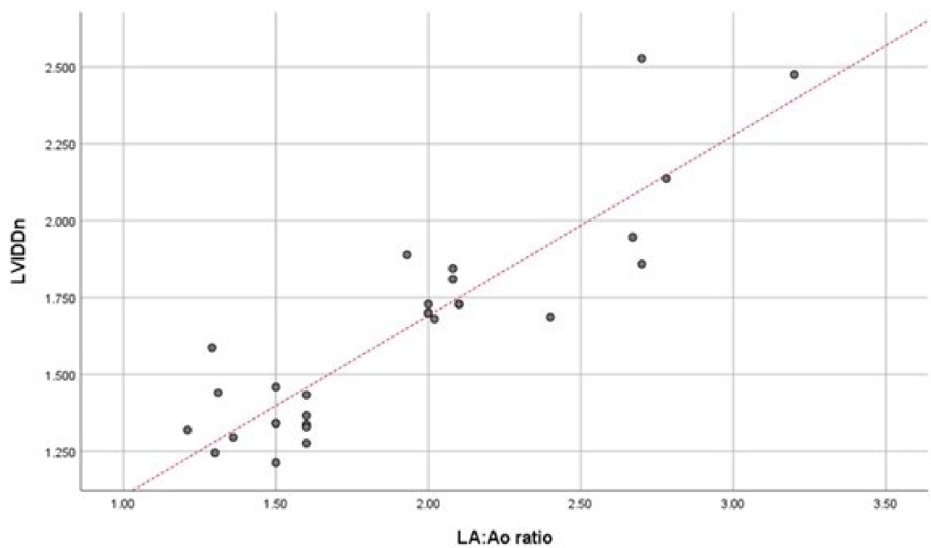

Fig. 6. Correlation analysis of LA:Ao ratio and LVIDDn ($r = 0.896$, $p < 0.01$).

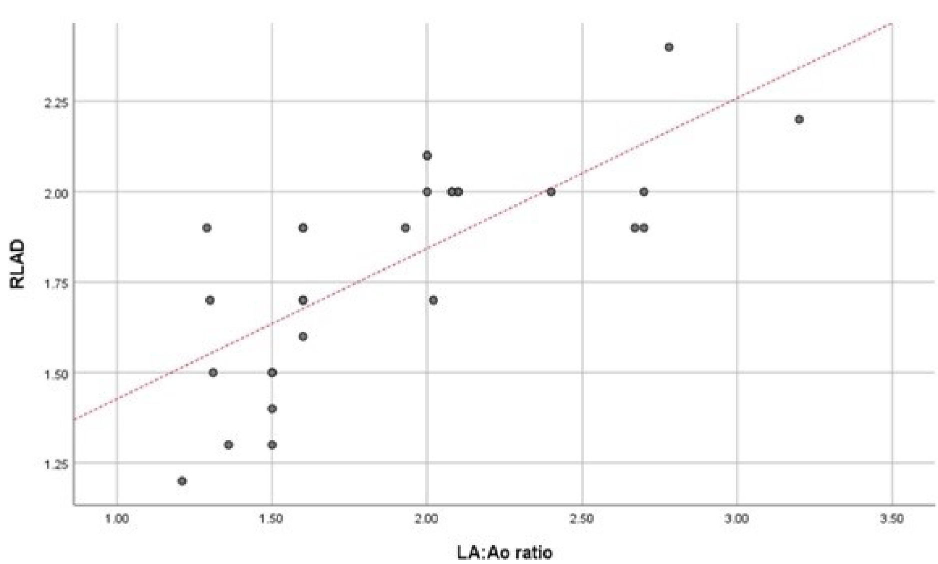

Fig. 7. Correlation analysis of LA:Ao ratio and RLAD ($r = 0.744$, $p < 0.01$).

ing the VHS, LVIDDn, and RLAD values with the LA:Ao ratio. The measurement most highly correlated with LA:Ao ratio was the LVIDDn (Pearson correlation coefficient = 0.896), followed by the RLAD (Pearson correlation coefficient = 0.744), and the VHS (Pearson correlation coefficient = 0.701) (Figs. 5-7).

