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Comparative clinico-pathological studies in occult and overt cardiomyopathies in dogs#

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Abstract

Dilated cardiomyopathy (DCM), the primary myocardial disease, is the second most prevalent acquired cardiac condition in dogs after mitral valve disease. Although overt forms characterised by prominent clinical signs are typically easier to diagnose, occult cardiomyopathy (OCM) cases with no clinical symptoms, remain less recognised and inadequately researched. This study aimed to identify and analyse both occult and overt forms of cardiomyopathy in dogs, comparing their clinical and pathological features with a healthy control group. Eight dogs with clinical diagnosis of overt DCM, displaying signs of congestive heart failure and eight dogs with electrocardiographic and echocardiographic changes indicative of DCM without clinical symptoms were selected. Dogs with overt DCM exhibited signs of visceral and pulmonary congestion, while a soft systolic cardiac murmur was the only clinical sign observed in dogs with OCM. The OCM dogs showed a significantly elevated respiratory rate, whereas overt DCM dogs exhibited elevated values for all physiological parameters except temperature. Most haematological parameters indicating anaemia were significantly lower in overt DCM dogs, while only VPRC levels showed a significant decrease in OCM dogs. Hypocalcaemia in overt DCM was the only serum biochemical abnormality identified in both forms of cardiomyopathy. Serum alterations of thyroid hormones were not associated with occurrence of cardiomyopathies. Among cardiac markers studied, serum CK-MB did not reveal any significant changes in either OCM or DCM, while elevated NT proBNP levels, well above the cut off was noticed in OCM but not in DCM making it as more reliable cardiac marker for OCM.

Keywords: *Cardiomyopathy, DCM, occult, OCM*

Mammalian heart is considered as the muscular pump of the closed circulatory system and it is the first organ to become functional during the embryonic development (Majkut and Discher, 2012). It is estimated that 10 to 15 per cent of dogs suffer from some form of cardiovascular disease (Hoque *et al.,* 2019). Cardiomyopathy in dogs is defined as a primary myocardial disease of unknown origin, characterized by reduced contractility and dilated chambers, often affecting the left or both ventricles (O'Grady and O'Sullivan, 2004), in the absence of coronary artery disease, hypertension, valvular heart disease and congenital heart disease sufficient to cause the observed myocardial abnormality (Alvarez *et al.,*

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2017). Dilated cardiomyopathy (DCM) was reported to be the common phenotype of cardiomyopathies in dogs and is regarded as the most common cause of congestive heart failure (CHF) and sudden cardiac death (SCD) in mid-sized and large breed dogs (Tidholm *et al.,* 2001) since its first report in 1970 (Ettinger *et al.,* 1970). The etiology of DCM in dogs is largely undetermined and is believed to be multifactorial, leading it to be classified as idiopathic (Stern and Meurs, 2017).

Canine DCM progress through distinct chronological stages before reaching the clinical condition marked by signs of CHF, referred to as stage C or overt stage. Stage A is characterised by a heart with normal morphology and electrophysiology, whereas stage B is marked by the presence of morphological or electrical abnormalities without any outward manifestation of clinical symptoms and is referred to as the preclinical or occult cardiomyopathy (OCM) (Wess, 2022). The occult phase typically evolves into the overt stage, characterised by clinical symptoms of heart disease, over a period of 2 to 4 years (Estrada and Maisenbacher, 2014). While diagnosing overt cardiomyopathy with signs of heart failure is straightforward, identifying the occult stage can be more challenging. The overt stage is characterised by a markedly reduced survival time, typically lasting months, weeks, or even days following diagnosis. This short survival time associated with overt DCM prompt veterinary cardiologists to detect the occult stage, as early identification could help prolong lifespan and improve quality of life. Research on the occurrence and clinico-pathological changes of occult cardiomyopathies in dogs remains limited.

Therefore, the current study was conducted to identify and compare the clinico-pathological changes in occult and overt stages of cardiomyopathies in dogs, in order to gain a deeper understanding of the distinguishing pathological changes associated with each form.

