

A retrospective study of myxomatous mitral valve disease:
Prevalence and predisposing factors of affected dogs

Thao H. X. Tran¹, Pongrawee Saenpanya², & Mai C. Duong¹

¹Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh City, Vietnam

²Thonglor International Pet Hospital, Bangkok, Thailand

ARTICLE INFO	ABSTRACT
Research Paper Received: February 21, 2025 Revised: April 02, 2025 Accepted: April 14, 2025 Keywords Canine Diagnostic imaging Myxomatous mitral valve disease Physical examination Prevalence *Corresponding author Tran Huynh Xuan Thao Email: thao.tran6899@gmail.com	Myxomatous mitral valve degeneration (MMVD) is the most common heart disease in small to medium-sized dog breeds (Dachshund, Miniature and Toy Poodles, Chihuahua, Pomeranian, Shih Tzu, Maltese...). The objective of this research was to study the prevalence of MMVD and predisposing factors of an affected population dogs in the Cardiology clinic at Thonglor International Pet Hospital, Bangkok, Thailand. Electronic medical records of 151 dogs confirmed with MMVD were collected. Assessment criteria included signalments (breed, age, sex, and body weight); physical examination findings (clinical signs and heart murmur grades); subjective measurement findings on diagnostic imaging (vertebral heart score (VHS), left atrial to aorta ratio (LA/Ao), normalized left ventricular internal diameter in diastole (LVIDDN), normalized left ventricular internal diameter in systole (LVIDSN), and fractional shortening (FS)). The prevalence of MMVD in the study population was 33.4%. Based on The American College of Veterinary Internal Medicine (ACVIM) consensus guidelines, the study population comprised 80 (53.0%) dogs in stage B1, 47 (31.1%) dogs in stage B2, and 24 (15.9%) dogs in stage C. The prevalence of the disease was higher in small-breed dogs over 10 years old. A high number of male dogs (58.9%) was affected by MMVD compared to female dogs (41.1%). Heart murmurs severity generally increased with disease stage. Coughing was the most common clinical sign, reported in 40.8% of MMVD population. Cardiomegaly (based on VHS), increased LA/Ao along with increased LVIDDN, and increased LVIDSN were significantly associated with ACVIM stages ($P < 0.001$).

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1. Introduction

Myxomatous mitral valve disease (MMVD) is the most common cardiovascular disease in dogs, accounting for more than 70% of heart diseases and typically reported in small-breed dogs (Atkins et al., 2009; Parker & Kilroy-Glynn, 2012). MMVD is a chronic disease characterized by progressive myxomatous degeneration of atrioventricular valves, leading to thickening and incomplete coaptation (Hezzell, 2018). The mitral valve is most affected, compared to tricuspid valves and other valves which are sometimes also involved (Orozco et al., 2019). These structural changes result in secondary mitral valve regurgitation (leakage) from the ventricle into the atrium. Over time, excessive regurgitant blood causes left atrial enlargement and left ventricular remodeling (Fox, 2012). A systolic murmur sound caused by mitral regurgitation is a hallmark sign detected on auscultation, providing information about disease severity (Ljungvall et al., 2014). In addition, compensatory mechanism for increased leaked volume can lead to elevated left atrial pressure, which transmits to the lungs and causes pulmonary edema. Although most dogs remain asymptomatic for years, some dogs experience evident disease progression, leading to chronic heart failure (CHF) associated with clinical signs and ultimately death (Hezzell, 2018).

Diagnosis of MMVD is challenging due to the long-term preclinical stage. Diagnosis requires a thorough physical examination, radiography and echocardiography to confirm the presence of MMVD (Keene et al., 2019). Previous studies showed that the prevalence and progression of the MMVD were strongly associated with breed, age, sex and body weight (Petrič, 2015; Pascon et al., 2021). Evidence of inheritance has been

reported in some highly susceptible breeds such as the Cavalier King Charles Spaniels and Dachshund although the genetic mode was not exactly clarified (Petrič, 2015). Small-sized dogs such as Poodles, Yorkshire terrier, Chihuahuas, and Shi-Tzu were most frequently affected. Furthermore, MMVD is more common in male dogs. The prevalence of MMVD markedly increases with age over 10 years old (Fox, 2012; Kenne et al., 2019). The aim of this study was to investigate the prevalence of MMVD in a practice-attending population and determine population characteristics of MMVD dogs. This information will help clinicians identify high-risk individuals and aid in prognostication of disease severity.

