

# Use of biomarkers as prognostic indicators in dogs with natural heartworm

<sup>1</sup>Mario de la Puente, <sup>2</sup>Rodrigo De Laval Galvis, <sup>3</sup>Jorge G. Rodríguez, <sup>4</sup>Ariel M. Duarte, <sup>5</sup>Amanda R. Riquett, <sup>6</sup>María de la Puente, <sup>7</sup>María B. Viloría

<sup>1</sup>Research Group I.A, Universidad del Norte, Colombia, <sup>2</sup>Faculty of Veterinary Medicine, University of Cordoba, Colombia, <sup>3</sup>Faculty of Veterinary Medicine, University of Cordoba, Colombia, <sup>4</sup>Faculty of Veterinary Medicine, University of Cordoba, Colombia, <sup>5</sup>Department of Veterinary Medicine, UDCA University, Colombia, <sup>6</sup>Department of Veterinary Medicine, UDCA University, Colombia, <sup>7</sup>Faculty of Biomedical Sciences, Simón Bolívar University, Colombia.

**Abstract.** Heartworm disease is a parasitic illness caused by the *Dirofilaria immitis* nematode. In its developed form, remains in the pulmonary artery and right side of the heart, resulting in pulmonary thromboembolism, myocarditis, and inflammation. A retrospective study was made in which was evaluated the usefulness of the Dimer-D, troponin I and C-reactive protein in sick dogs naturally infected with heartworm. There were evaluated the concentrations of D-Dimer, troponin I and C-reactive protein in 23 dogs, analyzed hematological variables, the presence or absence of microfilariae, the pulmonary hypertension and clinical signs. The respiratory problems were the most frequent clinical signs including dyspnea (74%), cough (30%), pulmonary hypertension (57%), and other signs of inflammation or pulmonary thromboembolism. Hematological changes were not found. Elevations of the Dimer-D were found in 73.9% of cases, where the patients with microfilariae (69.6%) showed higher values compared to amicrofilaremic (30.4%); males had a higher average (3,857.83 ng ml<sup>-1</sup>) compared to females (1,714.0 ng ml<sup>-1</sup>). Troponin I and C-reactive protein had elevations in 21.7 - 39.1% of cases without significant changes compared to sex or microfilariae. The measurement of Dimer-D, troponin I and C-reactive protein complements for the diagnosis, prognosis and therapeutic control in patients with *D. immitis* indicated inflammation, pulmonary thromboembolism and/or myocarditis.

**Key Words:** pulmonary hypertension, acute phase proteins, troponins.

**Copyright:** This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

**Corresponding Author:** M. de la Puente, email: mdelapuate@uninorte.edu.co

## Introduction

Pulmonary thromboembolism (PT) is the formation of clots in the pulmonary arterial circulation (Lynelle et al 1999). Dirofilariasis is also known as heartworm disease and is caused by a parasite of the genus *Dirofilaria immitis*, which in adult phase is located in the pulmonary artery or in its branches (McCall et al 2008). The adult parasite is in contact with the vascular endothelium triggering a proliferative endoarteritis, ending with the production of thrombi; the death of the parasites or fragments of them travel to the smaller branches of the lungs triggering PT, these effects leading to the development of pulmonary hypertension (PH) (Simón et al 2012). The presence of PT and PH causes damage to the myocardium due to volume and pressure overload (Goggs et al 2017).

