RESEARCH ARTICLE

Comprehensive Cardiac Assessment in Dogs using Electrocardiography, Echocardiography and Cardiac Biomarkers

Saurabh M. Parmar*, Manish D. Patel, Ramesh Chand Koli, Jignesh V. Vala, Sudhir A. Mehta, Hitesh C. Parmar

Abstract

Cardiac diseases are a major cause of morbidity and mortality in dogs and require timely diagnosis for effective clinical management. A total of 52 dogs with clinical suspicion of cardiac disease were examined and compared with six apparently healthy control dogs at Veterinary Clinical Complex, Kamdhenu University, Navsari, Gujarat. Diagnosis was established using ECG and echocardiography and supported by haemato-biochemical analysis and assessment of cardiac troponin-I (cTnI) and N-terminal pro-B-type natriuretic peptide (NT-proBNP). Dilated cardiomyopathy (DCM) was the most prevalent cardiac disorder (46.15%), followed by mitral valve disease (MVD) (38.46%), pericardial effusion (11.53%), and hypertrophic cardiomyopathy (3.84%). The most common clinical signs were exercise intolerance (92.30%), dyspnea (88.46%), and weakness (86.53%). ECG revealed atrial fibrillation (30.76%) and sinus tachycardia (25.00%) as the predominant rhythm abnormalities. Echocardiography demonstrated significant ventricular dilatation, increased E-point to septal separation, and reduced ejection fraction and fractional shortening in DCM, whereas MVD was characterized by marked left atrial enlargement and an increased left atrial-to-aortic root ratio. Haematological findings revealed mild anaemia, neutrophilia, and lymphopenia, while biochemical alterations were characterized by increased BUN and reduced serum albumin concentrations. Cardiac biomarkers showed marked diagnostic value, with elevated NT-proBNP concentrations and positive cTnI results in 70% of affected dogs. The findings indicate that ECG, echocardiography and cardiac biomarkers are valuable complementary tools for the accurate diagnosis and assessment of canine cardiac diseases.

Key words: Cardiac disease, Cardiac troponin-I, Dog, ECG, Echocardiography, NT-proBNP.

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Introduction

Cardiac disorders are increasingly recognized as an important cause of morbidity and mortality in dogs worldwide. Advances in veterinary cardiology, particularly in diagnostic imaging, electrocardiography and cardiac biomarker analysis have substantially improved the detection and characterization of cardiovascular diseases. Among the various canine cardiac disorders, degenerative mitral valve disease (MVD) and dilated cardiomyopathy (DCM) are the most prevalent, whereas hypertrophic cardiomyopathy (HCM), pericardial effusion and congenital cardiac defects are encountered less frequently (Tidholm and Jonsson, 1997; Borgarelli and Häggström, 2010). The clinical manifestations of cardiac disease vary according to the nature and severity of the underlying disorder and may range from exercise intolerance, coughing, and reduced activity to dyspnea, ascites, syncope, and congestive heart failure (Kittleson, 1998). Physical examination findings such as cardiac murmurs, arrhythmias, pulse deficits, and jugular venous distension often provide the first indication of cardiovascular dysfunction; however, these findings alone are insufficient for definitive diagnosis (Tilley *et al*., 2024).

Electrocardiography (ECG) remains a rapid, non-invasive and valuable tool for detecting arrhythmias, conduction abnormalities and chamber enlargement patterns associated with cardiac diseases (Moise, 2006). Nevertheless, its ability to identify structural cardiac changes is limited. Echocardiography is therefore regarded as the gold standard for evaluating cardiac morphology and function allowing detailed assessment of chamber

[1]Department of Veterinary Medicine, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Navsari-396450, Gujarat, India

[2]Veterinary Clinical Complex, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Navsari-396450, Gujarat, India

Corresponding Author: Dr. Saurabh M Parmar, Veterinary Clinical Complex, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Navsari-396450, Gujarat, India. e-mail: drsaurabh@kamdhenuuni.edu.in

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dimensions, myocardial contractility, valvular integrity and hemodynamic status (Borgarelli and Haggstrom, 2010; Boon, 2011). In addition, haematological and biochemical evaluations provide supportive information regarding systemic consequences of cardiac dysfunction including inflammatory responses, renal and hepatic perfusion abnormalities and metabolic disturbances (Rubio *et al.,* 2020).

