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RESEARCH ARTICLE

Comparative evaluation of cardiac biomarkers and thoracic radiographic findings in dogs suffering from cardio-pulmonary affections

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The objective of this study was to analyse clinical biomarkers and radiographic variability for detecting cardio-pulmonary affections in dogs. The study included two groups: group I (control) with six healthy dogs and group II (affected) with 23 dogs diagnosed with cardio-pulmonary conditions, irrespective of age, breed, and sex. Comprehensive haemato-biochemical analysis assessed parameters such as complete blood count, liver and kidney function tests, and electrolyte levels. Radiographic examinations identified structural and functional abnormalities in the heart and lungs. Group II exhibited significant deviations, including changes in haemoglobin concentration, white blood cell counts, and enzyme activities, along with notable radiographic abnormalities like cardiomegaly, pulmonary oedema, and pleuaral effusion. Integrating haemato-biochemical data and radiographic imaging provided a robust framework for the early detection and diagnosis of cardio-pulmonary diseases in dogs, emphasizing the importance of a multidisciplinary approach in veterinary diagnostics.

Keywords: Biomarkers, Cardio-pulmonary affection, Dogs, Radiographic findings

Cardio-pulmonary affections in dogs are critical health issues that necessitate accurate and timely diagnosis to ensure effective treatment and management. These conditions encompass a broad spectrum of diseases affecting the heart and lungs, including heart failure, pulmonary hypertension, and various cardiomyopathies. Advanced diagnostic tools are essential to improve outcomes for affected dogs. This study focuses on the role of specific clinical biomarkers and radiographic variability in detecting these affections.

Clinical biomarkers provide crucial insights into the pathophysiological processes underlying cardio-pulmonary diseases. Biomarkers such as troponin I, adiponectin, lactate dehydrogenase (LDH), C-reactive protein (CRP), and creatine kinase-MB (CK-MB) have shown promise in diagnosing and monitoring these conditions. Endothelin-1 is a potent vasoconstrictor implicated in pulmonary hypertension and heart failure, indicating vascular endothelial dysfunction (Leuchte *et al.*, 2004). Troponin I is a specific marker of myocardial injury, providing valuable information on cardiac muscle damage (Oyama and Sisson, 2004). NT-proBNP, a peptide released in response to cardiac stress, is widely used to diagnose heart failure and other cardiac conditions (Hsu *et al.*, 2010). Adiponectin, an adipocyte-derived hormone, has anti-inflammatory and cardioprotective properties, with lower levels often associated with heart disease (Ouchi *et al.*, 2003). LDH, an enzyme involved in energy production, can indicate tissue damage and hypoxia in various organs, including the heart and lungs (Johnson *et al.*, 2009). CRP, an acute-phase protein, serves as a marker of systemic inflammation and has been linked to cardiovascular diseases (Yasojima *et al.*, 2001). CK-MB is an isoenzyme of creatine kinase found primarily in cardiac tissue, and its elevation is indicative of myocardial infarction or other cardiac injuries (Adams *et al.*, 1993).

Radiographic imaging complements biomarker analysis by providing a non-invasive means to visualize structural and functional changes in the thoracic cavity. Thoracic radiographs can detect cardiomegaly, pulmonary oedema, pleural effusion, and other abnormalities, offering critical insights into the extent of cardio-pulmonary affections (Gunn-Moore and Moxon, 2020). The integration of biomarker data with radiographic findings enhances diagnostic accuracy, enabling a comprehensive assessment of the patient's health status.

This study aims to evaluate the efficacy of these clinical biomarkers and radiographic variability in detecting cardio-pulmonary affections in dogs. By comparing a control group of healthy dogs with a group of dogs diagnosed with cardio-pulmonary conditions, irrespective of age, breed, and sex, correlation of diagnostic markers with radiographic features is being evaluated that can aid in the early detection and effective management of these diseases in veterinary practice.

Materials and Methods

The present study was conducted on 29 dogs, irrespective of age, breed and sex which were divided into two groups: group I (n=6): Clinically healthy dogs; and group II (n=23): dogs with exercise intolerance, coughing, dyspnea, oedema over the dependent part and confirmed by radiographic examination.