The use of biomarkers has grown in veterinary medicine, particularly in patients with *D. immitis* (Carretón et al 2011). Troponin I (nTcI), for example is one of the myofibrillar proteins that regulates the interaction of calcium with myosin and actin. Its blood elevation correlates with myocardial injury or myocyte necrosis. It has high specificity and sensitivity as a cardiac biomarker (Darcy et al 2005) (Becattini et al 2007). D-dimer is generated during thrombus formation when the factor XIIIa cross-links the terminal D domains of fibrin (Tracy, 2002). The increase in its concentrations is present in dogs with PT (Epstein et al 2013),

but it should be noted that this increase is not useful in order to verify the formation of clots, due to their low specificity (Nelson et al., 2003) (Janata et al 2003). The C-reactive protein (CRP) is an acute phase protein that helps restore homeostasis and limit bacterial growth independently of antibodies in response to inflammation, infection or trauma (Murata et al 2004) (Kumar et al 2015). These proteins are used for diagnosis, prognosis and therapeutic monitoring; it is highly sensitive, indicating inflammatory processes, but is not very specific (Eckersall et al 2010). It is the most used acute phase protein in dogs and is reported that it alters in the presence of *D. immitis* (Méndez et al 2014). The general objective of the present report was to evaluate the use of cardiopulmonary and inflammatory biomarkers (cTnI, D-dimer and CRP) in dogs infected with *D. immitis* as prognosis in the presentation of PT, myocarditis and inflammation, and to perform an adequate therapeutic plan.

## Materials and methods

The medical records of the Mastervet Veterinary Clinic in the city of Barranquilla (Colombia) were used to perform a retrospective study on patients with heartworm disease from January 2016 to January 2017. During this period, 54 individuals were positive. However, only 23 clinical reports were analyzed, since they included cardiopulmonary and inflammatory biomarkers as

a complement for the diagnosis of PT, myocarditis and inflammation. The parameters that were evaluated included: clinical history, laboratory tests, existence of microfilariae, presence of pulmonary hypertension and survival.

The diagnosis was made through ELISA commercial test that detects circulating antigens (antigen rapid heartworm Ag test kit 2.0, Bionote Laboratories, Republic of Korea) according to the manufacturer's specifications. The presence or absence of microfilariae was evaluated in positive dogs using Knott's modified test. For the diagnosis of PH, the patients underwent echocardiogram with spectral and color Doppler (Mindray Z6Vet) placing them in right lateral recumbency with the transducer placed in the third intercostal space; the reports were carried out by the same person. The age range of the studied individuals was from 2 to 10 years old (mean of 5.26), including 5 females and 18 males.

Blood samples were taken from the jugular or cephalic vein in each patient. For the measurement of cTnI and D-dimer were used red and blue cap tubes, respectively for later analysis in a certified human laboratory in the city. The samples for D-dimer were centrifuged immediately until the plasma was obtained. On the other hand, the blood count was evaluated in an automatic analyzer (Mindray BC-2800Vet) in a purple cap tube. The measurement ranges for cTnI were  $<0.02 \text{ ng ml}^{-1}$  (Oyama *et al* 2004), for D-dimer  $<250 \text{ ng ml}^{-1}$ , where there was evidence of a specificity of 90% and a sensitivity of 80% (Epstein *et al* 2013) and for the CRP  $<12 \text{ mg L}^{-1}$  (Méndez *et al* 2014). The values below these were taken as negative and the values above as positive.

### Statistical analysis

The data collected were tabulated through office Excel 2007, using InfoStat (version 2008 for Windows) for later analysis. It was used descriptive statistics (Mean, proportion and range), and the test of difference between two proportions. The confidence intervals for the different hematological variables, D-dimer tests, CRP and cTnI were estimated between the patients.

## Results

Table 1 shows the percentages and confidence intervals (95%) of the clinical signs that had the patients studied. Highlighting the proportion of depressed individuals with a range from 66 to 97%,

Table 1. Average values of the clinical signs that had patients infected with *D. immitis*

| Clinical signs       | Percentage | CI (95%)     |
|----------------------|------------|--------------|
| Fever                | 35         | (16.0- 57.0) |
| Decay                | 87         | (66.0-97.0)  |
| Dehydration          | 43         | (23.0-66.0)  |
| Cough                | 30         | (13.0-53.0)  |
| Icterus              | 17         | (0.5-39.0)   |
| Dyspnea              | 74         | (52.0-90.0)  |
| Pulmonary heptension | 57         | (34.0-77.0)  |
| Pruritus             | 26         | (10.0-48.0)  |
| Syncope              | 17         | (0.5-39.0)   |
| Microfilariae        | 70         | (47.0-87.0)  |
| Death                | 0.9        | (0.1-28.0)   |

followed by dyspnea with ranges from 52 to 90%. Pulmonary hypertension was diagnosed in 34 to 77% of the population, while dehydration was presented in 23 to 66%. Patients with microfilaraemia had a range from 47 to 87%.