2. Materials and Methods

2.1. Animals

A total of 452 dogs admitted to the Cardiology unit, Thonglor International Pet Hospital, Bangkok, Thailand from November 1, 2021 to November 30, 2022 were included. Among them, 151 dogs were confirmed to have MMVD based on a thorough diagnostic evaluation, including physical examination, radiography, and echocardiography (2D mode, M-Mode, and color flow Doppler).

2.2. Data collection and assessment criteria

Physical examination including signalments (breed, age, sex, and body weight), clinical signs, and murmur grades were collected through observation and auscultation. Murmur grade was classified as soft (I - II), moderate (III), loud (IV), or thrilling (V - VI) according to the murmur grading system described by Ljungvall et al. (2014). In radiographic examination, the vertebral heart scale (VHS)

was measured in right lateral radiographic projections following the method of Gugjoo et al. (2013). Echocardiographic examinations were performed using 2D, M-mode, and Doppler modalities. In echocardiography, dogs were placed in the right lateral position for the right parasternal long axis and short axis views, in the left lateral position for the left apical long axis view. The severity of disease was classified based on the American College of Veterinary Internal Medicine (ACVIM) consensus guidelines (Keene et al., 2019). The variables collected from echocardiography were the left ventricular internal diameter at end diastole (LVIDD) and end systole (LVIDS), both normalized to body weight using the method described by Cornell et al. (2004); the ratio of left atrium diameter to aortic diameter (LA/Ao); and left ventricular shortening fraction (FS).

2.3. Statistical analysis

Statistical analyses were performed using commercial software (IBM SPSS version 24.0). Categorical variables were presented as number (n) and percentage (%). The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Normally distributed variables were presented as mean and standard deviation (SD) (mean $\pm$ SD); while non-normally distributed variables were presented as median and interquartile range [median (IQR)].

Categorical variables were compared among study groups using Chi-square test. Differences in radiographic and echocardiographic indices among stages were evaluated using One way ANOVA followed by a multiple comparison test for normally distributed variables or the Kruskal-Wallis test followed by a multiple comparison test for non-normally distributed variables. Statistical significance was defined as $P < 0.05$.

3. Results and Discussion

3.1. The rate of MMVD dogs in Cardiology unit and the rates of MMVD dogs among ACVIM stages

Of the 452 dogs admitted to the Cardiology unit of Thonglor International Pet Hospital in Bangkok, Thailand, 151 (33.4%) were diagnosed with MMVD. This prevalence is higher than that reported in previous study by Pascon et al. (2021) of 30.3%. This is because the prevalence of the disease typically varies based on epidemiological factors age, sex, and breed distribution. Differences in epidemiological factors of population will lead to overall prevalence differences of the disease because old, male, small-sized dogs have been reported to have a higher prevalence of MMVD. However, the observed disease progression patterns in this study align with previous reports of Franchini et al. (2021) and Pascon et al., (2021), showing incidence are closely related to specific breed, age, and body weight characteristics.

According to the ACVIM consensus guidelines (Keene et al., 2019), MMVD dogs in this study were classified in three different stages including stages B1, B2, and C. The majority of dogs with MMVD were classified as stage B1 (53.0%), followed by stage B2 (31.1%) and stage C (15.9%). Notably, no dogs were classified as stages A or D. In agreement with previous studies (Pascon et al., 2021, Trofiniak & Slivinska, 2021), stage B1 predominated in this study population when compared to stages B2 and C. This may be because our study was collected from an international pet hospital, where routine cardiac disease screenings and preoperative examinations are commonly performed. These practices likely result in a higher detection rate of asymptomatic patients (stage B dogs).

3.2. The rates of MMVD dogs according to signalments (breed, sex, age, and body weight) among stages

All 151 dogs diagnosed with MMVD in this study represented 16 different breeds (Table 1). The most prevalent breeds among MMVD-affected dogs were Chihuahuas (31.1%), followed by Pomeranian (27.2%) and Poodles (10.6%). This finding supports the research by Mattin et al. (2015) and by Pascon et al. (2021) indicating that MMVD is a common cardiovascular disease in small breed dogs. Parker & Kilroy-Glynn (2012) proposed several explanations for why small breeds are more susceptible to MMVD than large breeds. One possibility is that smaller dogs have a higher heart-to-body size ratio. Another

possibility is that if small breeds share many of the same genetic mutations responsible for their small size, they may also carry associated genes that increase their susceptibility to MMVD. Additionally, the longer lifespan of small dogs compared to larger dogs may contribute to higher diagnosis rates, as they are more likely to live long enough for the disease to develop and progress. Interestingly, despite Cavalier King Charles Spaniels being a breed known to be at high risk for MMVD at a young age in previous studies (Mattin et al., 2015, Franchini et al., 2021), they represented only 1.3% of the affected dogs in this study. This low representation may be due to the limited number of this breed presenting to the hospital during the study period, possibly reflecting breed preferences of Thai owners.