More recently, cardiac biomarkers such as cardiac troponin-I (cTnI) and N-terminal pro-B-type natriuretic peptide (NT-proBNP) have emerged as sensitive indicators of myocardial injury and cardiac stress. These biomarkers complement conventional diagnostic methods and contribute significantly to disease diagnosis, assessment of severity and prognostication (Oyama and Singletary, 2010; Winter *et al.,* 2017). Despite considerable advances in canine cardiology, information on the incidence and clinicopathological characteristics of cardiac diseases in dogs under Indian conditions remains limited, particularly in South Gujarat. Therefore, the present study was undertaken to determine the incidence of canine cardiac diseases and evaluate ECG, echocardiographic, haemato-biochemical, and cardiac biomarker alterations.

Materials and Methods

The present study was conducted from January-2021 to December-2022 at the Veterinary Clinical Complex in collaboration with the Department of Veterinary Medicine, College of Veterinary Science and Animal Husbandry, Kamdhenu university, Navsari, Gujarat, India. Out of 5566 dogs presented during this period, 52 dogs of different breeds, age, and sex with clinical suspicion of cardiac disease were included, while six apparently healthy dogs brought for routine vaccination were selected as controls after obtaining informed owner consent. A comprehensive clinical history was documented for each case followed by general and cardiovascular examinations. Physiological parameters such as rectal temperature, heart rate and respiratory rate were measured according to established guidelines (Tilley *et al*., 2024).

Electrocardiography was performed using a standard 12-lead ECG system with animals positioned in right lateral recumbency (Tilley and Burtnick, 1999). The tracings were analysed for rhythm disturbances and alterations in waveform morphology including P waves, QRS complexes, ST segments, T waves and interval measurements. Echocardiographic assessment comprising two-dimensional, M-mode and spectral doppler echocardiography was conducted using an ultrasound unit Sonosite M-Turbo fitted with a 5-8 MHz micro-convex transducer in accordance with the guidelines of Boon (2011) and Mattoon and Nyland (2020). The measurements taken included interventricular septal thickness during diastole and systole (IVSd, IVSs), left ventricular internal dimensions in diastole and systole (LVDd, LVDs), left ventricular posterior wall thickness in diastole and systole (LVPWd, LVPWs), ejection fraction (EF), fractional shortening (FS), left atrium (LA), aortic root (Ao), LA/Ao ratio and E-point septal separation (EPSS).

For laboratory investigations, blood samples were obtained aseptically in EDTA tubes for haematological analysis using an automated haematology analyser, while those in plain vials were used for serum biochemical assays, such as BUN, creatinine, total protein, albumin, ALT and AST using commercial kits and automated biochemical analyzer (Kaneko *et al*., 2008).

Cardiac troponin-I (cTnI) was initially screened using a canine-specific qualitative rapid test kit with a cut off value of 0.1 ng/mL. Positive samples were subsequently confirmed by ELISA. Plasma concentrations of N-terminal pro-B-type natriuretic peptide (NT-proBNP) were determined using a canine-specific ELISA kit according to the manufacturer's instructions. These markers were chosen for their established diagnostic accuracy in identifying myocardial damage and cardiac stress (Oyama and Singletary, 2010).

Statistical Analysis

Data obtained from clinical, ECG, echocardiographic, haemato-biochemical, and biomarker evaluations were expressed as mean ± standard error (SE), and compared using Student's 't' test, with significance set at $p<0.05$.

Results and Discussion

Distribution and Epidemiological Characteristics of Cardiac Diseases in Dogs

Among the 52 dogs diagnosed with cardiac diseases, dilated cardiomyopathy (DCM) was the most common disorder (46.15%), followed by mitral valve disease (MVD) (38.46%), pericardial effusion/cardiac tamponade (11.53%), and hypertrophic cardiomyopathy (HCM) (3.84%). The predominance of DCM and MVD concurred with previous reports identifying these conditions as the most common acquired cardiac diseases in dogs (Keene *et al.,* 2019; Luis Fuentes *et al.,* 2020). Cardiac diseases were most frequently observed in dogs older than 6 years (59.61%) followed by dogs aged 3-6 years (34.61%). Breed-wise, Labrador Retrievers were most commonly affected (50%) followed by German Shepherds (13.46%), non-descript dogs (11.53%), Golden retriever and Doberman Pinscher (5.76% each) and others, whereas, Male dogs (82.69%) showed a higher incidence than females (17.30%). Similar age, breed, and sex distributions have been reported previously suggesting that

advancing age, breed predisposition, and sex-related factors may influence the occurrence of canine cardiac diseases (Schrope, 2015; Creevy *et al*., 2022; Rajkumar and Kamran, 2025).