Materials and methods

A total of 104 apparently healthy adult dogs, representing various breeds and sexes, with no owner-reported cardiac symptoms, were selected from the K9 squad of the Kerala Police Force and households across 12 districts of Kerala. These dogs underwent 24-hour Holter electrocardiographic (ECG) monitoring, following standard protocols using a three-lead digital Holter ECG analyser and recorder system (TLC 9803) from Contec Medical Systems Co., Ltd., China during the period from January to May 2024. All the Holter ECG tracings were manually examined for identifying ECG abnormalities suggestive of DCM *ie.* a minimum of 100 ventricular premature complexes or VPCs in 24 hours as per Oyama (2016) and tall T waves, wide P waves, deep Q waves, conduction delays and fragmented QRS complexes according to Silvetti *et al.* (2023). Eleven dogs showing at least one ECG change indicative of DCM were selected for further echocardiographic evaluation. Eight dogs with a DCM score of six or more in the scoring system proposed by Dukes-McEwan *et al*. (2003) for OCM were selected as the OCM group. Eight dogs presented to the Teaching Veterinary Clinical Complex at Mannuthy or Kokkalai and diagnosed with the overt form of DCM formed the DCM group. Eight apparently healthy dogs, selected from the screened population with normal findings on Holter monitoring, clinical examination and laboratory tests were selected as the healthy control.

Details regarding chief presenting complaint and salient clinical symptoms were collected by anamnesis. Abnormalities in parameters such as temperature, pulse rate, respiratory rate and capillary refill time were evaluated during the general clinical examination. All the animals were subjected to detailed physical examination, cardiac auscultation, lung auscultation and abdominal palpation with particular focus on cardiovascular system.

Two millilitres of whole blood was collected from the cephalic vein into a vacutainer tube containing tripotassium ethylene diamine tetra acetic acid (K3 EDTA) as anticoagulant for haematological investigation. Haematological parameters were estimated using a three part fully automated haematology analyser (Mythic™ 18 Vet, Orphée SA, Switzerland). Four millilitres of blood was collected from cephalic vein in clot activator vials and serum was separated by centrifugation (1,000 - 2,000 x g) for ten min. Biochemical parameters such as blood urea nitrogen (BUN, mg/dL), creatinine (mg/dL), calcium (mg/dL), alanine transaminase (ALT, IU/L) and alkaline phosphatase (ALP, IU/L) were estimated by a semi-automatic serum biochemical analyser (Master T, Hospitex Diagnostics, Italy) using commercially available biochemical kits supplied by Alpha technologies, Chennai, India as per manufacturer's guidelines. The concentration of serum electrolytes like sodium, potassium and chloride in mmol/L were evaluated by a fully automated serum biochemical analyser (Selectra Pro S Lite, Q-Line Biotech, New Delhi, India) using biochemical kits supplied by Pathozyme diagnostics, Maharashtra, India. Serum total tetraiodothyronine (T4) and triiodothyronine (T3) were estimated by radioimmunoassay using 2470-WIZARD^2 Automatic Gamma Counter (Perkin Elmer Life Sciences, Wallac Oy). Serum levels of creatine kinase-MB was evaluated by immunoinhibition using a fully automated serum biochemical analyser (Selectra Pro S Lite, Q-Line Biotech, New Delhi, India).

In a clot activator vial, two millilitres of blood was collected from cephalic vein, 0.5 to 1.0 ml of serum was separated by centrifugation and stored at - 20°C until further processing. The frozen serum was thawed and NT-pro BNP level was estimated by sandwich ELISA using a BIO-RAD iMark™ microplate reader with canine specific NT-proBNP ELISA kit manufactured by Wuhan Fine Biotech Co., Ltd., Wuhan, China as per manufacturer's guidelines. The data

collected from various observations in the present study were analysed statistically using SPSS Version 24.0. The parameters of the healthy control group, as well as the occult and overt cardiomyopathy groups, were compared using one-way analysis of variance (ANOVA).

Results and discussion

Occurrence of occult cardiomyopathy

The present study diagnosed 7.79 per cent (eight out of 104) of apparently healthy, adult dogs with OCM. Limited amount of research data pertaining to the occurrence of OCM are available in dogs and those studies yielded variable results. A comparable occurrence rate was recorded by Filipejová *et al.* (2024), who diagnosed OCM in 17 out of 232 Weimaraner dogs (7.33 per cent). Higher occurrences were recorded by Oyama *et al.* (2007) in 21 out of 118 (17.80 per cent) client owned mixed breed dogs and Singletary *et al.* (2012) in 73 out of 155 asymptomatic Dobermans (47.10 per cent).