Table 1. The rate of dogs with Myxomatous mitral valve degeneration (MMVD) by breeds

Breeds	Dogs with MMVD (n)	Rate (%)
Chihuahuas	47	31.1
Pomeranian	41	27.2
Poodles	16	10.6
Mixed	14	9.3
Shih Tzu	7	4.6
Miniature Pinscher	4	2.6
Beagle	4	2.6
Golden Retriever	3	2.0
Yorkshire Terrier	3	2.0
Cavalier King Charles Spaniel	2	1.3
Pekingese	2	1.3
Spitz	2	1.3
Thai	2	1.3
French ulldog	2	1.3
Dachshund	1	0.7
Labrador Retriever	1	0.7

n: number of dogs with MMVD.

Table 2 presented demographic data for dogs diagnosed with MMVD. No signalment had statistical significance between groups ($P > 0.05$). A slight male predominance was observed, with 58.9% male dogs compared to 41.1% female dogs. The result was in line with the general trend observed in other studies (Mattin et al., 2015; Franchini et al., 2021), which have shown that MMVD are more prevalent in male dogs.

The age of an onset ranged from 8 to 17 years, with a median age of 12 years (interquartile range: 10 - 13). However, the median age in this study was higher than that of previous studies (Kim et al., 2017; Toaldo et al., 2018; Pascon et al., 2021). However, all these studies found that middle-aged and older dogs are primarily affected by MMVD, with age being a recognized predisposing factor for this disease.

Body weight in the MMVD-affected dogs ranged from 2.3 to 33.8 kg, with a median weight of 5.1 kg (interquartile range: 4 - 7.2). The large majority (94.7%) of affected dogs weighed less than 20 kg, which was consistent with previous studies (Mattin et al., 2015; Franchini et al., 2021) that have reported a higher prevalence of MMVD in small- and medium-sized breeds. However, the median value of body weight in this study was lower than the medians reported in these mentioned studies, which were 10.9 kg (interquartile range: 8.3 - 15.75) and 7.9 kg (interquartile range: 1 - 82.4), respectively. This difference was due to the greater proportion of small-sized dogs in our study. However, all these studies agreed that MMVD occurred mostly in small- to medium-sized dogs.

Table 2. Distribution of Myxomatous mitral valve degeneration (MMVD) by sex, age, and body weight among stages

Factors	Stage B1	Stage B2	Stage C	Total	<i>P</i>
Sex n (%)					0.812
Male	48 (60.0)	26 (55.3)	15 (62.5)	89 (58.9)	
Female	32 (40.0)	21 (44.7)	9 (37.5)	62 (41.1)	
Age (years)	12 (10 - 13)	11 (9 - 14)	12 (11 - 13)	12 (10 - 13)	0.157
Body weight groups n (%)					0.296
< 20 kg	75 (93.8)	45 (95.7)	23 (95.8)	143 (94.7)	
≥ 20 kg	5 (6.2)	2 (4.3)	1 (4.2)	8 (5.3)	
Body weight (kg)	4.8 (3.8 - 7.4)	5.2 (4.4 - 7.4)	4.9 (3.7 - 6)	5.1 (4 - 7.2)	0.849
Total n (%)	80 (53.0)	47 (31.1)	24 (15.9)	151 (100.0)	

n: number of dogs with MMVD.

3.3. Physical examination findings

Table 3 summarizes the physical findings observed across the different MMVD stages. A

statistically significant association was found between clinical signs and disease stages ($P < 0.001$).

Among the 151 MMVD-affected dogs, 66 cases (43.7%) were asymptomatic, while 85 cases (56.3%) exhibited clinical signs. The rate of asymptomatic cases in this study was higher than that reported in previous studies (Kim et al., 2017; Franchini et al., 2021) which recorded only 5.9 and 7% asymptomatic cases, respectively. These results may be explained by study's setting within an international pet hospital, where routine cardiac screenings and preoperative examinations are standard practice, leading to increased detection of asymptomatic MMVD. Coughing (40.8%) was the most prevalent clinical sign, consistent with previous reports (Kim et al., 2017; Franchini et al., 2021). In dogs with more advanced MMVD, the most common causes of cough were the mainstem bronchial compression due to LA dilation and concurrent airway disease (Ferasin et al., 2013). All dogs in Stage C exhibited clinical signs due to the development of CHF. Dyspnea and tachypnea (respiratory rate > 30 bpm) were most frequently observed in stage C. However, these clinical

signs can be caused by other respiratory diseases rather than CHF, particularly in stage B1 or stage B2 dogs.