History and Clinical Signs in Cardiac Diseases

Exercise intolerance (92.3%), dyspnea (88.5%), weakness (86.5%), and inappetence (67.3%) were the most common clinical signs observed in dogs with cardiac diseases. Weight loss (63.5%) and abdominal enlargement (53.8%) were also frequently recorded, whereas coughing (44.2%), vomiting (23.1%), and syncope (17.3%) were less common. These manifestations are consistent with reduced cardiac output, impaired tissue perfusion, pulmonary congestion and venous stasis associated with cardiac dysfunction. Similar clinical findings have been reported in dogs with degenerative mitral valve disease, dilated cardiomyopathy and congestive heart failure (Keene *et al*., 2019; Luis Fuentes *et al*., 2020).

Vital Parameters in Cardiac Diseases

Dogs with cardiac diseases exhibited significantly ($p<0.001$) higher heart rate and respiratory rate compared with healthy controls, whereas rectal temperature remained within the physiological range and did not differ significantly between groups (Table 1). The observed tachycardia and tachypnea likely reflect compensatory sympathetic activation, reduced cardiac output and pulmonary congestion. Similar observations have been reported in canine patients with chronic valvular heart disease and congestive heart failure (Keene *et al.,* 2019; Luis Fuentes *et al.*, 2020).

Table 1: Vital parameters in cardiac diseases (Mean ± SE)

Parameters	Control (n=6)	Treatment (n=52)
Temperature (°F)	101.33 ±0.247	101.79 ±0.123
Heart rate (bpm)	112.83 ±6.263*	173.35 ±5.304*
Respiration rate (rpm)	23.17 ±1.167*	47.56 ±1.994*

*Significant difference at $p<0.001$

Cardiovascular Findings in Dogs

The most common cardiovascular abnormalities included tachycardia (86.53%), pale conjunctival mucosa (75.0%), cardiac murmurs (65.38%), weak pulse or pulse deficits (65.38%), ascites (53.84%), jugular venous distension (34.61%), pedal edema (23.07%) and muffled heart sound on auscultation (19.23%). Other less common symptoms were congested conjunctival mucosa, pulsus paradoxus, bounding pulse/wiry, and Murmurs on auscultation. These findings are indicative of impaired cardiac performance, reduced peripheral perfusion, valvular insufficiency and congestive heart failure. Similar clinical abnormalities have been described in dogs with myxomatous mitral valve disease, dilated cardiomyopathy and right-sided heart failure (Keene *et al*., 2019).

Electrocardiographic Findings in Cardiac Diseases

Electrocardiographic evaluation revealed atrial fibrillation (30.76%) and sinus tachycardia (25.00%) as the most common rhythm abnormalities in dogs with cardiac diseases. Among waveform alterations, P mitrale (40.38%), tall R wave (>3 mV) (34.61%) and low-voltage QRS complexes/electrical alternans (19.23%) were the predominant findings (Table 2). The frequent occurrence of atrial fibrillation (Fig. 1) and P mitrale (Fig. 2) was consistent with left atrial enlargement observed on echocardiography and may reflect advanced valvular or myocardial disease as previously reported in dogs with myxomatous mitral valve disease and dilated cardiomyopathy (Keene *et al*., 2019; Na *et al*., 2021; Guglielmini *et al*., 2023). Tall R waves (Fig. 3) were compatible with left ventricular enlargement, whereas low-voltage QRS complexes and electrical alternans (Fig. 4) were suggestive of pericardial effusion or altered cardiac electrical activity, findings that have been documented in canine cardiac disorders associated with ventricular remodeling and pericardial disease (Luis Fuentes *et al*., 2020; Ogawa *et al*., 2022). These findings highlight the utility of ECG in detecting rhythm disturbances and providing supportive evidence of cardiac chamber enlargement in dogs with cardiac diseases, corroborating previous reports on electrocardiographic alterations in canine heart disease (Na *et al*., 2021; Ogawa *et al*., 2022; Arcuri *et al*., 2024).