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All the animals were subjected to thorough clinical examination, haematological analysis, serum biochemistry and radiographic examination in order to study the pattern of cardio-pulmonary affections in dogs. The following parameters were evaluated in all the animals.

Haematological analysis

Five milliliters of blood was collected in sterile EDTA vials from the cephalic vein on day 0, 15 and 30 for the analysis of haematological parameters using fully automated haematological analyzer. The haematological parameters estimated in suspected dogs were haemoglobin (Hb), erythrocyte sedimentation rate (ESR), packed cell volume (PCV), total platelet count, total erythrocyte count (TEC), total leukocyte count (TLC) and differential leukocyte count (DLC).

Biochemical analysis

Biochemical analysis was done using ERBA kits through TRANSASIA - ERBA EM 200 automatic serum analyser. The biochemical parameters analysed were serum alanine aminotransferase (ALT), serum aspartate aminotrans-ferase (AST), total plasma proteins (TP), albumin, albumin:globulin ratio, gamma glutamyl transferase (GGT), triglycerides, total cholesterol, blood urea nitrogen (BUN), serum creatinine, lactate dehydrogenase (LDH), sodium ion, potassium ion, calcium ion, magnesium ion and chloride ion.

Biomarker analysis

Three milliliters of blood was collected from the cephalic vein into a centrifuge tube without anticoagulant for separation of plasma and serum. Separated sera samples were stored in aliquots in refrigerator at -20ºC until the batch analyses were performed. The plasma concentrations of adiponectin, LDH and MB fraction of creatine kinase (CK-MB), as well as the serum concentration of cardiac troponin I (cTnI) and C-Reactive Proteins (CRP) were measured using commercially available kits. The kits used for measurement were all species specific.

Radiographic analysis

The x-ray machine (Allengers Medical System Ltd.) was used to take radiographs. The images were captured on Photostimulable Plates (PSP) and processed through digital radiography system (Konica Minolta Pvt. Ltd.) and images were stored in image capture software system. All animals were placed in lateral and ventro-dorsal position without sedation to obtain radiographic images of thoracic region.

Vertebral Heart Scale measurements were taken according to the protocol established by Buchanan and Bucheler (1995). The Cardio-thoracic ratio (CTR) was assessed by comparing the greatest width of the heart silhouette and the distance between the thoracic walls at height T8, according to methodology described by Hasan *et al*. (2012). Cardiac roundness was evaluated by calculating the Sphericity Index (SI). This was achieved by determining the ratio between the maximal long axis and the maximal short axis of the cardiac silhouette, measured using the vertebral heart score (VHS) system. Measurements were taken from both the lateral and ventrodorsal thoracic radiographic views to obtain the lateral SI and ventrodorsal SI, respectively. The global SI was then represented by the mean of the lateral and ventrodorsal SI values (Guglielmini *et al*., 2014).

Results and Discussion

The prominent clinical findings recorded in animals of group II were respiratory distress (n=18, 78.26%), pale mucous membrane (n=6, 26.08%), systolic murmur (n=4, 17.39%), tachycardia (n=2, 8.69%), ascites (n=2, 8.69%), muffled heart sound (n=2, 8.69%) followed by pericardial effusion (n=1, 4.34%) and pleural effusion (n=2, 8.69%). Guglielmini (2003) also reported findings such as jugular pulses, irregular heart rhythm, weak pulses, pulse deficits, and a systolic murmur with a point of maximum intensity at the left sixth intercostal space in dogs with cardiomyopathies. According to Kulka *et al*. (2017), the progression of chronic mitral valve disease (CMVD) in dogs leads to mitral valve regurgitation during systole, causing heart murmurs over the mitral valve area and, in severe cases, congestive heart failure (CHF), which accounts for 75% of CHF causes. O'Shaughnessy *et al*. (2021) reported that heart murmur, coughing, and panting were the most common clinical findings at the time of NT-proBNP measurement in dogs. Sisson (2010) indicated that fluid accumulation occurs due to systemic venous congestion secondary to right-sided heart failure.

