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An Assessment of Thoracic Inlet Heart Score in Maltese Dogs with ACVIM Stage B Myxomatous Mitral Valve Disease

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Abstract Myxomatous mitral valve disease (MMVD) is the most common cardiac disease in dogs. Vertebral heart score (VHS) is used for the diagnosis, treatment, and monitoring of MMVD, and it is one of the criteria used to distinguish between stages B1 and B2 according to the American College of Veterinary Internal Medicine (ACVIM) guidelines. The thoracic inlet heart score (TIHS) method is simple to perform and provides practitioners with an additional tool for evaluating dogs with clinical signs compatible with MMVD stage B. Previous studies have evaluated TIHS. In our study, we assessed correlations of TIHS with other radiographic and echocardiographic indices in Maltese dogs with MMVD stages B1 and B2. Eighty-seven Maltese dogs with MMVD stage B1 or B2, which visited Chungnam National University Veterinary Medicine Teaching Hospital, were included in this study. Each dog was diagnosed with MMVD ACVIM stage B1 or B2 through physical examination, cardiac auscultation, thoracic radiography, and echocardiography, with evaluation of TIHS, VHS, vertebral left atrial size (VLAS), left atrial to the aotic root ratio (LA:Ao ratio), and left ventricular internal diameter in diastole, normalized for body weight (LVIDDn). TIHS increased as the disease progressed and showed a significant difference between stages B1 and B2. Furthermore, TIHS positively correlated with VHS, LA:Ao ratio, and LVIDDn. The correlation coefficients revealed the strongest significant correlations between TIHS and VHS. In conclusion, TIHS can help diagnose and monitor MMVD in Maltese dogs, in addition to measuring VHS.

Key words ACVIM, TIHS, MMVD, maltese, dog.

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Introduction

MMVD is the most common cardiac disease in dogs. The diagnosis of MMVD is based on clinical signs, physical examination, and radiographic and echocardiographic evaluation (6). The prevalence of MMVD varies between breeds; however, MMVD may occur in small breeds like the Cavalier King Charles Spaniel and Bull Terrier (2). Degenerative changes in the mitral valve prevent effective cardiac function, leading to regurgitation of blood flow, and progressive valvular regurgitation decreases cardiac output, resulting in ventricular remodeling and dysfunction (6). Therefore, diagnosing MMVD before the onset of clinical symptoms and initiating medical treatment is important, as recommended by the ACVIM consensus guidelines.

As heart failure progresses, left-sided cardiac remodeling occurs, leading to enlargement of the left ventricle and left atrium, which serves as an important indicator of disease severity (2). Therefore, direct measurement of LA:Ao ratio and LVIDDn by echocardiography is considered the gold standard for monitoring patients with heart failure (7). However, measuring these indices with echocardiography often requires a skilled practitioner and can be challenging due to the patient's condition.

Accordingly, thoracic radiography can serve as an alternative tool for evaluating cardiomegaly, with VHS being utilized as an objective indicator for assessing cardiomegaly (1). There were Studies suggesting limitations, though, such as interobserver differences in reference point selection, conversion into vertebral units, and manubrium malformations (5). In patients with anomalous vertebrae, the diagnostic reliability of these measurements is particularly compromised (5). TIHS normalizes heart size to body size using the thoracic inlet length (TI). According to recent studies on TIHS, the average value measured in healthy subjects is 2.86 ± 0.27, with more than 90% of patients having a score of less than 3.25. Additionally, no significant differences in TIHS have been identified between sex, patient size, and various species, suggesting it could be a reliable index of cardiomegaly (11,12).

Although previous studies on TIHS were conducted on patients with MMVD (12), Maltese dogs, which represent a substantial proportion of the domestic breed population, were not included. Maltese dogs are the most common breed in South Korea and have a genetic predisposition for MMVD (8). The purpose of this study, then, is to compare TIHS with other imaging indices for evaluating cardiomegaly specifically in Maltese dogs with MMVD.