The confidence interval (95%) of the concentration of hematocrit was from 38.29 to 47.77%. Females had average of 39.24%, and males of 44.08%. Hemoglobin and the count of red blood cells had a reliability of 95%, being found within 12.19-5.43 and 15.14  $\text{g dl}^{-1}$  -6.72  $\times 10^{12}$ , respectively. With respect to the leukocyte values, the average was 15.22  $\times 10^9 \text{ L}^{-1}$ . In the differential leukocyte count it was observed an average of 11.46  $\times 10^9 \text{ L}^{-1}$  for neutrophils, 2.45  $\times 10^9 \text{ L}^{-1}$  to lymphocytes and 0.76  $\times 10^9 \text{ L}^{-1}$  for monocytes. Platelet count had a mean of 258.32  $\times 10^9 \text{ L}^{-1}$ . Females had an average of 286.36  $\times 10^9 \text{ L}^{-1}$  and males had an average of 250.53  $\times 10^9 \text{ L}^{-1}$  in the platelet count (Table 2). D-dimer levels were high in 73.9% of the cases, with a mean of 3,391.78  $\text{ng ml}^{-1}$ . Of this increase, 69.6% of the individuals had microfilaremia. Plasma levels of D-dimer in males had a significantly higher mean compared to females (3,857.83 vs 1,714.0  $\text{ng ml}^{-1}$ ). The cTnI values were high in 21.7% of patients with a mean of 0.10  $\text{ng ml}^{-1}$ . Males showed increases in serum levels with a mean of 0.13  $\text{ng ml}^{-1}$ , whereas females remained within the normal 0.01  $\text{ng ml}$ . Finally, the CRP values were high in 39.1% of the individuals; both females and males had increases in their values, with a mean of 47.4  $\text{mg ml}^{-1}$  for males and 36.0  $\text{mg ml}^{-1}$  for females (Table 3). The microfilaremic patients did not show changes compared to the amicrofilaremic individuals for the values of cTnI and CRP.

## Discussion

Few studies have documented the usefulness of Dimer-D, cTnI and CRP for their use in daily clinic. These cardiopulmonary and inflammatory biomarkers are recently used in veterinary medicine for the diagnosis of cardiovascular diseases (Boswood *et al* 2009), and studied in patients with *D. immitis* (Carretón *et al* 2011) experimental mode with myocardial damage and adulticide treatments of patients infected with *D. immitis* (Carretón *et al* 2013b). The measures for the Dimer-D, CRP and cTnI as biomarkers in the diagnosis, prognosis and treatment of lesions caused by the parasite, indicated myocardial damage, TE and inflammation.

The heartworm provoke in the host lesions in the artery and pulmonary parenchyma, triggering PH and PT due to thrombus formation or fragments due to the death of the adult parasites (Bowman *et al* 2009). Patients who had heartworm developed in the initial stages respiratory signs and in the final phase congestive signs, vena cava syndrome or sudden death. Within the respiratory clinical signs it is described coughing as one of the first signs (McCall *et al* 2008); 13 to 53% of the patients had coughing, but there was dyspnea in a greater proportion of individuals with a range from 52 to 90%. Thromboembolism has a poor prognosis and is potentially fatal. The most frequent signs are tachypnea, dyspnea, and depression. Other signs may be hemoptysis, cyanosis, syncope, collapse and sudden death (Goggs *et al* 2017). The common signs that patients had were suggestive of PT in different degrees, but these signs are non-specific and inconsistent.