The haematology profiles for dogs affected with cardio-pulmonary affection are presented in table 1. There was a significant (P<0.05) decrease in the mean values of lymphocytes in group II (22.26±2.05) when compared to group I (30.16±2.32). The value of neutrophils (%) showed non-significant increase from group I to group II. A significant (P<0.05) increase in the mean value of monocyte was observed in group II in comparison to group I. There were no significant differences observed in the haematological parameters between healthy dogs and those with cardiopulmonary conditions in the current study. The present findings fit with findings in human patients indicating that the prevalence of anaemia comorbidity with heart failure (HF) increases with increasing severity of New York Heart Association (NYHA) functional status and that anaemia is a prognostic factor for mortality as suggested by Silverberg *et al*. (2003). However, Farabaugh *et al*. (2004) reported significantly lower levels of haematocrit and haemoglobin, and higher counts of leukocytes, neutrophils, and platelets in dogs with congestive heart failure (CHF) compared to healthy dogs, particularly noting elevated platelet counts, which contradicts the findings of the present study. The probable reason for changes in the haema-

Table 1: Haematological values in dogs with cardio-pulmonary affections (Mean±SE).

Sl. No.	Parameter	Group I	Group II
1.	Hb (g/dL)	11.13±0.66	10.17±0.75
2.	TLC (x1000/cu mm)	10.84±1.74	15.62±1.60
3.	Lymphocyte (%) *	30.16±2.32a	22.26±2.05b
4.	Neutrophil (%)	65.66±2.17	70.73±1.95
5.	Monocytes (%) *	2.16±0.60a	4.34±0.69b
6.	Eosinophil (%)	2.00±0.73	1.04±0.47
7.	ESR (mm/hr)	16.00±2.69	16.95±0.89
8.	PCV (%)	37.02±2.52	32.88±1.97
9.	TEC (million/cu mm)	6.84±0.53	5.76±0.28
10.	Total Platelets Count (x1000/cmm)	361.16±28.47	278.47±35.92

Means with different superscripts vary significantly; * P≤ 0.05; **P≤0.01

Table 2: Biomarker values of dogs with cardio-pulmonary affections (Mean±SE).

Sl. No.	Parameter	Group I	Group II
1.	Adiponectin (ng/mL) **	0.24±0.05a	1.34±0.41b
2.	CK-MB (pg/mL)	13.48±4.79	22.64±5.47
3.	CRP (mg/L)	0.25±0.20	0.07±0.01
4.	LDH (pg/mL)	9.81±1.41	13.35±3.30
5.	Troponin-I (ng/mL) **	0.08±0.02a	0.31±0.05b

Means with different superscripts vary significantly; * P≤ 0.05; **P≤0.01

Table 3: Thoracic radiographic values in dogs with cardio-pulmonary affections (Mean±SE)

Sl. No.	Parameter	Group I	Group II
1.	Vertebral Heart Score(VHS)	9.83±0.30	10.09±0.74
2.	Cardiothoracic Ratio(CTR)	48.67±2.21	45.61±3.25
3.	Lateral Cardiac Sphericity Index (LCSI)	1.00±0.00	0.91±0.06
4.	Ventro-Dorsal Cardiac Sphericity Index (VCSI)	1.00±0.00	0.96±0.07
5.	Global Cardiac Sphericity Index (GCSI)	1.00±0.00	0.91±0.06

Means with different superscripts vary significantly; * P≤ 0.05; **P≤0.01

tology parameters could be related to enhanced corticosteroid production or other neurohormonal alterations that occur in heart failure and many cases of CHF may present with a stress leukogram and an elevated leukocyte count as stated by Ristic (2004).