Chief complaint and clinical symptoms of overt DCM

Lethargy, respiratory distress and exercise intolerance were the chief complaints in dogs with DCM and were observed in seven out of eight dogs (87.50 per cent). The other clinical symptoms reported in DCM included, cough in six out of eight dogs (75 per cent), distended abdomen in five dogs (62.50 per cent), cachexia in three dogs (37.50 per cent), limb oedema in two dogs (25 per cent) and syncope in one dog (12.5 per cent). Stage C-DCM dogs with congestive heart failure had signs of visceral and pulmonary congestion such as lethargy, dyspnoea, exercise intolerance, cough, ascites, syncope and weight loss (Dukes-McEwan *et al*., 2003). Clinical symptoms like syncope were not considered specific to DCM and reported to be predominant in some breeds like Boxer (Wess, 2022) as observed in a case in the present study.

Clinical signs

The recorded clinical signs in dogs with occult and overt cardiomyopathies are presented and compared in Fig.1

In dogs with OCM, the only clinical sign identified during clinical examination was a soft systolic cardiac murmur at the left cardiac apex which was present in four out of eight dogs (50 per cent). Although, physical examination of the cardiovascular system in OCM dogs were reported to be normal (McCauley *et al.,* 2020), a soft systolic murmur, often attributed to valvular insufficiency secondary to diastolic enlargement of the cardiac chambers might be commonly observed (Wess, 2022). The predominant clinical signs identified during clinical examination of dogs in DCM group included cardiac murmur in seven out of eight dogs (87.50 per cent), cough, tachypnea and expiratory dyspnea in six dogs (75 per cent), hepatomegaly, ascites and pulmonary crackles in five dogs (62.50 per cent), tachycardia (more than 160 beats/min) and pulse deficit in two dogs (25 per cent), and distension of jugular vein and cyanotic mucous membrane in one dog each (12.5 per cent). A soft, moderate-intensity systolic murmur over the left apex, consistent with mitral regurgitation, with or without gallop sounds was commonly detected during auscultation of the heart in overt DCM dogs (Oyama, 2016; Stern and Meurs, 2017; Wess, 2022).

Ascites in DCM develops due to the accumulation of interstitial fluid in the peritoneum, caused by elevated central venous pressure from increased venous congestion, vasoconstriction and elevated blood volume