Table 2. Hematological average values studied in patients with heartworm disease

| Hematological values                         | Average (CI)           | Females n= 5 (CI)  | Males n=18 (CI)     |
|--|------------------------|--------------------|---------------------|
| Hematocrit %                                 | 43.03 (38.29-47.77)    | 39.24 (21.0-50.0)  | 44.08 (17.09-65.40) |
| RBC x10 <sup>12</sup> L <sup>-1</sup>        | 6.07 (5.43-6.72)       | 5.62 (3.10-7.10)   | 6.20 (2.50-8.70)    |
| Hemoglobin g dL <sup>-1</sup>                | 13.67 (2.19-15.14)     | 12.72 (7.0-16.60)  | 13.93 (5.60-18.70)  |
| WBC x10 <sup>9</sup> L <sup>-1</sup>         | 15.22 (10.02-20.42)    | 17.22 (8.70-44.6)  | 14.67 (6.10-58.90)  |
| Neutrophils x10 <sup>9</sup> L <sup>-1</sup> | 11.46 (6.41-16.52)     | 12.80 (5.10-39.90) | 11.09 (0.59-53)     |
| Lymphocytes x10 <sup>9</sup> L <sup>-1</sup> | 2.45 (1.85-3.04)       | 2.38 (0.69-3.90)   | 2.47 (0.62-5.20)    |
| Monocytes x10 <sup>9</sup> L <sup>-1</sup>   | 0.76 (0.54-0.97)       | 1.28 (0.80- 2.10)  | 0.61 (0.18-1.40)    |
| Platelets x10 <sup>9</sup> L <sup>-1</sup>   | 258.32 (212.05-304.58) | 286.36 (188-393)   | 250.53 (114-466)    |

CI: confidence interval, RBC: Red blood cells, WBC: White blood cells

Table 3. Mean values of cardiopulmonary and inflammatory biomarkers of dogs infected with the heartworm

| Variable                              | Result   | Males n=5 | Females N=18 |
|---------------------------------------|----------|-----------|--------------|
| D-dimer ng ml <sup>-1</sup>           | 3.391.78 | 3.857,83  | 1.714.0      |
| Troponin I ng ml <sup>-1</sup>        | 0.1      | 0.13      | 0.01         |
| C-reactive protein mg L <sup>-1</sup> | 44.8     | 47.4      | 36           |

There are no findings of pathognomonic laboratories for the diagnosis of the heartworm, thromboembolism, or the severity of the disease that the patient is facing. The majority of dogs with heartworm disease have a normal blood count (Montoya et al 2012). The complete blood count does not discriminate the occurrence of PT (Goggs et al 2017). In hematological alterations during the formation of thrombi, the thrombocytopenia, anemia and leukocytosis are reported and leukopenia is the least frequent (Respass et al 2012). In our study the hematocrit remained within normal limits (38.29 - 47.77%). Females showed a red blood cell count that was lower compared to the males. Platelet count can be normal or high despite the formation of clots that could cause platelet consumption in patients infected with *D. immitis* as reported by Lynelle et al in 1999 (thrombocytopenia in 40% of cases). In our study, it remained within the reference values in the range from 212 to 304 x10<sup>9</sup> L<sup>-1</sup> despite the D-dimer plasma increases. In addition, a range of leukocytes was observed from 10.02 to 20.42 x10<sup>9</sup> L<sup>-1</sup> with a tendency to leukocytosis where males showed higher increase compared to females. The increase is suggestive for pulmonary inflammation generated by parasites at this level or by PT. The leukocyte increase as a risk factor has been reported in canine patients (Thawley et al 2016) and human patients (Buxhofer-Ausch et al 2012). 30% of the patients did not present microfilaremia, suggestive of the age of the parasites or the immune response to microfilariae or adult parasites (McCall et al 2008). Arterial endothelial alteration and reduction of the pulmonary arterial diameter due to thrombus or to the presence of adult parasites, together with inflammatory mediators, can lead to the presentation of PH (Simón et al 2012). This pathology was reported from 68% (Serrano et al 2017a) to 70.4% (62-88%) (Serrano et al 2017b). A similar finding was observed in 57% (34-77%) of the studied population which was considered a frequent and severe phenomenon of the disease; it was present at the time of the diagnosis and it persisted 120 days after the application of adulticide therapy (Serrano et al 2017a). The classic triad of signs of PT in humans include dsypnea, pain in the chest and hemoptysis; dsypnea occurs around from