The findings of this study are in concurrence with those of Kumar *et al*. (2010), Kumar *et al*. (2016) and Kulka et al. (2017) have also observed no significant alterations in the complete blood count of dogs with hypertrophic cardiomyopathy (HCM) and various stages of cardiomyopathies as suggested by American College of Veterinary Internal Medicine (ACVIM). Although dogs with cardiopulmonary conditions in the current study exhibited lower levels of haemoglobin, erythrocyte count, and packed cell volume compared to healthy dogs, these differences were not statistically significant. Similar trends were observed by Martin *et al*. (2009) and Sesh *et al*. (2013) who suggested that the decreased packed cell volume in CHF dogs with dilated cardiomyopathies (DCM) may be attributed to fluid retention causing haemodilution. Macdonald *et al*. (2009) documented thrombocytopenia in 13.3% of dogs with pericardial effusions. Significant differences were noted in the counts of monocytes and lymphocytes between healthy dogs and those with cardiopulmonary conditions, consistent with the patterns reported by Sesh *et al*. (2013). Mazzotta *et al*. (2016) also observed a noteworthy increase in the total leukocyte count associated with pulmonary arterial hypertension (PAH), possibly due to an inflammatory response linked to anisocytosis in PAH or stress induced by the disease and hospitalization. Jan *et al*. (2018) observed a non-significant decrease in haemoglobin, total erythrocyte count, and packed cell volume in geriatric dogs with heart failure compared to healthy geriatric dogs of the same age.

The biomarker mean values of dogs with cardio-pulmonary affections were depicted in table 2. The mean values of CK-MB and LDH showed non-significant increase in group II than in group I. However, the mean values of CRP showed non-significant decrease in group II as compared to group I. Adiponectin can slow the progression of cardiovascular diseases such as cardiac hypertrophy, ischemic injury, and atherosclerosis in humans (Hopkins *et al*., 2007; Goldstein *et al*., 2009). In dogs, dilated cardiomyopathy is linked to elevated adiponectin concentrations compared to both healthy dogs and those with MMVD. However, no significant difference in adiponectin concentration was observed between dogs with MMVD and healthy dogs (Damoiseaux *et al*., 2014). Adiponectin showed a highly significant increase (P<0.01) in diseased populations compared to healthy controls. Contrary to these findings, Kim *et al*. (2016) reported significantly lower concentrations of adiponectin in dogs with MMVD (P=0.0009). They also noted that serum adiponectin concentrations were significantly lower in ISACHC class 1 dogs (P <0.0001) than in healthy dogs, while concentrations in ISACHC class 3 dogs were significantly higher than in ISACHC class 1 dogs (P=0.0081). In humans, a stepwise increase in adiponectin with increasing heart failure (HF) severity has been described by George *et al*. (2006) and Szabó *et al*. (2014). Recent studies have also shown an association between increased serum adiponectin concentrations and a higher risk of mortality in HF patients (Szabó *et al*., 2014). In humans, CRP functions as a mediator of inflammation and an indicator of phlogosis. It has been analyzed in relation to atherosclerosis, coronary artery disease (CAD), acute coronary syndromes, and heart failure (HF), and is now considered to play a role in the development and progression of HF (Ridker, 2003; Ceron *et al*., 2005; Liquori *et al*., 2014). There was no significant change in the mean values of Vertebral Heart Score, Cardiothoracic Ratio, Lateral Cardiac Sphericity Index, Ventro-Dorsal Cardiac Sphericity Index and Global Cardiac Sphericity Index in group I and group II (Table 3). However, pneumonic changes, rounding of heart, ascites and sternal alignment were also prominent in affected dogs. Thoracic radiographic findings of the present study were cardiomegaly, pulmonary oedema (hypervascularisation of lungs), elevated trachea, reverse D shaped heart and prominence of the left atrium. Along with this, one case of pericardial effusion was aspirated under ultrasonographic guidance at the level of 4th-6th intercoastal space. The aspirated serosanguinous fluid was subjected to laboratory estimation, where the pH of given sample was found to be 7 with trace amount of glucose and protein content of +++. Microscopic examination showed abundant RBCs throughout the field. Culture sensitivity testing of the sample confirmed the presence of *Staphylococci* and *Streptococci* spp.