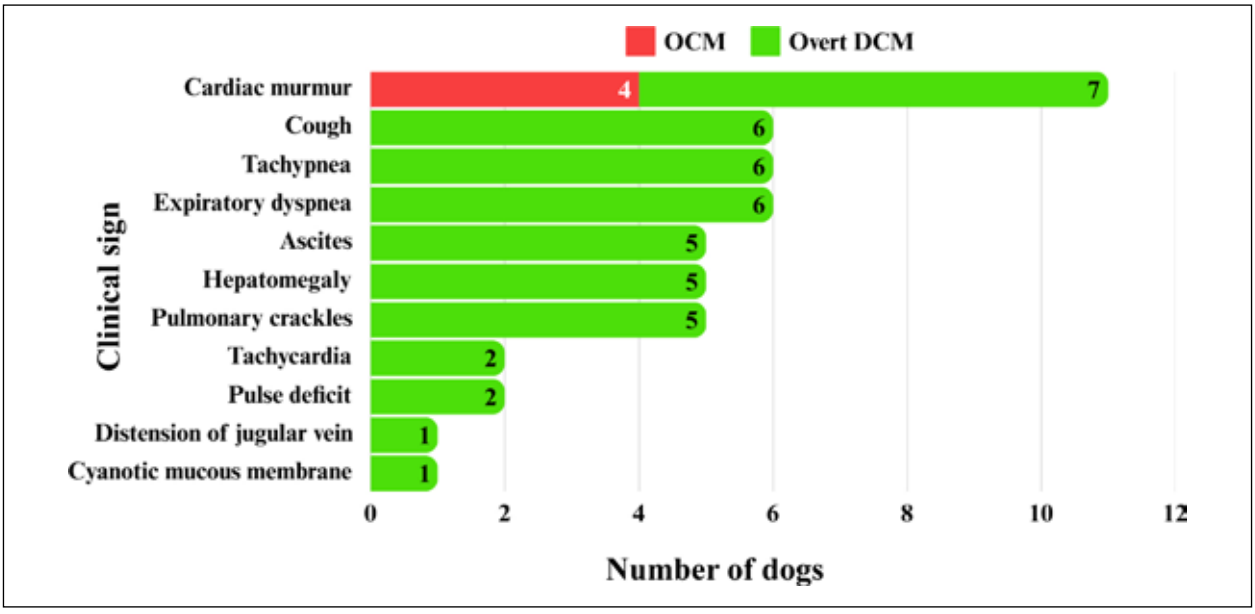

Fig. 1: Clinical signs noticed in dogs with occult and overt cardiomyopathies

due to right-sided CHF (Dori *et al.,* 2023). The primary causes of dyspnoea in cardiac patients were identified as a combination of excessively increased ventilatory demand and the development of restrictive constraints on mechanical ventilation due to pulmonary oedema or pleural effusion (Dubé *et al.,* 2016).

Cough in cardiac patients is not a specific sign and can result from left atrial dilation and main stem bronchus compression (Strickland, 2016) and pulmonary oedema (Oyama, 2016). But some authors concluded that cough might not happen in left atrial dilation and bronchial compression without concurrent tracheobronchial disease (Ferasin, 2017).

Physiological parameters

Observations noticed for various physiological parameters dogs with occult and overt cardiomyopathies are summarized in Table 1.

The only physiological parameter that showed a change in dogs with OCM was a significantly increased ($p<0.05$) respiratory rate (73.86 ± 5.19/min) than that of healthy controls. Schober *et al.* (2010) proposed that respiratory rate could serve as an early diagnostic marker for congestive signs in DCM. Dogs with overt DCM exhibited significant increase in respiratory rate (81.63 ± 11.49/min), heart rate (HR) (134.75 ± 12.79/min), pulse rate (117.13 ± 7.93/min) and capillary refill time (CRT) (1.38 ± 0.08 sec) compared to that of healthy controls. Increase in the heart rate and pulse rates in DCM group has been attributed to sympathetic activation aimed at restoring falling cardiac output (Stern and Meurs, 2017).

Haemogram

The haemogram of dogs with occult and overt cardiomyopathies as well as healthy dogs are presented in table 2.

A significantly decreased ($p<0.01$) volume of packed red cells (VPRC) value was observed in dogs with OCM compared to healthy controls. While in the DCM group, apart from a decrease in VPRC, significant reduction was also noticed in total erythrocyte count (TEC), haemoglobin (Hb), mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) when compared to that of healthy controls.

Anaemia characterised by reductions in parameters such as TEC, Hb and VPRC has been reported

Table 1. Comparison of physiological parameters between healthy control and dogs with occult and overt cardiomyopathies

Parameters	Healthy (n=8)	OCM (n=8)	DCM (n=8)	F-value	P-value
Temperature(°F)	101.66 ± 0.11	101.50 ± 0.24	102.24 ± 0.40	1.96^{ns}	0.167
Heart rate/min	77.25 ± 9.33^{a}	100.43 ± 9.91^{a}	134.75 ± 12.79^{b}	7.365**	0.004
Pulse rate/min	77.25 ± 9.34^{a}	99.57 ± 10.96^{ab}	117.13 ± 7.93^{b}	4.749*	0.021
Respiration rate/min	44.50 ± 5.76^{a}	73.86 ± 5.19^{b}	81.63 ± 11.49^{b}	5.861**	0.010
Capillary Refill time (CRT) (sec)	1.00 ± 0.00^{a}	1.00 ± 0.00^{a}	1.38 ± 0.08^{b}	19.565**	< 0.001

*** Significant at 0.01 level; * Significant at 0.05 level; ns: non-significant*

Means having different letter as superscript differ significantly

Table 2. Comparison of haematological parameters between healthy control and dogs with occult and overt cardiomyopathies