59 to 90% (Lynelle et al 1999) and 90% (Klein et al 1989) of the cases. Data that is similar to the reported information were found in our study in ranges from 52 to 90%. Dimer-D is a fibrin degradation product; high plasma concentrations indicate the presence of thrombi or their degradation. This test is more sensitive and specific as opposed to thromboelastography. Studies have found no significant differences between, but several experimental approaches did find a correlation between the presence of thrombi and an increase of Dimer-D (Thawley et al 2016; Lennon et al 2013). In addition, it was reported that dogs naturally and experimentally infected with *D. immitis* have deposits of Dimer-D in 34.8% to 40% of pulmonary tissue (Carretón et al 2013a), and 47% in heartworm-infected patients (Carretón et al 2011). In our investigation there were deposits of Dimer-D in 73.9% of pulmonary tissue. Thrombosis is more common in females than in males (Thawley et al 2016; Stokol et al 2003). The relation of coagulation to sex has been identified using thromboelastography in humans in healthy individuals (Gorton et al 2000) and trauma patients (Schreiber et al 2005), possibly caused by the increase in fibrinogen, factor III and low concentrations of S protein that would explain the tendency to thrombosis in people (Lowe et al 1997). The hormonal role was not fully elucidated, but females were more likely even if they are sterile (Thawley et al 2016). Epidemiological studies of the coagulation factors have not been reported in dogs or if females or males produce more thrombi, but in this study it was found that males (3,857.83 ng ml<sup>-1</sup>) had an average higher with respect to females (1,714.0 ng ml<sup>-1</sup>). The cTnI is a sensitive and specific biomarker of myocardial injury which has been used as a diagnosis in various cardiac pathologies in dogs (Oyama et al 2004). Slight increases in cTnI were found in dogs with circulating, microfilaremic and amicrofilaremic antigens in infected individuals (Carretón et al 2011). 21.7% of evaluated patients showed increases of the cTnI. Males had higher values compared to females. It was that the increase of cTnI is caused by the PH and consequently due to the right heart failure (Carretón et al 2012), but the analysis of the data did not showed any relation between the increase of cTnI and

the presence of PH. Similar results were reported by Carretón *et al* (2012) where they correlated microscopic findings and myocardial with staining anti-cTnI antibodies. Meanwhile, the levels of Dimer-D and CRP did increase in PH, which suggests that the presence of thrombi and inflammation can develop this pathology (Ben *et al* 2007).

## Conclusions

This retrospective study reaffirmed the effectiveness of the use of biomarkers in predicting the evolution of dogs with *D-Immitis* disease through the mean hematological values showed in Table 2 and the average cardiopulmonary and inflammatory values in Table 3. However, unlike other similar experiments, our study reported a greater coverage of Dimer-D in lung tissues of 73.9%. On the other hand, despite epidemiological studies of the coagulation factors have not been reported in dogs or if females or males produce more thrombi, this study found that males had an average higher compared to females. Both results opens the door for future trials and analysis under similar conditions. The analysis of the data did not showed correlation between cTnI and the presence of PH.