Table 2: ECG findings in various canine cardiac diseases

Sr. No.	ECG findings	Frequency (n=52)	
		No.	%
I Rhythm			
1	Sinus tachycardia	13	25.00
2	Atrial fibrillation	16	30.76
3	Ventricular premature complexes	03	5.76
4	Atrial premature complexes	02	3.84
5	Sinus arrest	02	3.84
II Complex morphology			
1	P pulmonale	03	5.76
2	P mitrale (Bifid wave)	21	40.38
3	R wave (>3mV)	18	34.61
4	Wide QRS complex	03	5.76
5	Low voltage QRS complex/ electrical alterans	10	19.23
6	ST coving/ depression	05	9.61
7	Deep Q wave	04	7.69
8	Prolonged PR interval	03	5.76
9	J wave	03	5.76

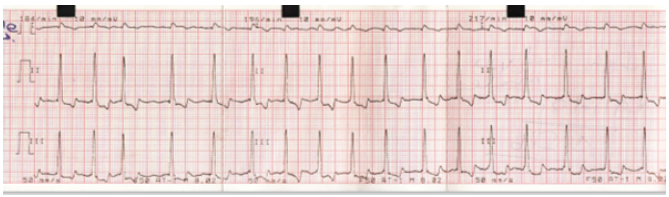


Fig. 1: Electrocardiogram showing atrial fibrillation in a dog with cardiac disease.



Fig. 2: Prolong Bifd P wave suggestive of Left atrial enlargment pattern in dog.

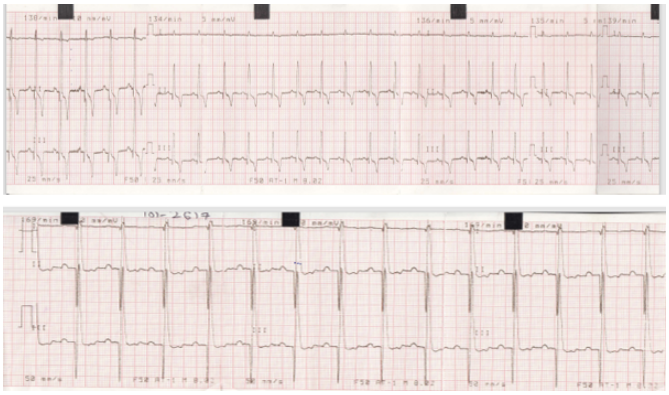


Fig. 3: Deep Q wave, peak R wave and ST coving with sinus tachycardia suggestive of DCM in dog.



Fig. 4: Low voltage QRS complex and electrial alterans suggestive of pericardial effusion in dog.

Haemato-Biochemical Alterations in Cardiac Diseases

Dogs with cardiac diseases showed a mild reduction in haemoglobin, packed cell volume, and erythrocyte count compared with healthy controls, indicating mild anaemia associated with chronic cardiac dysfunction. Total leukocyte count was significantly increased and accompanied by neutrophilia and lymphopenia (Table 3). These alterations may be attributed to systemic inflammation, stress response, impaired tissue perfusion and haemodilution associated with cardiac disease. Similar haematological findings have been reported in dogs with cardiac disorders by Bodh *et al.* (2016) and Hamilton-Elliott *et al.* (2018). Although non-specific, these haematological changes provide supportive evidence of systemic involvement in canine cardiac disease.

Table 3: Mean (±SE) haemato-biochemical values in dogs with cardiac diseases and healthy controls

Parameters	Control (n=6)	Cardiac diseases (n=52)
Hb (g/dL)	11.57±0.48	10.79±0.28
PCV (%)	36.49±1.03	33.18±0.94
RBC (10^6/µL)	5.85±0.18	5.23±0.09
WBC (10^3/ µL)	11066±912	14301±936
Neutrophils (%)	70.66±0.71	74.75±1.34
Lymphocytes (%)	22.50±0.76	19.78±1.23
Eosinophils (%)	2.30±0.33	2.11±0.13
Monocyte (%)	4.50±0.56	3.32±0.26
BUN (mg/dL)	25.66±2.37	44.39±4.28
Creatinine (mg/dL)	0.61±0.05	0.72±0.06
Total protein (g/dL)	6.35±0.24	6.17±0.13
Albumin (g/dL)	2.97±0.06*	1.65±0.05*
ALT (IU/L)	47.17±4.61	44.46±3.45
AST(IU/L)	27.17±4.80	27.03±1.31

*significant difference at p<0.001

Dogs with cardiac diseases exhibited significantly higher BUN concentrations and lower serum albumin levels than healthy controls (Table 3). The increased BUN may be attributed to reduced renal perfusion and secondary renal involvement associated with cardiac dysfunction, whereas hypoalbuminemia could result from haemodilution, congestive hepatopathy, or chronic disease-related nutritional impairment. Similar biochemical alterations have been reported in dogs with cardiac disorders by Rubio *et al.* (2020) and Bodh *et al.* (2016). Serum creatinine showed a mild increase, while total protein, ALT, and AST did not differ significantly between groups. These findings suggest that biochemical changes in canine cardiac disease primarily reflect secondary renal and metabolic consequences of cardiovascular dysfunction.

