

# DOPPLER ECHOCARDIOGRAPHY DERIVED HEMODYNAMIC INDICES IN MITRAL VALVE DISEASES IN DOGS.

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## ABSTRACT

The study entitled “Doppler echocardiography derived hemodynamic indices in mitral valve diseases in dogs” was carried out at Madras Veterinary College Teaching Hospital, Echo Doppler Unit. The study comprised of healthy Spitz dogs as normal group and mitral regurgitant (MR) Spitz dogs comprised of mitral valve insufficiency with six no. in each group. The left heart indices and Doppler derived indices were recorded in these dogs. The data were statistically analysed and the following were the observations. A significant increase in EDV, ESV, SV, EF and LA/Ao were observed in dogs with MR Compared to normal dogs and no significant change in fractional shortening (FS) was observed in dogs with MR Compared to normal dogs. In Doppler derived indices there was a significant difference in regurgitation velocity (pV) and pressure gradient (PG) in dogs with different degree of mitral regurgitation and no pV and PG were observed in normal dogs. Doppler derived indices more specifically pV and PG remains not only as sensitive indicator of mitral valve regurgitation otherwise known as mitral valve insufficiency but also it aids in determination of systemic BP directly in the presence mitral valve insufficiency. Since this method is non-invasive, fast and safe

**KEYWORDS:** Doppler Echocardiography, Dogs, Mitral Regurgitation, Fractional Shortening

## 1. INTRODUCTION

Mitral regurgitation (MR) is a systolic leakage of the mitral valve with blood flowing back from the left ventricle in to the left atrium due to poor coaptation of the mitral leaflets. The assessment of valvular insufficiency uses all echocardiographic modalities to assess the significance and severity of the leak. Two-dimensional (2D) and M-mode echocardiography are used to define valve morphology and structure including the type of lesion and the presence of valvular prolapse or ruptured chordae tendineae. Measurement of chamber size and function helps to define both the chronicity and the extent of remodeling. Colour-Flow doppler rapidly identifies the presence of regurgitation. Attention to the jet area with respect to the receiving chamber, the width of the jet at its orifice, and the area of flow convergence adds accuracy in assessing the severity of regurgitant volume. Spectral doppler helps in the measurement regurgitant volume and fraction and is used to measure regurgitant orifice area. Pulsed-Wave doppler and Continuous-Wave doppler assess hemodynamic severity by evaluating spectral trace density, velocity of flows, and flow profiles. (Zoghbi et al., 2003).

The progressive MR induces cardiac remodeling characterized by left atrial (LA) and left ventricular (LV) dilatation, eccentric myocardial hypertrophy, and the narrowing of small (intramural) coronary arteries may play roles in the pathogenesis of LV remodeling (Killingsworth et al., 2008). Despite preservation of global LV shortening, LV dysfunction can eventually develop in CDVD (McGinley et al. 2007), along with increases in LA and pulmonary venous and pulmonary arterial pressures. By this stage, many dogs are symptomatic for heart failure and echocardiography can identify and track many of these developments non-invasively and offers useful information about the heart and circulation in chronic MR (Serres et al., 2007a).

The MR related to chronic degenerative mitral valve disease as a result of myxomatous degeneration represents the most common acquired cardiovascular disease in dogs and also chronic degenerative valvular disease (CDVD) is the most important cause of heart failure in dogs (Haggstrom et al., 2005; Bonagura and Schober, 2009).

Various research has been done in human medicine and presently Echo doppler is being used in the diagnosis mitral valvular disorders, where as in canines, mitral valvular diseases particularly mitral valve regurgitation due to mitral valve insufficiency still has to be explored thoroughly. In this backup, the present study was taken up with the objective "To evolve doppler echocardiography derived velocity and pressure gradient in mitral valvular regurgitation in dogs".

## 1. MATERIALS AND METHODS.

The study population consisted of client-owned apparently healthy Spitz dogs of different age group attended outpatient ward for general health check-up as normal group (six numbers) and the animals were selected through a physical and electrocardiographic examination, those showing any clinical sign of cardiomyopathy were excluded. Eighteen Spitz dogs with mitral regurgitation of different age group attended out-patient ward were randomly selected and three groups were formed each contained six dogs. All the selected dogs were examined by two-dimensional, M-mode, and CF and PW doppler echocardiography and all the data were recorded in the proper formats containing the name, number, gender, age, body weight and echocardiographic measurements.