The prominent thoracic radiographic findings of the present study were cardiomegaly (93.75%), pulmonary oedema (hypervascularisation of lungs), elevated trachea and prominence of the left atrium. In a previous study of Lord and Suter (1999), an increase in sternal contact was considered to reflect only right ventricular enlargement, but Carlsson *et al*. (2009) demonstrated that the increase in sternal contact may be affected by both left and right ventricular enlargement. Cardiogenic pulmonary oedema was also reported by Myreng and Smiseth (1990) and Ohno *et al*. (1994), who suggested that its development is largely due to the magnitude of volume overload, leading to increased left ventricular filling pressure (LVFP). All the above findings on thoracic radiographs are often the hallmarks for radiographic diagnosis of cardiac diseases in dogs (Root and Bahr, 2002). The pulmonary artery or vein becomes enlarged depending on the cardiac diseases such as the enlarged pulmonary artery found in pulmonary hypertension and venous congestion in mitral regurgitation (Hamlin, 2005). The pericardial effusion observed in the present study is consistent with the findings of Tappin (2010), who reported that thoracic radiography is useful in detecting large-volume pericardial effusions, typically presenting as a markedly enlarged cardiac silhouette and elevation of the trachea. Such effusions may be idiopathic (Mellanby *et al*., 2002) or of unknown etiology (Gugjoo *et al*., 2014).

In conclusion, cardiac biomarkers are highly effective for early screening and identifying subclinical cardiac disease, as they provide information regarding the metabolic and myocardial dysfunctions of the heart. The elevated biomarker levels observed in all dogs of the diseased group further support their value in detecting underlying cardiopulmonary disorders. Although echocardiography offers unparalleled detailed visualization of cardiac structure and function, its requirement for specialized expertise, along with the higher cost associated with biomarker estimation, can limit their routine use. Thus, thoracic radiography emerges as a simple, accessible, and practical technique for the preliminary assessment of cardiac status in canine patients.

References

Adams, J.E., Sicard, G.A., Allen, B.T., Bridwell, K.H., Lenke, L.G., Dávila-Román, V.G. and Jaffe, A.S. 1993. Diagnosis of perioperative myocardial infarction with measurement of cardiac troponin I. New Eng. J. Med. **330**: 670-674.

Buchanan, J.W. and Bucheler, J. 1995. Vertebral scale system to measure canine heart size in radiographs. J. Am. Vet. Med. Assoc. **206**: 194-199.

Carlsson, C., Häggström, J., Eriksson, A., Järvinen, A.K., Kvart, C. and Lord, P. 2009. Size and shape of right heart chambers in mitral valve regurgitation in small-breed dogs. J. Vet. Int. Med. **23**: 1007-1013.

Ceron, J.J., Eckersall, P.D. and Martinez-Subiela, S. 2005. Acute phase proteins in dogs and cats:

Current knowledge and future perspectives. Vet. Clin. Pathol. **34**: 85-89.

Damoiseaux, C., Merveille, A.C., Krafft, E., Da Costa, A.M., Gomart, S., Jespers, P., Michaux, C., Clercx, C., Verhoeven, C. and McEntee K. 2014. Effect of physiological determinants and cardiac disease on plasma adiponectin concentrations in dogs. J. Vet. Int. Med. **28**: 1738-1745.

Farabaugh, A.E., Freeman, L.M., Rush, J.E. and George, K.L. 2004. Lymphocyte subpopulations and hematologic variables in dogs with congestive heart failure. J. Vet. Int. Med. **18**: 505-509.

George, J., Patal, S., Wexler, D., Sharabi, Y., Peleg, E., Kamari, Y., Grossman, E., Sheps, D., Keren, G. and Roth, A. 2006. Circulating adiponectin concentrations in patients with congestive heart failure. Heart **92**: 1420-1424.

Goldstein, B.J., Scalia, R.G. and Ma, X.L. 2009. Protective vascular and myocardial effects of adiponectin. Nature Clin. Pract. Cardiovasc. Med. **6**: 27-35.

Gugjoo, M.B., Saxena, A.C., Hoque, M., Mahendran, K. and Zama, M.M.S. 2014. Pericardial effusion in Labrador Retriever dog. Asian J. Anim. Sci. **8**: 34-37.

Guglielmini, C. 2003. Cardiovascular diseases in the ageing dog: diagnostic and therapeutic problems. Vet. Res. Comm. **27**: 555-560.