Materials and Methods

Animals

This study was conducted on Maltese dogs who visited Chungnam National University Veterinary Medicine Teaching Hospital between 2019 and 2023, with a total of 87 patients participating. Patients diagnosed with MMVD stage B1 or B2 were selected according to the ACVIM consensus guidelines (6), based on physical examination, cardiac auscultation, thoracic radiography, and echocardiography. Stage B1 subjecs were asymptomatic dogs with mitral regurgitation caused by MMVD (6). Stage B2 subjects were dogs who met the criteria of ACVIM consensus guidelines (murmur intensity $\geq$ 3/6; echocardiographic LA:Ao ratio $\geq$ 1.6; LVIDDn $\geq$ 1.7; VHS $\geq$ 10.5) (6). Patients with congenital heart disorders, such as pulmonary stenosis, ventricular septal defects, and patent ductus arteriosus, or those who had undergone mitral repair surgery were not included in this study.

Thoracic radiography

VHS, VLAS, and TIHS were measured using thoracic radiography. Only the thoracic radiographs taken during inspiration were evaluated, and a right lateral view with both front limbs extended forward was used to identify the sternal manubrium. To measure VHS, the long axis (LAx) and short axis (SAx) of the cardiac silhouette were aligned parallel to the cranial edge of the fourth thoracic vertebra, and the sum of the total vertebrae was measured. To measure VLAS, a line was drawn and measured (in arbitrary units) from the center of the most ventral aspect of the left atrium where it intersected with the dorsal border of the caudal venacava. And a second line that was equal in length to the first was drawn beginning at the cranial edge of the 4th thoracic vertebra and extending caudally just ventral and parallel to the

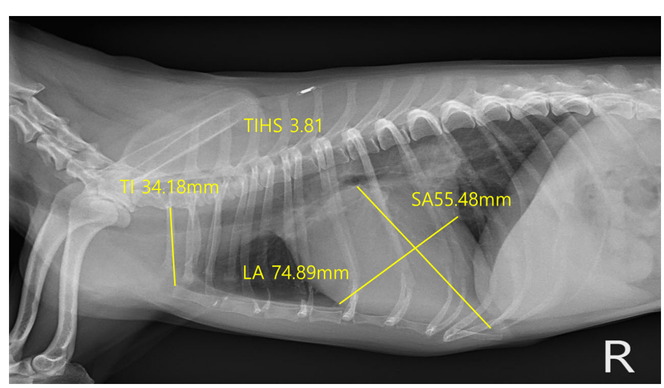

Fig. 1. TIHS measurement in a Maltese dog diagnosed with MMVD stage B2. LAx, heart long axis; SAx, heart short axis; TI, thoracic inlet length.

vertebral canal. Lastly, the VLAS was defined as the length of the second line expressed in vertebral body units to the nearest 0.1 vertebra (1,10). For measuring TIHS, the measurement began by drawing LAx and SAx. LAx was drawn from the cardiac apex to the middle of the ventral border of the carina, and SAx was drawn perpendicularly to the LAx, from where the caudal vena cava intersects the caudal border of the cardiac silhouette to the cranial border of the cardiac silhouette. TI was measured by drawing a line between the craniodorsal manubrium and the cranioventral aspect of the first thoracic vertebra. TIHS was then calculated by dividing the sum of the LAx and SAx by the TI: TIHS = (SAx + LAx)/TI (12) (Fig. 1).

Echocardiography

Every patient underwent an echocardiographic examination, performed from both right and left parasternal positions in two-dimensional mode, M-mode, and Doppler mode. MMVD staging and heart size evaluation were carried out using LA:Ao ratio and LVIDDn. LA:Ao ratio measures the cross-sectional length of the left atrium relative to the aortic root at the aortic level in the right parasternal short-axis view, serving as an indicator of left atrial enlargement. LVIDDn is the ratio of the left ventricle internal diameter measured at the papillary muscle level in the right parasternal short-axis view at end-diastole, normalized to body weight. It serves as an indicator of left ventricular enlargement.