The selected dogs were subjected to complete CF, PW doppler echocardiographic examination and grouped as normal, mild MR, Moderate MR and severe MR dogs as shown below.

| Group No. | Spitz dogs  | No. of Dogs | Age (Years)    | Body weight (Kg) |
|-----------|-------------|-------------|----------------|------------------|
| I         | Normal      | 6           | 3 to 5 years   | 5 to 7.5         |
| II        | Mild MR     | 6           | 8.5 to 7 years | 7 to 10          |
| III       | Moderate MR | 6           | 5 to 13 years  | 6 to 11.5        |
| IV        | Severe MR   | 6           | 5 to 14 years  | 5 to 14          |

## 2.1 Procedure of 2D, M-Mode, Colour Flow and Pulsed Wave Doppler Echocardiography in Dogs.

Echocardiographic examination was performed in conscious dogs. The dogs were gently restrained in lateral recumbency and 2D, M mode Doppler echocardiographic evaluation was done with 1.9MHz tissue harmonic phased array transducer in a Aloka SSD 3500 machine. During echocardiographic recording, each dog was manually restrained without giving any tranquilizers or anesthetics. A thick acoustic gel layer was placed between the transducer and the site of examination after hair removal. Three individual measurements of each variable were performed and the average data was obtained. All examinations were recorded on videotape for further evaluations.

In 2D echocardiography the left atrium to aorta root ratio (LA/Ao) was calculated using right parasternal short axis view at the level of aorta. Left parasternal short axis view used for M-mode measurement of EF calculation and FS calculation at the level of chordae tendineae. The right parasternal long axis view is used for the CF doppler examination of mitral regurgitation and after colour flow mapping, PW doppler cursor is placed over the regurgitant jet in left atria and the diastolic mitral flow velocity and mitral valve regurgitation were measured using standard right parasternal short axis view.

### Parameters under study.

**1.Left Heart Indices-(2D and M-Mode Echocardiography):** End Diastolic Volume (EDV), End Systolic Volume (ESV), Ejection Fraction (EF), Stroke Volume (SV), Fractional Shortening (FS), and Left Atrium to Aortic root ratio (LA/Ao)

**2.Pulsed Wave Doppler Derived Indices:** Regurgitant Velocity (pV), Pressure Gradient (PG)

**3.Statistical analysis.**

The data in the present study were subjected to statistical analysis using the IBM-SPSS software.

## 4.RESULTS

The present study was carried out Madras Veterinary College Teaching Hospital, Echo-Doppler Unit. The left heart indices and Doppler derived indices were evaluated in normal dogs, dogs with different degree of mitral regurgitation with 6 cases in each. The results and discussions of the study were presented below.

### 4.1 Left Heart Indices

The mean  $\pm$  SD of EDV were  $9.6 \pm 3.3$ ml,  $25.44 \pm 7.12$ ml,  $37.64 \pm 15.05$ ml and  $156.59 \pm 36.91$ ml for normal dogs and dogs with mild, moderate and severe MR respectively. The ESV were  $1.9 \pm 0.7$ ml,  $2.78 \pm 1.18$ ml,  $4.64 \pm 1.41$ ml and  $27.44 \pm 5.63$ ml for normal dogs and dogs with mild, moderate and severe MR respectively.

The mean  $\pm$  SD of SV were  $7.7 \pm 2.7$  ml,  $22.67 \pm 6.12$ ml,  $33.01 \pm 14.31$ ml and  $129.15 \pm 33.1$  ml for normal dogs and dogs with mild, moderate and severe MR respectively. The EF were  $80.5 \pm 3.8$  %,  $89.25 \pm 2.6$  %,  $86.76 \pm 5.4$  % and  $82.18 \pm 2.91$  % for normal dogs and dogs with mild, moderate, and severe MR respectively.

The mean  $\pm$  SD of FS were  $42.2 \pm 3.9$ %,  $52.70 \pm 3.75$ %,  $49.68 \pm 6.10$ % and  $43.87 \pm 3.06$  % for normal dogs and dogs with mild, moderate and severe MR respectively. The mean  $\pm$  SD of LA/Ao were  $1.0 \pm 0.1$ ,  $1.57 \pm 0.11$ ,  $1.81 \pm 0.22$  and  $2.25 \pm 0.37$  for normal dogs and dogs with mild, moderate and severe MR respectively.