Parameters	Healthy (n=8)	OCM (n=8)	DCM (n=8)	F-value	P-value
TEC ($x10^6/mm^3$)	5.65 ± 0.23^{a}	4.95 ± 0.26^{ab}	4.43 ± 0.45^{b}	3.53*	0.049
Hb (g/dL)	14.88 ± 0.85^{a}	13.31 ± 0.74^{a}	10.04 ± 0.97^{b}	8. 388**	0.002
VPRC (%)	39.38 ± 1.42^{a}	33.00 ± 2.43^{b}	26.50 ± 2.30^{c}	10.075**	0.001
MCV (fL)	67.48 ± 1.24^{a}	67.03 ± 1.55^{a}	60.21 ± 2.51^{b}	4.822*	0.020
MCH (pg)	26.58 ± 0.65^{a}	27.06 ± 0.51^{a}	23.45 ± 1.15^{b}	5.436**	0.013
MCHC (g/dL)	39.34 ± 0.85	40.17 ± 0.62	38.88 ± 0.53	0.879^{ns}	0.431
TLC($x10^3/mm^3$)	8.94 ± 0.51	7.85 ± 0.38	9.66 ± 0.96	1.720^{ns}	0.205
LYMPH (%)	19.75 ± 2.76	27.47 ± 3.51	22.42 ± 2.11	1.904^{ns}	0.175
MON (%)	5.20 ± 0.70	5.05 ± 0.63	4.83 ± 0.52	0.096^{ns}	0.909
GRAN (%)	73.46 ± 3.54	66.57 ± 3.47	72.75 ± 2.54	1.339^{ns}	0.285
PLT ($x10^3/mm^3$)	247.50 ± 36.71	217.14 ± 19.75	183.63 ±16.61	1.522^{ns}	0.243

*** Significant at 0.01 level; * Significant at 0.05 level; ns: non-significant*

Means having different letter as superscript differ significantly

in dogs with overt DCM by several authors (Vishnurahav, 2017; Saikrishna *et al*., 2022 and Athira, 2024). Studies in humans have explained the pathophysiology of anaemia in heart failure as multifactorial, involving erythropoietin deficiency due to concurrent renal insufficiency, the anaemic effects of inflammatory cytokines such as tumour necrosis factors and interleukins, absolute iron deficiency and haemodilution from plasma expansion (Yu and Huang, 2016; Jonaitienė *et al.,* 2021). Rivera *et al.* (2023) identified haematocrit as the most sensitive parameter for discriminating iron-deficient anaemia in a study involving 170 Filipino women. The association between heart failure, renal insufficiency and anaemia has not been extensively studied in dogs, and thus, data from human studies have been extrapolated to explain anaemia in dogs with DCM. Hence, further large scale studies targeting specific risk factors of anaemia in canine DCM are required to confirm the association briefed above.

The present study found similar values for all leukogram parameters and platelet count in both occult and overt cardiomyopathies compared to healthy control dogs. Domanjko Petrič *et al.* (2018) reported that normal leucocyte counts could be observed in dogs with cardiac failure. However, Vishnurahav *et al.* (2017) and Saikrishna *et al.* (2022) recorded increased values for leucocytes and granulocytes in dogs with overt DCM.

Serum biochemistry

The mean ± S.E values of serum biochemical parameters of dogs with occult and overt cardiomyopathies and healthy dogs are presented in the Table 3.

The present study recorded similar values for all serum biochemical parameters between OCM dogs and healthy controls. In DCM dogs, all the parameters except serum calcium was similar to that of healthy controls. Serum calcium was significantly lower ($p<0.01$) in DCM dogs (9.01 ± 0.38 mg/dL) when compared with that of both healthy controls (10.08 ± 0.20 mg/dL) as well as OCM dogs (10.56 ± 0.40 mg/dL).