Discussion

The purpose of this study was to compare accuracy of RLAD and VHS with left atrial-to-aortic root (LA:Ao) ratio in Maltese dogs with MMVD stage B1 and with stage B2. In this study, significantly higher VHS, RLAD, LA:Ao ratio and LVIDDn measurements were identified in stage B2.

The Maltese breed is one of the most common breeds in South Korea and is genetically prone to acquire heart disease (10). In previous studies, the VHS and VLAS of normal Maltese dogs has been studied, but the radiographic heart size, particularly the RLAD value, of Maltese with MMVD has not been studied (1).

In addition, although the results and accuracy of RLAD values have been examined in two studies, it is difficult to exclude a breed-dependent effect because both studies included several species (9,13). In this study is meaningful in that it was the first study to measure the RLAD value in only the Maltese breed.

In these previous studies, the mean value of RLAD in stage B1 and B2 was 1.54 ± 0.42 and 2.34 ± 0.43 (9), and the mean value of RLAD in the group with an absence of left atrial enlargement was 1.41 ± 0.23, while that of the group with left atrial enlargement was 2.54 ± 0.52 (13). According to this study, the mean values of RLAD were 1.58 ± 0.23 in stage B1 and 2.01 ± 0.16 in stage B2, which are similar to the results of these previous studies in other breeds. However, further research is needed on how the RLAD value may differ between each breed.

The usefulness of RLAD was shown by its positive correlation (Pearson correlation coefficient = 0.744) with LA:Ao ratio in this study. The correlation of VHS and LA:Ao ratio was also shown to be positive, but it was inferior to that of RLAD. A previous study also investigated the correlation between the LA:Ao ratio and thoracic radiographic data, RLAD showed a strong correlation, followed by VHS (13). This is similar to the results in the present study.

LVIDDn has the strongest correlation with the LA:Ao ratio, but since it should be obtained through echocardiography, it may not be possible to measure it without high compliance of the client, and frequent monitoring is difficult. Since the RLAD measurement is based on the VHS, measuring the two methods together provides a more accurate result for estimating heart size.

VHS tends to increase from stage B1 to stage B2; however, there was no significant difference between the two groups. On the other hand, the mean value of RLAD tends to increase from stage B1 to stage B2, showing a significant difference between the two groups.

This is thought to be due to the fact that, when dividing patients with heart disease, staging was performed according to the ACVIM consensus. Therefore, even if the patient's VHS value was 10.5 or higher, if the remaining echocardiogram values were not satisfied, the patient was classified as B1.

The limitation of VHS includes low accuracy due to dependance solely on radiography, multiple breed-associate variation, interobserver variability, and influence of respiratory and cardiac cycles (5,12). In this study, since the study was limited to Maltese dogs, breed variation was not a factor, but it is difficult to rule out the other sources of error.

Although RLAD is a method to measure the MMVD level based on VHS, it showed a significantly higher ability to determine the stage of MMVD in this study. Therefore, considering the problem of VHS accuracy and the results of RLAD values in this study, it might be more accurate to evaluate cardiac size based on radiographic measurement with RLAD rather than VHS.

This study is limited in that there were no subjects with stages C or D. In a previous study, the sensitivity and specificity using the cut-off value of 1.8 of the RLAD value were 90.2% and the 79.3% respectively (9), which were slightly lower than in another study (sensitivity 93.5%, specificity 96.8%) (13). Therefore, when stages C and D are included, the results and usefulness of RLAD may change, so further research is needed.

We could not include a subject group of healthy Maltese dogs, as most owner of these dogs did not want to proceed with echocardiography. Also, even VHS and RLAD were measured by one person, echocardiographic indices were not measured by one person which can be one of the nature of retrospective study.

Conclusions

This study, conducted on Maltese dogs with heart disease, showed that RLAD values in dogs with ACVIM stage B1 and B2 MMVD were significantly different. RLAD also showed a higher correlation than VHS with the LA:Ao ratio, measured by echocardiography. RLAD may be useful as an accurate and repeatable way to radiographically identify LA enlargement in dogs with MMVD.

Conflicts of Interest

The authors have no conflicting interests.

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