The Significant increase in SV and EF was observed in dogs with MR when compared the normal dogs and the Significant increase in FS was observed in dogs with mild MR and when compared the normal dogs and no significant difference between normal dogs, moderate and severe MR dogs. Significant increase in the percentage of LA/Ao was observed in dogs with MR when compared the normal dogs

In this study, the significant changes in the left heart indices in dogs with MR are due to mitral valve regurgitation and associated LA dilatation. The normal values of the percentage of FS in moderate and severe MR dogs were suggestive of myocardial failure due to end-stage mitral valve regurgitation. If the FS is more than 75% in those dogs, then the dogs are having only mitral valve regurgitation without myocardial failure.

### 4.2 Doppler Derived Indices.

The mean  $\pm$  SD of pV were  $1.47 \pm 0.34$  m/s,  $3.21 \pm 0.46$  m/s and  $4.57 \pm 0.34$  m/s for dogs with mild, moderate and severe MR, respectively. The PG were  $9.06 \pm 4.12$  mmHg,  $41.96 \pm 11.38$  mmHg and  $83.98 \pm 12.30$  mmHg for dogs with mild, moderate and severe MR, respectively.

The significant increase of pV and PG were observed in dogs with MR when compared between mild, moderate and severe MR dogs, and in normal dogs pV and PG indices were absent.

**Table: 1 The Mean  $\pm$ SD of 2D M-mode echocardiography derived hemodynamic indices of Left side heart in normal and MR dogs**

| Indices     | Group 1 (Normal MR)* | Group 2 (Mild MR) | Group 2 (Moderate MR)* | Group 4 (Severe MR) | F         |
|-------------|----------------------|-------------------|------------------------|---------------------|-----------|
| LVIDd (cm)  | 2.1 $\pm$ 0.2        | 2.92 $\pm$ 0.25   | 3.30 $\pm$ 0.45        | 5.36 $\pm$ 0.41     | 96.119**  |
| LVIDs (cm)  | 1.2 $\pm$ 0.2        | 1.39 $\pm$ 0.18   | 1.65 $\pm$ 0.19        | 3.01 $\pm$ 0.20     | 117.003** |
| EDV (ml)    | 9.6 $\pm$ 3.3        | 25.44 $\pm$ 7.12  | 37.64 $\pm$ 15.05      | 156.59 $\pm$ 36.91  | 65.592**  |
| ESV (ml)    | 1.9 $\pm$ 0.7        | 2.78 $\pm$ 1.18   | 4.64 $\pm$ 1.41        | 27.44 $\pm$ 5.63    | 100.688** |
| SV (ml)     | 7.7 $\pm$ 2.7        | 22.67 $\pm$ 6.12  | 33.01 $\pm$ 14.31      | 129.15 $\pm$ 33.17  | 53.779**  |
| EF %        | 80.5 $\pm$ 3.8       | 89.25 $\pm$ 2.67  | 86.76 $\pm$ 5.41       | 82.18 $\pm$ 2.91    | 6.575**   |
| FS%         | 42.2 $\pm$ 3.9       | 52.70 $\pm$ 3.75  | 49.68 $\pm$ 6.10       | 43.87 $\pm$ 3.06    | 7.610**   |
| LA (cm)     | 1.1 $\pm$ 0.1        | 1.13 $\pm$ 0.06   | 1.13 $\pm$ 0.06        | 1.13 $\pm$ 0.06     | 20.996**  |
| Ao (cm)     | 1.1 $\pm$ 0.1        | 1.08 $\pm$ 0.07   | 1.08 $\pm$ 0.07        | 1.08 $\pm$ 0.07     | .032 NS   |
| LA/Ao ratio | 1.0 $\pm$ 0.1        | 1.57 $\pm$ 0.11   | 1.81 $\pm$ 0.22        | 2.25 $\pm$ 0.37     | 35.450**  |