It is well established that adequate concentration and proper intracellular transport of calcium in myocytes are crucial for cardiac contractility. The amplitude and kinetics of myocardial calcium cycling determine cardiac contractility (Marks, 2013). Therefore, a reduction in intracellular calcium concentration can disrupt normal cardiac myocyte function. Additionally, hypocalcaemia has been identified as a cause of reversible cardiomyopathy in humans (Ari *et al*., 2009; Behaghel and Donal, 2011; Válek *et al*., 2020; Kharel *et al*., 2024; Rupasinghe *et al.,* 2024), and a significant association between serum calcium levels and cardiovascular mortality has been established (Reid *et al*., 2017). However, research on serum calcium and cardiomyopathies in dogs is scarce and hence a larger study is warranted. Hypocalcaemia was identified in a Great Dane that died of cardiomyopathy in India (Shah *et al*., 2020).

The present study reported absence of significant relationship between hypothyroidism and cardiomyopathies as there was no significant difference in concentrations of total T3 and T4 in serum between dogs with OCM, DCM and healthy controls. It was well established that hypothyroidism could produce functional, electrophysiological and rhythm changes over heart (Panciera, 2001). There are reports substantiating evidence for association (Flood and Hoover, 2009) and dissociation (Beier *et al.,* 2015) of hypothyroidism with DCM in dogs and most of the recent studies failed to establish a direct causal relationship of low thyroid levels and DCM in dogs (Kosková *et al.,* 2022). Hence, research data pertaining to the role of hypothyroidism as causal factor for canine DCM were mostly controversial and contradictory as reported by Borgarelli *et al.* (2001).

Table 3. Comparison of serum biochemical parameters between healthy control and dogs with occult and overt cardiomyopathies

Parameters	Healthy (n=8)	OCM (n=8)	DCM (n=8)	F-value	P-value
BUN (mg/dL)	13.63 ± 1.29	12.99 ± 1.06	18.48 ± 4.07	1.312^{ns}	0.292
Creatinine (mg/dL)	1.12 ± 0.06	1.18 ± 0.06	1.23 ± 0.12	0.464^{ns}	0.635
ALT (IU/L)	20.00 ± 1.46	29.98 ± 3.98	37.17 ± 12.49	1.247^{ns}	0.309
ALP (IU/L)	52.81 ± 8.37	52.08 ± 10.08	76.89 ± 12.97	1.769^{ns}	0.196
Sodium (mmol/L)	133.86 ± 2.32	139.00 ± 1.89	134.21 ± 1.85	1.874^{ns}	0.179
Potassium (mmol/L)	3.75 ± 0.20	4.20 ± 0.33	4.17 ± 0.18	1.126^{ns}	0.344
Chloride (mmol/L)	99.16 ± 1.72	102.97 ± 1.40	99.47 ± 1.36	1.866^{ns}	0.181
Calcium (mg/dL)	10.08 ± 0.20^{a}	10.56 ± 0.40^{a}	9.01 ± 0.38^{b}	5.784**	0.010
Total T3 (ng/mL)	1.37±0.18	1.19±0.14	1.39±0.26	0.287^{ns}	0.753
Total T4 (µg/dL)	2.89±0.39	3.12±0.38	2.46±0.19	1.042^{ns}	0.371

*** Significant at 0.01 level; ns non-significant*

Means having different letter as superscript differ significantly

Cardiac markers

Variations noticed in the levels of cardiac markers in serum of dogs with occult and overt cardiomyopathies and healthy dogs are presented in table 4.

Comparable levels of creatine kinase-MB (CK-MB) were observed in healthy dogs and those with occult and overt cardiomyopathies. In all the three groups, the CK-MB values were above the normal population reference range for dogs (4.9–6.3 IU/L), as reported by Montes *et al.* (1987).

Elevated CK-MB levels have been noted in dogs with overt DCM by Vishnurahav (2017) and Haritha *et al.* (2020). However, serum CK-MB is generally considered less useful for diagnosing sub-acute or chronic conditions of myocardial damage, as elevated levels typically return to normal within three days (Loughrey and Young, 2014).