Murmur intensity was strongly associated with MMVD severity ($P < 0.001$) (Table 4). Dogs in stage B1 are most often presented with soft (57.5%) or moderate (30.0%) murmurs. In stage B2, moderate (44.7%) and loud (48.9%) murmurs were predominant, with a smaller proportion of dogs exhibiting thrilling murmurs (6.4%). Notably, no stage B1 dogs had thrilling murmurs, and no stage B2 dogs had soft murmurs. In contrast, all stage C cases with CHF exhibited loud or thrilling murmurs, accounting for 29.2 and 70.8%, respectively. These differences in murmur intensity across MMVD stages were in line with previous reports (Ljungvall et al., 2014; Franchini et al., 2021). Assessing the intensity of the left apical systolic murmur is a valuable indicator for evaluating MMVD severity, as stated in the ACVIM consensus guidelines (Keene et al., 2019).

Table 3. The grading of heart murmur intensity among Myxomatous mitral valve degeneration (MMVD) stages

Clinical signs	Stage B1	Stage B2	Stage C	Total n (%)
Cough	27 (32.1)	23 (46.0)	21 (52.5)	71 (40.8)
Asymptomatic	47 (56.0)	19 (38.0)	0 (0.0)	66 (37.9)
Dyspnea	5 (5.9)	5 (10.0)	9 (22.5)	19 (11.0)
Tachypnea	4 (4.8)	3 (6.0)	7 (17.5)	14 (8.0)
Syncope	1 (1.2)	0 (0.0)	3 (7.5)	4 (2.3)
Total n (%)	84 (48.3)	50 (28.7)	40 (23.0)	174 (100.0)

n: number of clinical signs presenting in dogs with MMVD.

Table 4. The grading of heart murmur intensity among Myxomatous mitral valve degeneration (MMVD) stages

Murmur grades		Stage B1	Stage B2	Stage C	Total n (%)
I	Soft	7 (8.8)	0 (0.0)	0 (0.0)	7 (4.6)
II		39 (48.7)			39 (25.8)
III	Moderate	24 (30.0)	21 (44.7)	0 (0.0)	45 (29.9)
IV	Loud	10 (12.5)	23 (48.9)	7 (29.2)	40 (26.5)
V	Thrilling	0 (0.0)	3 (6.4)	15 (62.5)	18 (11.9)
VI			0 (0.0)	2 (8.3)	2 (1.3)
Total n (%)		80 (53.0)	47 (31.1)	24 (15.9)	151 (100.0)

n: number of dogs with stage of MMVD.

3.4. Radiographic and echocardiographic findings

Table 5 summarizes the radiographic and echocardiographic findings across the

different MMVD stages. Statistically significant associations with disease stages were observed in subjective collected variables ($P < 0.001$) These variables included VHS, LVIDDN, LVIDSN, and LA/Ao.

Table 5. Result of radiographic and echocardiographic variables in dogs with different ACVIM stages of Myxomatous mitral valve degeneration (MMVD)

Index	Stage B1	Stage B2	Stage C	Total	<i>P</i>
VHS	10.22 (9.51 - 10.52) ^a	10.89 (10.6 - 11.23) ^b	11.97 (11.14 - 12.43) ^c	10.50 (10.00 - 11.00)	< 0.001
LA/Ao	1.46 (1.22 - 1.51) ^a	1.77 (1.70 - 1.91) ^b	2.31 (2.04 - 2.54) ^c	1.60 (1.37 - 1.83)	< 0.001
LVIDDN (mm)	1.41 (1.33 - 1.54) ^a	1.77 (1.61 - 1.80) ^b	1.90 (1.82 - 2.15) ^c	1.59 (1.41 - 1.75)	< 0.001
LVIDSN (mm)	0.71 ± 0.14 ^a	0.82 ± 0.16 ^b	0.91 ± 0.18 ^c	0.77 ± 0.17	< 0.001
FS (%)	48.61 ± 8.17	50.77 ± 8.07	51.73 ± 6.85	49.78 ± 7.34	0.142

ACVIM: American college of veterinary internal medicine; VHS, vertebral heart score, LA/Ao, left atrial-to-aortic ratio; LVIDDN (cm), left ventricular internal dimension in diastole normalized to body size; LVIDSN (cm), left ventricular internal dimension in systole normalized to body size; FS (%), fractional shortening. Values represented with same superscript letters for dogs with stages of MMVD did not differ significantly ($P < 0.001$).