Guglielmini, C., Toaldo, M.B., Poser, H., Menciotti, G., Cipone, M., Cordella, A., Contiero, B. and Diana, A. 2014. Diagnostic accuracy of vertebral heart score and other radiographic indices in the detection of cardiac enlargement in cats with different cardiac disorders. J. Feline Med. Res. **16**: 812-825.

Gunn-Moore, D. and Moxon, R. 2020. Radiographic imaging in the diagnosis of canine heart disease. Vet. Radiol. Ultrasound **61**: 245-258.

Hamlin, R.L. 2005. Geriatric heart diseases in dogs. Vet Clin. North Am. Small Anim. Pract. **35**: 597-615.

Hasan, M.A., Lee, S.L., Kim, D.H. and Lim, M.K. 2012. Automatic evaluation of cardiac hypertrophy using cardiothoracic area ratio in chest radiograph images. Comp. Met. Prog. Biomed. **105**: 95-108.

Hopkins, T.A., Ouchi, N., Shibata, R. and Walsh, K. 2007. Adiponectin actions in the cardiovascular system. Cardiovasc. Res. **74**: 11-18.

Hsu, A., Kittleson, M.D. and Pion, P.D. 2010. Evaluation of plasma N-terminal pro-B-type natriuretic peptide concentration in dogs with congestive heart failure. J. Vet. Int. Med. **24**: 962-968.

Jan, A., Wani, S.A., Ashraf, T., Nisar, M., Taifa, S., Parray, O.R. and Nabi, S.U. 2018. Studies on hemato-biochemical, radiological and echocardiographic changes in geriatric canine heart failure. J. Pharmacog. Phytochem. **7**: 1197-1200.

Johnson, S.E., McMullan, D.M. and Noren, G.R. 2009. The role of lactate dehydrogenase in assessing canine heart disease. J. Vet. Cardiol. **11**: 123-131.

Kim, H.S., Kang, J.H., Jeung, E.B. and Yang, M.P. 2016. Serum concentrations of leptin and adiponectin in dogs with myxomatous mitral valve disease. J. Vet. Int. Med. **30**: 1589-1600.

Kulka, M., Garncarz, M., Parzeniecka-Jaworska, M. and Klucinski, W. 2017. Serum paraoxonase 1 activity and lipid metabolism parameter changes in Dachshunds with chronic mitral valve disease: Assessment of its diagnostic usefulness. Polish J. Vet. Sci. **20**: 723-729.

Kumar, K.S., Nagaraj, P., Kumar, V.V.V.A. and Rao, D.S.T. 2010. Hypertrophic cardiomyopathy in 12 dogs (2004-2008): first report in India. Vet. Arhiv. **80**: 491-498.

Kumar, K.S., Srikala, D., Ayodhya, S. and Kumar, V.V.V. 2016. Diagnosis and management of heart failure in dogs- A clinical study. Intas Polivet **17**: 121-128.

Leuchte, H.H., El Nounou, M., Tuerpe, J.C., Hartmann, G., Huber, R.M. and Lohmeyer, K. 2004. N-terminal pro-brain natriuretic peptide and pulmonary hypertension. Am. J. Resp. Crit. Care Med. **170**: 534-539.

Liquori, M.E., Christenson, R.H., Collinson, P.O. and Defilippi, C.R. 2014. Cardiac biomarkers in heart failure. Clin. Biochem. **47**: 327-337.

Lord, P.F. and Suter, P.F. 1999. Radiology. In: Textbook of Canine and Feline Cardiology, Fox, P.R., Sisson, D. and Moise, N.S. (Eds.), 2nd edn. Saunders, Philadelphia. pp 107-129.

MacDonald, K.A., Cagney, O. and Magne, M.L. 2009. Echocardiographic and clinicopathologic characterization of pericardial effusion in dogs: 107 cases (1985-2006). J. Am. Vet. Med. Assoc. **235**: 1456-1461.

Martin, M.W.S., Johnson, M.J.S., and Celona, B. 2009. Canine dilated cardiomyopathy: A retrospective study of signalment, presentation and clinical findings in 369 cases. J. Small Anim. Pract. **50**: 23-29.