Statistical analysis

Statistical analyses were performed using a commercial computer-based software program (IBM SPSS statistics 26.0, SPSS Inc., USA). The median, standard deviations, and other statistics were calculated to identify age, body weight, VHS, VLAS, LA:Ao ratio, LVIDDn, and TIHS according to the MMVD ACVIM stages. A Shapiro-Wilk test was performed for the normality test of the indices, which resulted in no normality. The indices of each group were presented as median (interquartile range). Mann-Whitney tests were conducted to compare the difference in age, body weight, VHS, VLAS, LA:Ao ratio, LVIDDn, and TIHS between dogs with MMVD ACVIM stage B1 and with stage B2. Spearman's rank correlation coefficient was evaluated to determine the correlation between the VHS, VLAS, LA:Ao ratio, LVIDDn, and TIHS. A p-value of <0.05 was considered to have statistical significance.

Results

Animals

A total of 87 Maltese dogs were included in this study. The clinical data for age, sex, and body weight are summarized in Table 1. The Maltese dogs were divided into two groups according to the MMVD ACVIM guidelines as follows: 23

Table 2. The difference in radiographic and echocardiographic indices between each group

Index	ACVIM B1	ACVIM B2	p-value
VHS	9.5 (9.2-9.7)	10.7 (10.6-11.2)	0.000*
VLAS	2.1 (2.0-2.1)	2.25 (2.1-2.5)	0.002*
LA:Ao ratio	1.38 (1.25-1.52)	1.81 (1.65-2.08)	0.000*
LVIDDn	1.36 (1.27-1.43)	1.80 (1.76-2.2)	0.000*
TI	36.1 (32.9-40.1)	37.3 (33.9-41.2)	0.331
SAx	47.3 (42.6-53.3)	51.9 (47.4-55.4)	0.004*
LAx	58.3 (52.9-64.9)	63.1 (59.9-69.6)	0.002*
SAx + LAx	106.9 (95.6-113.4)	115.2 (108.6-124.5)	0.000*
TIHS	2.81 (2.78-3.17)	3.13 (2.89-3.35)	0.016*

Values represented as the median (interquartile range).
VHS, vertebral heart score; VLAS, vertebral left atrial size; LA:Ao ratio, left-atrial-to-aortic-root ratio; LVIDDn, left ventricular internal diameter in diastole, normalized for body weight; TI, thoracic inlet length; SAx, short-axis length; LAx, long-axis length; TIHS, thoracic inlet heart score.
*$p < 0.05$.

Table 1. The differences in sex, age, and body weight between each group

Characteristics		Total (n = 87)	Group		p-value
			ACVIM B1 (n = 23)	ACVIM B2 (n = 64)	
Sex[1]	Male	1 (1.15)	0 (0.00)	1 (1.57)	
	Castrated male	35 (40.23)	10 (43.48)	25 (39.06)	
	Female	5 (5.75)	0 (0.00)	5 (7.81)	
	Spayed female	46 (52.87)	13 (56.52)	33 (51.56)	
Age (year)[2]		11 (9-14)	11 (8-13)	12 (9-14)	0.321
Body weight (kg)[2]		3.35 (2.6-4.2)	3.05 (2.5-4.0)	3.4 (2.6-4.2)	0.333

[1]Values represent the number (%).
[2]Values as the median (interquartile range).

dogs with stage B1 and 64 dogs with stage B2. No significant correlations were found regarding age and body weight between the two groups.

Table 3. **The correlation coefficient values of TIHS in relationship with other radiographic and echocardiographic indices**

Index	VHS	VLAS	LA:Ao ratio	LVIDDn
TIHS	0.468**	0.222*	0.358**	0.274**

Values represent the Spearman's rank correlation coefficients.
VHS, vertebral heart score; VLAS, vertebral left atrial size; LA:Ao ratio, left-atrial-to-aortic-root ratio; LVIDDn, left ventricular internal diameter in diastole, normalized for body weight; TIHS, thoracic inlet heart score.
**$p < 0.01$, *$p < 0.05$.

Radiography and echocardiography

The diagnostic data from the radiographs and echocardiographs for each group are summarized in Table 2. The values of VHS, VLAS, LA:Ao ratio, LVIDDn, and TIHS with SAx, LAx, and (SAx + LAx) were larger in the stage B2 group compared to the stage B1 group. All indices showed significant differences except for TI ($p < 0.05$).