Cardiac Biomarkers in Cardiac Diseases

Cardiac biomarkers showed marked alterations in dogs with cardiac diseases. Cardiac troponin-I (cTnI) was positive in 70% of affected dogs but was undetectable in healthy controls, indicating myocardial injury and cardiomyocyte damage. Similarly, serum NT-proBNP concentration was significantly (p<0.001) higher in diseased dogs than in controls (527.46 ±29.38 vs. 226.34 ±32.95 pg/mL) reflecting increased myocardial wall stress and cardiac remodelling. These findings were consistent with previous studies that identified cTnI as a sensitive marker of myocardial injury and NT-proBNP as a reliable indicator of cardiac dysfunction and heart failure severity in dogs (Oyama *et al*., 2008; Winter *et al.,* 2017). The results support the diagnostic utility of both biomarkers as adjuncts to ECG and echocardiography in the assessment of canine cardiac diseases.

Echocardiographic Findings in Cardiac Diseases

Echocardiographic examination revealed distinct structural and functional alterations in dogs with dilated cardiomyopathy (DCM) (Fig. 5) and mitral valve disease (MVD) (Fig. 6, 7). Dogs with DCM showed significant ventricular dilatation, characterized by increased LVIDd and LVIDs accompanied by reduced ejection fraction (EF) and fractional shortening (FS) indicating severe systolic dysfunction (Table 4) (Fig. 8). Increased EPSS further supported impaired myocardial contractility. These findings are characteristic of DCM and reflect progressive ventricular remodeling and reduced pump function (Luis Fuentes *et al*., 2020). In contrast, dogs with MVD exhibited marked left atrial enlargement, evidenced by increased left atrial diameter and LA/Ao ratio, together with moderate reductions in EF and FS (Table 4) (Fig. 9, 10). These changes were consistent with chronic volume overload secondary to mitral regurgitation and represent recognized echocardiographic features of myxomatous mitral valve disease (Keene *et al*., 2019; Oyama *et al*., 2023). Overall, echocardiography proved valuable in differentiating DCM from MVD by identifying disease-specific structural and functional abnormalities and remains the cornerstone for the diagnosis and assessment of canine cardiac diseases.

Table 4: Mean (±SE) echocardiographic parameters in dogs with cardiac diseases and healthy controls

Parameters	Control (n=6)	DCM (n=24)	MVD (n=20)
IVSd (cm)	0.87±0.04	0.64±0.03	0.66±0.04
LVDd (cm)	3.22±0.26	5.54±0.13*	5.14±0.25*
LVPWd (cm)	0.79±0.07	0.59±0.04	0.62±0.05
IVSs (cm)	1.19±0.09	0.71±0.04*	0.87±0.07
LVDs (cm)	2.18±0.21	4.62±0.15*	4.13±0.26*
LVPWs (cm)	1.20±0.06	0.81±0.05*	0.95±0.06
EF (%)	61.50±1.39	34.87±1.96*	43.10±3.42
FS (%)	32.80±1.50	17.06±1.13*	19.63±1.64*
LA (cm)	2.38±0.07	4.12±0.14*	3.93±0.20*
Ao (cm)	2.18±0.03	2.04±0.09	1.90±0.06
LA/Ao ratio	1.08±0.01	2.17±0.07*	2.22±0.16*
EPSS (cm)	0.40±0.02	1.60±0.13*	0.63±0.04

*significant difference at p<0.01



Fig. 5: RPLAX echocardiographic view demonstrating enlargement of all four cardiac chambers in a dog with DCM.



Fig. 6: Echocardiographic image showing pericardial effusion in a dog.