The VHS is an index for assessing the presence of radiographic cardiomegaly. A VHS ranging from 8.5 to 10.5 is considered normal for the majority of dog breeds (Kvart & Pedersen, 2005). The median VHS in this study was 10.50 (interquartile range: 10.00 - 11.00) and differed significantly between stages ($P < 0.001$). This value was slightly lower than the median of 11.2 (interquartile range: 8 - 13.5) reported by Franchini et al. (2021). While the median VHS for stage B2 dogs in the current study was also lower than that in Franchini et al. (2021), it remained consistent with the reference values for stage B2 recommended by the ACVIM consensus guidelines (Keene et al., 2019). Dogs in stage C had the highest median of 11.97 (interquartile range: 11.14 - 12.43) which was remarkably higher than those values in stages B1 and B2. A difference was also observed by Franchini et al. (2021). These results highlight the association between cardiomegaly and progressive cardiac remodeling, reflected by increasing VHS values with advancing disease stages.

The LA/Ao ratio is a valuable index for assessing left atrial dilatation, which typically occurs due to significant mitral regurgitation. The median value was 1.60 (interquartile range: 1.37 - 1.83), with statistically significant differences between stages. Dogs in stage C had a markedly higher median LA/Ao ratio of 2.31 (interquartile range: 2.04 - 2.54) compared to other stages ($P < 0.001$). Similarly, dogs in stage B2 had a higher LA/Ao ratio of 1.77 (interquartile range: 1.70 - 1.91) than stage B1, which had the median value of 1.46 (interquartile range: 1.22 - 1.51) ($P < 0.001$). These results are in agreement with previous studies by Franchini et al. (2021) and Trofiniak & Slivinska (2021), which also reported a progressive increase in the LA/Ao ratio with advancing ACVIM stages. This reflects

the disease progression and the severity of volume overflow that leads to structural changes in the left atrium.

The LVIDDN is a commonly used index for assessing the degree of left ventricular dilation, which occurs due to volume overload as mitral regurgitation progresses (Chetboul & Tissier, 2012). The median LVIDDN was 1.59 (interquartile range: 1.41 - 1.75) with significant differences observed across three stages ($P < 0.001$). The median LVIDDN was 1.41 (interquartile range: 1.33 - 1.54) in stage B1, 1.77 (interquartile range: 1.61 - 1.8) in stage B2, and 1.90 (interquartile range: 1.82 - 2.15) in stage C, demonstrating a progressive increase in value with disease severity. While similar results were observed by Franchini et al. (2021) and Trofiniak & Slivinska (2021), the values in the present study were lower than those reported in their study. There was a significant relationship between LVIDDN and the clinical status, with LVIDDN increasing with disease severity (left ventricular enlargement), as stated ACVIM consensus guidelines (Keene et al., 2019) for classifying preclinical MMVD dogs into stage B1 or B2 (LVIDDN ≥ 1.7).

The LVIDSN is commonly used for assessing systolic function although it is dependent on cardiac loading conditions (Menciotti & Borgarelli, 2017). LVIDSN > 1.26 can be a suggestion for left ventricular systolic dysfunction. The mean LVIDSN was 0.77 ± 0.17 , with significant differences between the study groups ($P < 0.001$). The LVIDSN in stage C dogs had the highest mean (0.91 ± 0.18) and differed statistically from stages B1 (0.71 ± 0.14) and B2 (0.82 ± 0.16) ($P < 0.001$). Similarly, the LVIDSN was also significantly higher in B2 dogs compared to those in stage B1 ($P < 0.001$). This increasing trend in mean LVIDSN values with disease

progression aligns with the findings reported by Franchini et al. (2021). However, while Franchini et al. (2021) did not find a significant difference between stages B2 and C, the present study did.

Percentage of FS is an indicator for assessing myocardial systolic function, influenced by factors such as preload, afterload and sympathetic tone. While FS values can experience a gradual increase (over 50%) during the progression of MMVD, they may return to normal levels in advanced stage (Chetboul & Tissier, 2012; Reynolds et al. 2012). In the present study, FS showed a negligible increase of values in the progression to the advanced stage of heart failure. However, no statistically significant association was found between FS values and the different MMVD stages ($P > 0.05$). This suggests that FS may be influenced by the factors mentioned.

4. Conclusions

Myxomatous mitral valve degeneration is a common heart disease in dogs with the higher prevalence of MMVD found in small-sized breeds, middle-aged to old-aged, and male dogs. Murmur intensity could be used for early disease detection in high-risk individuals. Radiographic and echocardiographic examination of MMVD dogs across different stages revealed that increases in VHS, LA/Ao, LVIDDN, and LVIDSN are clinical relevance in assessment of the progression of MMVD in dogs.

Conflict of interest

The authors declare that there is no conflict of interest.

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