The correlation between TIHS and other indices showed statistically significant positive correlations. The correlation coefficient values between TIHS and the other indices are shown in Table 3. The measurement most highly correlating with TIHS was VHS (correlation coefficient = 0.468), followed by LA:Ao ratio (correlation coefficient = 0.358). The graphs of correlation are represented in Figs. 2-5.

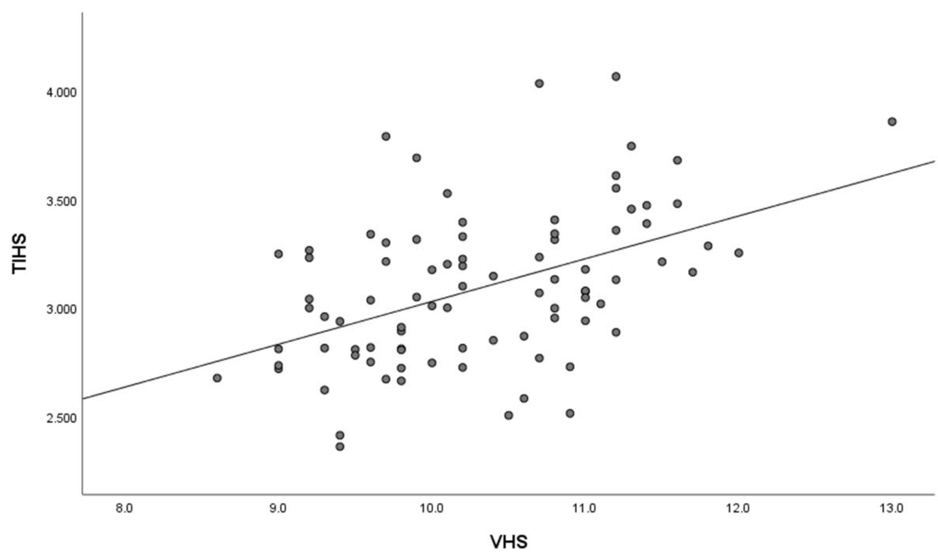

Fig. 2. Correlation analysis of TIHS and VHS ($r = 0.468$, $p < 0.01$).

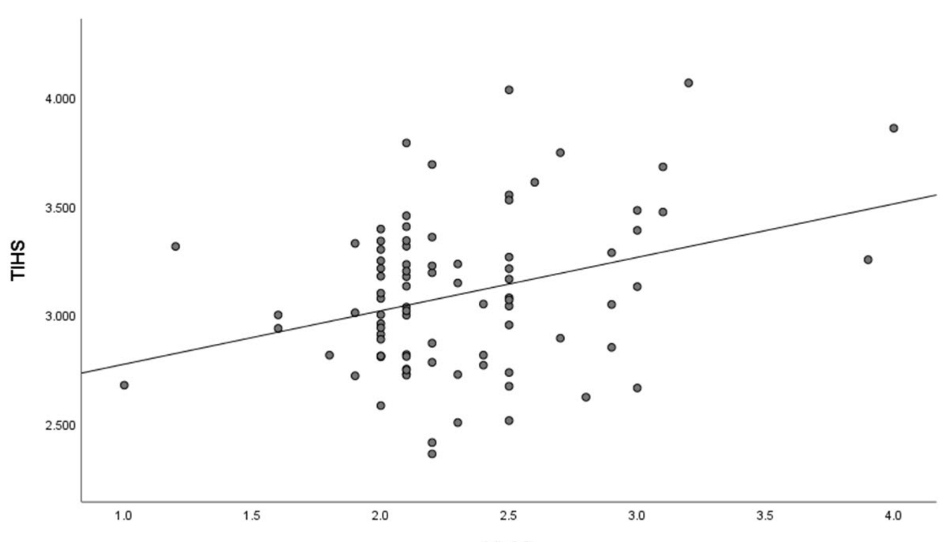

Fig. 3. Correlation analysis of TIHS and VLAS ($r = 0.222$, $p < 0.05$).