Conclusions

Dilated cardiomyopathy and mitral valve disease were the most frequently diagnosed cardiac disorders in dogs presented to the Veterinary Clinical Complex, Kamdhenu University, Navsari, Gujarat. Exercise intolerance, dyspnea and weakness were the predominant clinical manifestations. ECG was useful for identifying rhythm disturbances and chamber enlargement patterns, while echocardiography effectively differentiated structural and functional abnormalities associated with dilated cardiomyopathy and mitral valve disease. Haemato-biochemical alterations mainly reflected secondary systemic effects of cardiac dysfunction. Cardiac biomarkers, particularly NT-proBNP and cardiac troponin-I, demonstrated significant diagnostic value in detecting myocardial injury and cardiac stress. The findings of this study highlight the complementary role of clinical examination, ECG, echocardiography and cardiac biomarkers in the accurate diagnosis and assessment of canine cardiac diseases and support their routine use in veterinary clinical practice.

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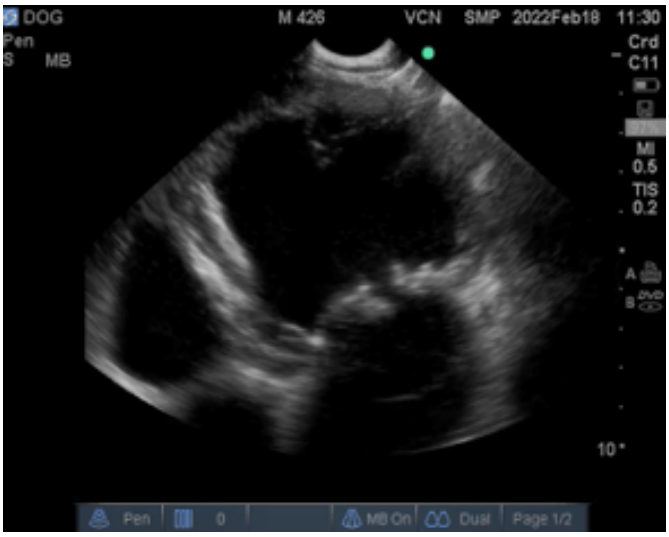


Fig. 7: Echocardiographic image showing leaflets due to myxomatous mitral valve disease in a dog.



Fig. 8: Echocardiographic image showing an increased left atrial-to-aortic root ratio (LA/Ao), indicative of left atrial enlargement in a dog.

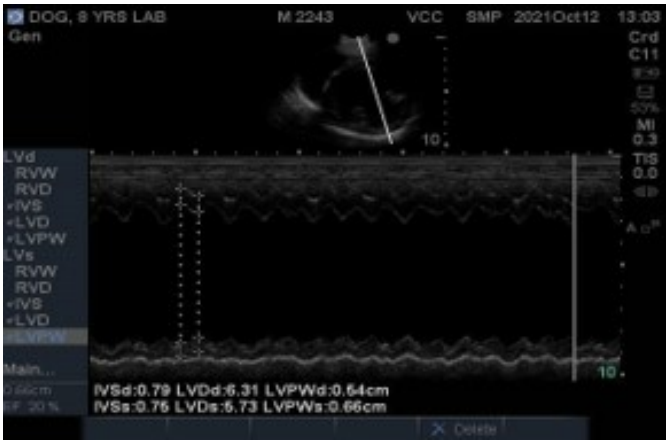


Fig. 9: M-mode echocardiogram showing decreased ejection fraction (EF) and fractional shortening (FS) in a dog with dilated cardiomyopathy (DCM).

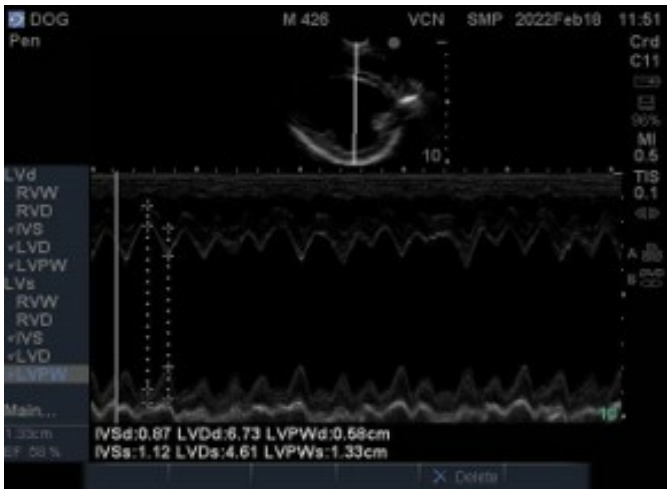


Fig. 10: M-mode echocardiogram showing left ventricular hyperkinesis in a dog with mitral valve disease (MVD).

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