Mazzotta, E., Guglielmini, C., Menciotti, G., Contiero, B., Baron Toaldo, M., Berlanda, M. and Poser, H. 2016. Red blood cell distribution width, hematology, and serum biochemistry in dogs with echocardiographically estimated precapillary and postcapillary pulmonary arterial hypertension. J. Vet. Int. Med. **30**: 1806-1815.

Mellanby, R.J., Villiers, E. and Herrtage, M.E. 2002. Canine pleural and mediastinal effusion a retrospective study of 81 cases. J. Small Anim. Pract. **43**: 447-451.

Myreng, Y. and Smiseth, O.A. 1990. Assessment of left ventricular relaxation by Doppler echocardiography. Comparison of isovolumic relaxation time and transmitral flow velocities with time constant of isovolumic relaxation. Circulation **81**: 260-266.

Ohno, M., Cheng, C.P. and Little, W.C. 1994. Mechanism of altered patterns of left ventricular filling during the development of congestive heart failure. Circulation **89**: 2241-2250.

O'Shaughnessy, S., Crawford, I., Arsevska, E., Singleton, D.A., Hughes, D., Noble, P.J., Hezzell, M. 2021. Clinical findings associated with N-terminal pro-B-type natriuretic peptide measurement in dogs and cats attending first opinion veterinary practices. Vet. Rec. e945. https://doi.org/10.1002/vetr.945.

Ouchi, N., Kihara, S., Arita, Y., Maeda, K., Kuriyama, H., Okamoto, Y. and Funahashi, T. 2003. Adiponectin, an adipocyte-derived plasma protein, inhibits endothelial NF-Kappa B signaling through a cAMP-dependent pathway. Circulation **107**: 671-674.

Oyama, M.A. and Sisson, D.D. 2004. Cardiac troponin-I concentration in dogs with cardiac disease. J. Vet. Int. Med. **18**: 831-839.

Ridker, P.M. 2003. Clinical application of C-reactive protein for cardiovascular disease detection and prevention. Circulation **107**: 363-369.

Ristic, J. 2004. Clinical assessment of the dog with suspected cardiac disease. In Pract. 26: 192-199.

Root, C.R. and Bahr, R.J. 2002. The heart and great vessels. In: Textbook of Diagnostic Veterinary Radiology, Thrall, D.E. (Ed.) 4th edn. W.B. Saunders, Philadelphia. pp 402-419.

Sesh, P.S.L., Venkatesan, P., Jeyaraja, K., Chandrasekar, M. and Pandiyan, V. 2013. Blood biochemical, enzymatic and haematological status of dogs affected with dilated cardiomyopathy. Int. J. Adv. Vet. Sci. Technol. **2**: 47-51.

Silverberg, D.S., Wexler, D., Blum, M. and Iaina, A. 2003. The cardio-renal anemia syndrome: Correcting anemia in patients with resistant congestive heart failure can improve both cardiac and renal function and reduce hospitalizations. Clin. Nephrol. **60** (Suppl 1): S93-S102.

Sisson, D. 2010. Pathophysiology of heart failure. In: Textbook of Veterinary Internal Medicine, Ettinger, S.E. and Feldman, F.C. (Eds), 7th edn. W.B. Saunders, Philadelphia. pp 1143-1158.

Szabó, T., Scherbakov, N., Sandek, A., Kung, T., von Haehling, S., Lainscak, M., Jankowska, E.A., Rudovich, N., Anker, S.D., Frystyk, J., Flyvbjerg, A., Pfeiffer, A.F.H. and Doehner, W. 2014. Plasma adiponectin in heart failure with and without cachexia: catabolic signal linking catabolism, symptomatic status, and prognosis. Nutr. Metab. Cardiovasc. Dis. **24**: 50-56.

Tappin, S. 2010. Idiopathic pericardial effusion in a seven-year-old Labrador Retriever. Small Anim. Cardiol. **15**: 22-27.

Yasojima, K., Schwab, C., McGeer, E. G. and McGeer, P.L. 2001. Human heart generates C-reactive protein and amyloid P. Cardiovasc. Res. **52**: 447-454.