\*\*p<0.01significantdifference

NS p > 0.05 Non-significant difference

**Table 2: The mean  $\pm$ SD of Doppler echocardiography derived hemodynamic indices of left side heart in MR dogs.**

| Indices   | Group 1 (Normal MR) | Group 2 (Mild MR) | Group 2 (Moderate MR) | Group 4 (Severe MR) | F        |
|-----------|---------------------|-------------------|-----------------------|---------------------|----------|
| pV (m/s)  | -                   | 1.47 $\pm$ 0.34   | 3.21 $\pm$ 0.46       | 4.57 $\pm$ 0.34     | 98.810** |
| PG (mmHg) | -                   | 9.06 $\pm$ 4.12   | 41.96 $\pm$ 11.38     | 83.98 $\pm$ 12.30   | 85.281** |

\*\*p<0.01significantdifference

NS p > 0.05 Non-significant difference

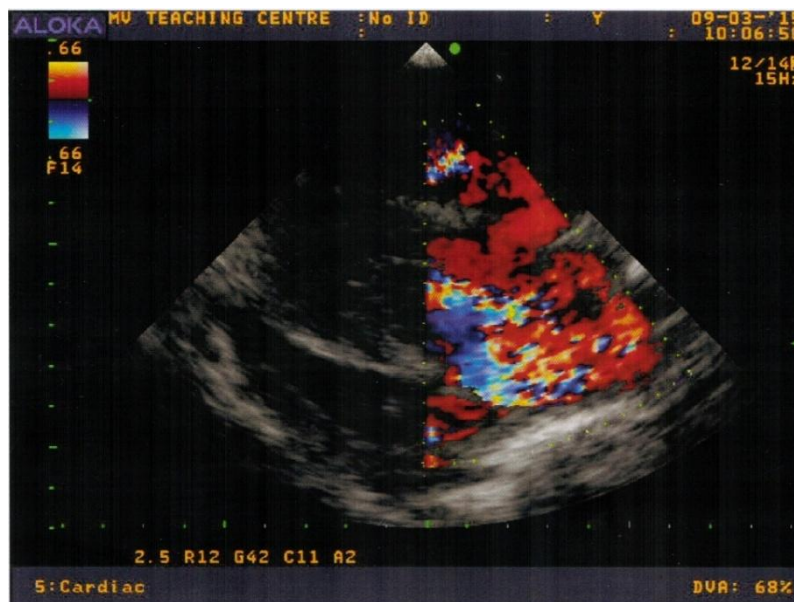


**Fig. 1. Colour flow (CF) Echo-doppler of right parasternal long Axis View of the image showing Mitral regurgitation in Dog.**



**Fig.2. 2 D Echocardiographic view of right parasternal short axis view at the level of Aorta and Left Atrium (LA) showing LA Dilatation**

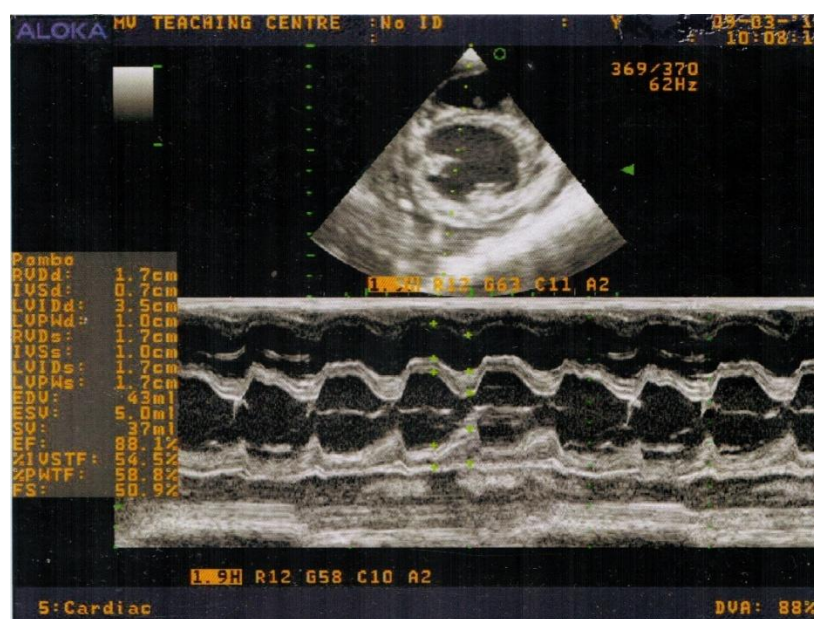


**Fig.3. M- Mode Echocardiographic measurement at the level of corda tendineae showing increased Fractional shortening (FS) in Mitral regurgitation in Dog.**