A statistically significant increase ($p<0.05$) in the levels of N-terminal pro b-type natriuretic peptide (NT proBNP) was observed in dogs with OCM when compared with that of control groups. The mean value obtained for OCM dogs was 1087.28 pmol/L. Brain natriuretic peptides (BNP), particularly NT-proBNP, are recognised as the most useful biomarkers for identifying both the occult and overt phases of DCM (Stern and Meurs, 2017). Serum levels ranging from 800 to 1800 pmol/L were associated with a high probability of heart disease in dogs (de Lima and Ferreira, 2017). Wess *et al.* (2011), Singletary *et al.* (2012) and Gordon *et al.* (2022) identified cut-off values of 400, 457 and 548 pmol/L respectively, for detecting OCM in dogs. However, Singletary *et al.* (2012) highlighted that NT-proBNP should not be considered as a definitive diagnostic test parameter for OCM in dogs, nor as a substitute for echocardiography or Holter ECG.

The overt DCM dogs in this study did not show a statistically significant difference in NT proBNP levels compared to healthy controls, although they exhibited a decreased mean value. Significant individual variability in NT proBNP concentrations has been reported in dogs, influenced by factors such as the timing of sample collection, circadian secretion patterns, physical activity at the time of sampling, age, fluid intake, and genetic variation (Kellihan *et al.,* 2009). This variability might have reflected in the higher standard error observed in the present study. While most studies have reported elevated NT proBNP levels in overt DCM (Oyama *et al.,* 2008; Wess *et al.,* 2011; Kumar *et al.,* 2014; Nikitina *et al.,* 2022), decreased NT proBNP levels have been documented in conditions such as pericardial effusion in dogs (Haßdenteufel *et al.,* 2012), reduced blood pressure (Jang *et al.,* 2023), and in specific breeds like Boxer (included in the overt DCM group), compared to Labrador Retrievers and Belgian Malinois (Sjostrand *et al.,* 2014) and in feline hypertrophic cardiomyopathy, even with values as low as 0 pmol/L (Singh *et al.,* 2010), The major contributors of NT proBNP, ventricular myocardium, undergoes marked myocardial remodelling in cardiomyopathy characterised by significant reduction of myocardial mass with increased fibrosis and degeneration of cardiomyocytes (Gasparini *et al.,* 2020) and conditions associated with reduced NT proBNP production have also been reported in humans (Madamanchi *et al.,* 2014). Injured cardiomyocytes from ischaemia, hypertrophy or remodelling may lose the ability to synthesise and secrete BNP and NT proBNP, even under conditions of wall stress. A weak negative correlation between body muscle mass and NT proBNP levels has also been observed (Ha Manh *et al.,* 2023). However, a precise understanding of the relationship between cardiac mass index and NT proBNP production is lacking. Consequently, factors such as reduced functional myocardial mass, breed variability, relatively lower blood pressure and pericardial effusion in overt DCM dogs of current study may have contributed to the reduced NT proBNP levels observed. Moreover, limitations, including a small sample size, variations with regard to breed and age, may also affect the conclusiveness of these findings. Therefore, a larger population study that control for potential confounding factors, such as false positive elevation or fall in NT proBNP levels, are needed with regard to the observations on NT proBNP levels.

Conclusion

The incidence of occult cardiomyopathy (OCM) in the present study was 7.69 per cent. The major clinico-pathological findings in OCM dogs were a soft systolic cardiac murmur, elevated respiratory rate, a low-grade anaemia, normal serum biochemical parameters and normal creatine kinase-MB values. Overt DCM dogs exhibited elevated values for respiratory rate, pulse rate and heart rates along with prolonged CRT values. All the haemato-biochemical values were normal in overt DCM dogs except for a moderate-grade anaemia and hypocalcaemia. NT proBNP values were significantly higher in OCM dogs where as it was normal in overt DCM dogs. Serum level of thyroid hormones was not associated with the occurrence of neither OCM nor DCM in dogs.

Table 4. Comparison of levels of cardiac markers in serum between healthy control and dogs with occult and overt cardiomyopathies

Parameters	Healthy (n=8)	OCM (n=8)	DCM (n=8)	F-value	P-value
Creatine Kinase – MB (IU/L)	27.12±7.07	25.45±4.54	35.00±9.79	0.445^{ns}	0.647
NT proBNP (pmol/L)	$212.69±77.78^{a}$	$1087.28±817.94^{b}$	$123.23±22.19^{a}$	4.559*	0.024

** Significant at 0.05 level; ns non-significant; means having different letter as superscript differ significantly*

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Conflict of interest

The authors declare that they have no conflict of interest.

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