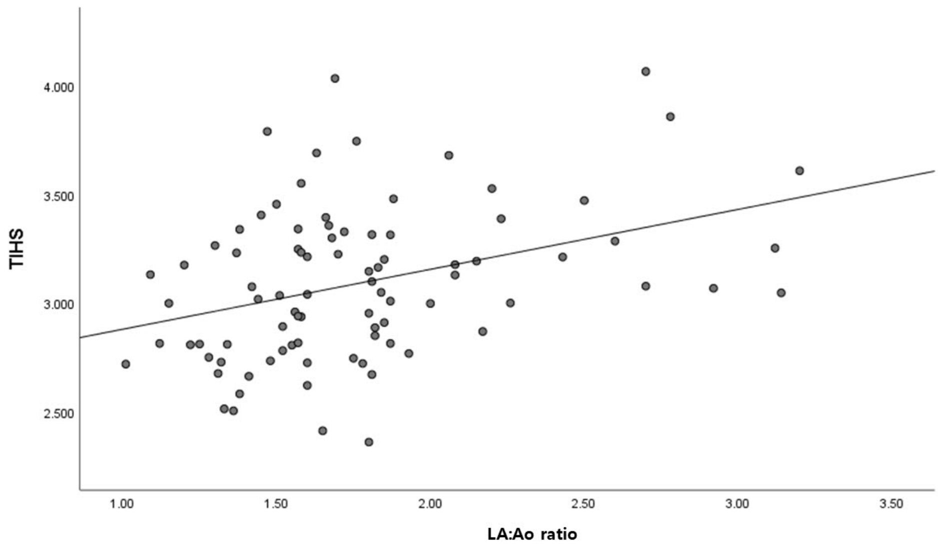

Fig. 4. Correlation analysis of TIHS and LA:Ao ratio ($r = 0.358$, $p < 0.01$).

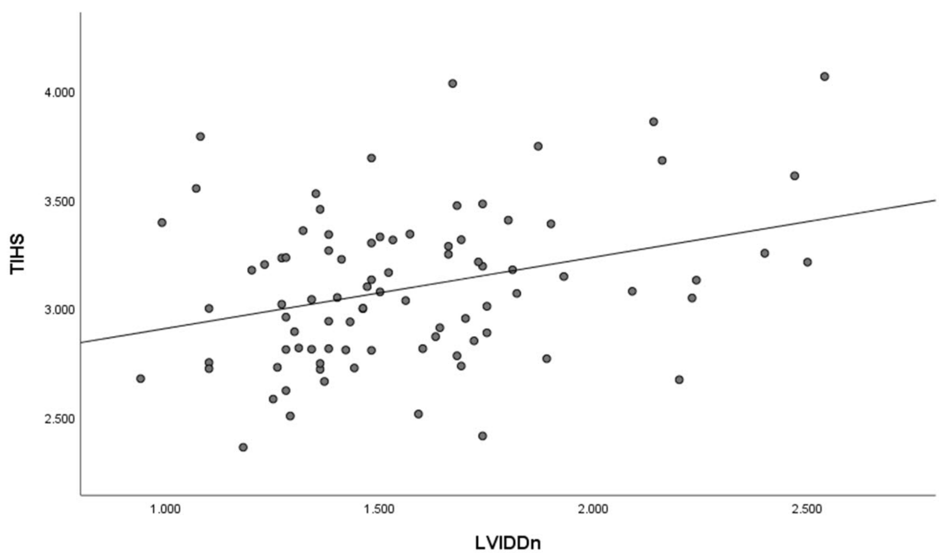

Fig. 5. Correlation analysis of TIHS and LVIDDn ($r = 0.274$, $p < 0.01$).

Discussion

Recently, it has been confirmed that the evaluation of cardiomegaly can be performed using a radiographic measurement method called TIHS (11). Further studies have shown that TIHS increases in dogs with MMVD as the disease progresses, demonstrating the effectiveness of TIHS in monitoring the progression of MMVD (12).