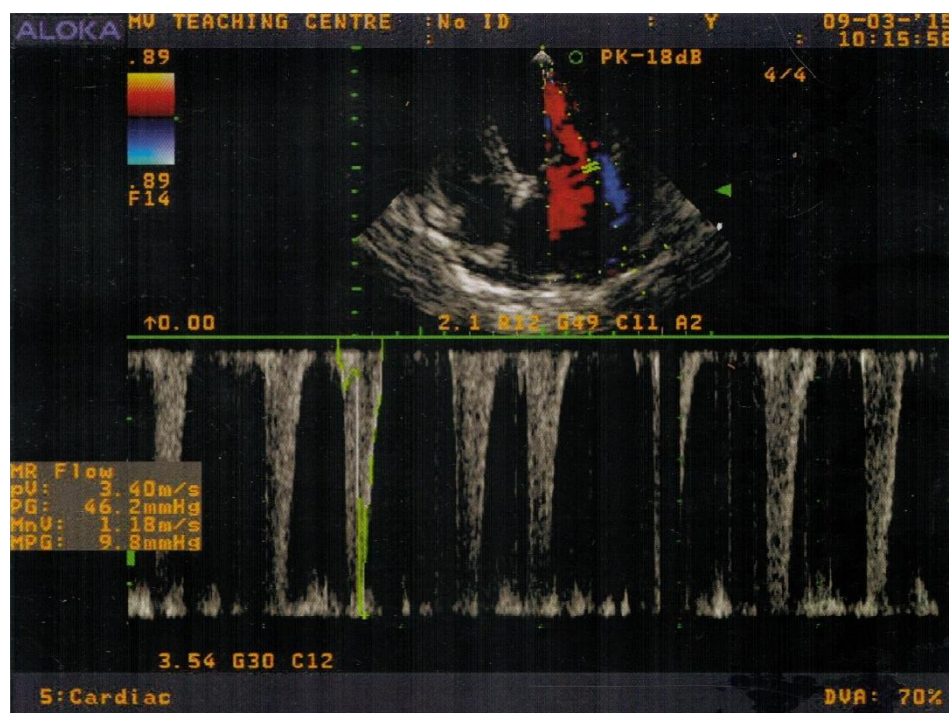


**Fig.4. Pulsed Wave (PW) Doppler measurement of Mitral Regurgitant flow showing Peak Velocity and Pressure Gradient.**

## 5. DISCUSSION.

The progressive alterations observed in the left heart and Doppler-derived indices across the four experimental groups (Normal, Mild MR, Moderate MR, and Severe MR) provide clear diagnostic insight into the hemodynamic remodeling that accompanies myxomatous mitral valve disease (MMVD) in small breed dogs.

### 5.1 Hemodynamic Correlates of Volumetric Overload

In this study, a step-wise, statistically significant increase was observed in End-Diastolic Volume (EDV), End-Systolic Volume (ESV), and Stroke Volume (SV) from normal control dogs to those suffering from severe mitral regurgitation (MR). In the severe MR group, the massive elevation of EDV ( $156.59 \pm 36.91$  ml) and ESV ( $27.44 \pm 5.63$  ml) reflects severe eccentric hypertrophy. This represents the heart's compensatory mechanism trying to accommodate the massive chronic volume overload shifting into the left atrium during systole.

The significant elevation of the Left Atrium-to-Aorta ratio (LA/Ao) ranging from  $1.0 \pm 0.1$  in normal dogs up to  $2.25 \pm 0.37$  in severe MR highlights progressive left atrial dilation. This is a critical hallmark of chronic volume overload caused by the regurgitant volume hitting the low-pressure atrial vault. These findings are fully supported by foundational work demonstrating that left atrial and left ventricular eccentric modeling directly correlate with the severity of the mitral regurgitant fraction in canine valvular disease (Borgarelli et al., 2008; Serres et al., 2007).

### 5.2 Systolic Function and the Fractional Shortening (FS) Paradox

The study demonstrated that Ejection Fraction (EF) and Fractional Shortening (FS) increased significantly in mild and moderate MR states but decreased toward normal baselines in the severe stage ( $FS = 43.87 \pm 3.06\%$ ). In early-stage mitral regurgitation, the left ventricle unloads a portion of its stroke volume into the low-pressure left atrium. This reduces the ventricular afterload and creates a false appearance of hyperdynamic systolic function, resulting in elevated FS values ( $52.70 \pm 3.75\%$  in mild MR).

However, as the disease progresses to end-stage severe MR, the myocardium undergoes chronic exhaustion, stretching, and subsequent structural failure. This leads to myocardial dysfunction. The normalization of FS in advanced stages ( $43.87\%$ ) actually indicates subclinical myocardial failure masked by the low afterload state. As noted in the results, an FS failing to exceed hyperdynamic levels ( $>75\%$ ) in the presence of severe structural reflux signals a drop in true myocardial contractility. This matches historical clinical observations where standard radial indices like FS overstate true ventricular performance in severe volume-overload states (Bonagura and Schober, 2002; Chetboul and Tissier, 2012).

### 5.3 Pathophysiological Relevance of Doppler Indices (pV and PG)

The complete absence of peak regurgitation velocity (pV) and pressure gradient (PG) in normal dogs confirms the anatomical integrity of the mitral valve apparatus in Group I. Conversely, a distinct, step-wise elevation in pV ( $1.47 \pm 0.34$  m/s in mild to  $4.57 \pm 0.34$  m/s in severe MR) and PG ( $9.06 \pm 4.12$  mmHg in mild to  $83.98 \pm 12.30$  mmHg in severe MR) was recorded.

According to the modified Bernoulli Equation, the pressure drops across the incompetent valve is directly proportional to the square of the jet velocity. The high velocity ( $4.57$  m/s) and steep pressure gradient ( $83.98$  mmHg) observed in the severe MR group indicate that a large systolic pressure difference remains between the left ventricle and left atrium.

In clinical veterinary practice, measuring these Doppler indices serves two vital diagnostic purposes:

1. Estimation of Ventricular Pressure: If systemic systolic blood pressure is measured concurrently, the peak regurgitant PG allows clinicians to non-invasively calculate peak left ventricular systolic pressure ( $LVSP = SAP + PG$ ), offering a reliable window into cardiac workload (Oyama et al., 2004).
2. Staging and Strategic Therapy: Because continuous-wave Doppler evaluation of pV and PG is non-invasive, fast, and safe, it effectively replaces risky invasive cardiac catheterization. Furthermore, tracking increases in these parameters enables early medical intervention (e.g., introducing neurohormonal modulators or positive inotropes) in asymptomatic patients before overt congestive heart failure manifests (Atkins et al., 2009; Häggström et al., 2008).

## 6. Summary and Conclusions

The present study was conducted at Madras Veterinary College, teaching hospital, Echo Doppler unit Chennai-07. The dogs were grouped into four and each group containing six no. of clinical cases of Spitz dogs as follows. Group I- Normal dogs, Group II- Dogs with mild mitral regurgitation, Group III- Dogs with moderate mitral regurgitation and Group IV- Dogs with severe mitral regurgitation.

The left heart indices and Doppler derived indices were recorded in these dogs. The data were statistically analyzed and the following were the observations. A significant increase in EDV, ESV, SV, EF and LA/ Ao were observed in dogs with MR Compared to normal dogs and no significant change in FS was observed in dogs with MR Compared to normal dogs. In Doppler derived indices there was a significant difference in regurgitation velocity (pV) and pressure gradient (PG) in dogs with different degree of mitral regurgitation and no pV and PG were observed in normal dogs.

Based on the above findings the following conclusions as follows.

The increased of pV and PG correlates positively with the severity of mitral regurgitation in dogs with mitral valve insufficiency and in normal dogs these parameters not all present and it is evidenced that we can use the sensitivity of pressure gradient for the fast diagnosis of mitral valve insufficiency in dogs and also the PG aids in determination of systemic BP directly in the presence mitral valve insufficiency by calculating left ventricular BP.

Echo Doppler PG calculation is non-invasive, fast and safe when compared with cardiac catheterization for pressure gradient determination. Also, PG determination helps the clinical practitioner to formulate a medical therapy in the initial stages of development of mitral valve insufficiency in asymptomatic dogs where the diagnosis of mitral regurgitation is incidental. So, it is advised to do a routine health check-up once in a year along with Echo-doppler to the normal dogs particularly small breeds of dogs like Spitz dogs.

The left heart indices could be used for the identification of Left ventricular and particularly left atrial dilation and myocardial failure in late stage or chronic mitral valve insufficiency in dogs.

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