The studies mentioned above evaluated various breeds such as the Labrador Retriever, Golden Retriever, Pitbull, Yorkshire Terrier, Beagle, Border Collie, Bull Terrier, Cavalier King Charles Spaniel, Chihuahua, and various crossbreeds; however, Maltese dogs, which are the most common breed in South Korea and genetically prone to MMVD, were not included (8,12). Accordingly, this study aims to compare the accuracy of TIHS with VHS, VLAS, LA:Ao ratio, and LVIDDn in Maltese dogs with MMVD stages B1 and B2. This is significant as it is the first study to evaluate TIHS exclusively in Maltese dogs diagnosed with MMVD and therefore the groups are uniform when age and body weight are evaluated.

Previously, the mean values of TIHS in dogs with MMVD stages B1 and B2 were found to be 2.98 ± 0.36 and 3.23 ± 0.34, respectively, while in control groups it was 2.91 ± 0.23 (12). According to the present study, the mean values of TIHS in Maltese dogs with MMVD stages B1 and B2 were similarly confirmed to be 2.96 ± 0.27 and 3.14 ± 0.37, respectively. Additionally, TIHS, VHS, VLAS, LA:Ao ratio, and LVIDDn were all significantly higher in the MMVD stage B2 group compared to the stage B1 group.

One study evaluated VHS before the onset of congestive heart failure (CHF), noting that it increased with disease progression (9). Considering that the methods for measuring VHS and TIHS both involve cardiac axis measurement and that these indices increase with disease progression in MMVD stages B1 and B2, the TIHS method can also be used as a monitoring index for disease progression in pre-clinical Maltese dogs with MMVD before the onset of CHF, which occurs in MMVD stages C and D.

Furthermore, compared to other radiographic and echocardiographic methods, the TIHS method has certain advantages as a diagnostic tool. First, potential sources of VHS variation include thoracic vertebral anomalies and the transformation into vertebral units, but the TIHS method can be applied even in patients with vertebral anomalies and does not require transformation into vertebral units, which may result in less variation (3). Second, in situations where echocardiography is not possible, the MMVD stage can be assessed using the TIHS method.

Previously, the correlation with TIHS was found to be higher with LVIDDn, followed by VHS and LA:Ao ratio, and for the left ventricle (12). However, in this study on Maltese dogs with MMVD, the correlation between TIHS and VHS was higher than with other radiographic and echocardiographic indices, followed by LA:Ao ratio, LVIDDn, and VLAS, respectively. This suggests that the TIHS method can be used to evaluate progressive cardiomegaly alongside VHS in Maltese dogs (1). Following VHS, TIHS showed a correlation with indices related to the left atrium. Therefore, assessing left atrial size and function using TIHS can provide valuable information on the level of cardiac compensation, as the left atrium modulates left ventricular filling and performance through its reservoir, conduit, and contractile functions (4).

There were several limitations in this study. First, We made ACVIM stage B1 and B2 groups without stage C and D. These MMVD stages are diagnosed and defined by the clinical signs of left-sided CHF. Since the severity of cardiomegaly may become more variable when patient data from these MMVD stages are included, diagnostic imaging indices were evaluated only in MMVD stages B1 and B2. In addition, the distinction between MMVD stages B1 and B2 is considered meaningful as it serves as an indication for treatment (6). However, if MMVD stages C and D are included, the results and usefulness of TIHS may change, so further studies that include these MMVD stages would be meaningful, especially regarding the predictability of CHF. Second, due to the retrospective nature of the study, the echocardiographic indices were not measured by a single person, which could have resulted in interobserver variability in the measurements. Finally, Although this study was conducted on a single breed, Maltese dogs, further research with larger sample sizes is needed to meet normality.

In conclusion, the present study, conducted on Maltese dogs with MMVD, has demonstrated that the TIHS method reveals significant differences between MMVD stages B1 and B2. TIHS also showed a higher correlation with VHS than with other diagnostic indices, indicating that the TIHS method can be used alongside VHS for monitoring cardiac disease before the onset of CHF. This research is believed to be the first evaluation of cardiomegaly in Maltese dogs. The findings may inform future studies on other diagnostic indices for monitoring cardiac disease in small animals.

Acknowledgements

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Conflicts of Interest

The authors have no conflicting interests.

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