## References

- Becattini C, Vedovati MC, Agnelli G. Prognostic value of troponins in acute pulmonary embolism: a meta-analysis. *Circulation* 2007;116:427-433. DOI:10.1161/CIRCULATIONAHA.106.680421.
- Ben SQ, Ni SS, Shen HH, Shi YX, Huang SB, Xu JH, Huang JF. The dynamic changes of LDH isoenzyme 3 and D-dimer following pulmonary thromboembolism in canine. *Thromb Res* 2007;120:575-583. DOI:10.1016/j.thromres.2006.12.015.
- Boswood A. Biomarkers in cardiovascular disease: beyond natriuretic peptides. *J Vet Cardiol* 2009;1:23-32. DOI:10.1016/j.jvc.2009.01.003.
- Bowman DD, Atkins CE. Heartworm biology, treatment, and control. *Vet Clin North Am small anim Pract* 2009;39:1127-1158. DOI:10.1016/j.cvsm.2009.06.003.
- Buxhofer-Ausch V, Gisslinger H, Thiele J, Gisslinger B, Kvasnicka HM, Müllauer L, *et al*. Leukocytosis as an important risk factor for arterial thrombosis in WHO-defined early/prefibrotic myelofibrosis: an international study of 264 patients. *Am J Hematol* 2012;87:669-672. DOI:10.1002/ajh.23217.
- Carretón E, Corbera JA, Justea MC, Morchón R, Simón F, Montoya A. *Dirofilaria immitis* infection in dogs: Cardiopulmonary biomarker levels. *Vet Parasitol* 2011;176:313-316. DOI:10.1016/j.vetpar.2011.01.015.
- Carretón E, González-Miguel J, Montoya-Alonso JA, Morchón R, Simón F, Passeri B, Cantoni AM, Kramer L. D-dimer deposits in lungs and kidneys suggest its use as a marker in the clinical workup of dogs with heartworm (*Dirofilaria immitis*) disease. *Vet Parasitol* 2013a;191:182-186. DOI:10.1016/j.vetpar.2012.08.008.
- Carretón E, Grandi G, Morchón R, Simón F, Passeri B, Cantoni M, *et al*. Myocardial damage in dogs affected by heartworm disease (*Dirofilaria immitis*): immunohistochemical study of cardiac myoglobin and troponin I in naturally infected dogs. *Vet Parasitol* 2012;189:390-393. DOI:10.1016/j.vetpar.2012.04.013.
- Carretón E, Morchón R, González-Miguel J, Simón F, Juste M C, Montoya-Alonso JA. Variation of D-dimer values as assessment of pulmonary thromboembolism during adulticide treatment of heartworm disease in dogs. *Vet Parasitol* 2013b;195:106-111.
- Darcy BA, Rowan JM, Kate DB, Cathy E, Marc S. Cardiac troponin I concentrations in normal dogs and cats using a bedside analyzer. *J Vet Cardiol* 2005; 7:27-32. DOI:10.1016/j.vetpar.2013.01.005.
- Eckersall PD, Bell R. Acute phase proteins: Biomarkers of infection and inflammation in veterinary medicine. *Vet J* 2010;185:23-27. DOI:10.1016/j.tvjl.2010.04.009.
- Epstein SE, Hopper K, Mellema MS, Johnson LR. Diagnostic Utility of D-Dimer Concentrations in Dogs with Pulmonary Embolism. *J Vet Intern Med* 2013;27:1646-1649. DOI:10.1111/jvim.12177.
- Goggs, R, Letendre, JA. Measurement of plasma cell-free DNA concentrations in dogs with sepsis, trauma neoplasia. *Journal of Veterinary Emergency and Critical Care* 2017;27:307-314. DOI:https://doi.org/10.1111/vec.12592.
- Gorton HJ, Warren ER, Simpson NA, Lyons GR, Columb MO. Thromboelastography identifies sex-related differences in coagulation. *Anesth Anal* 2000;91:1279-1281.
- Janata K, Holzer M, Laggner AN, Müllner M. Cardiac troponin T in the severity assessment of patients with pulmonary embolism: cohort study. *BMJ* 2003;8:312-313.
- Klein MK, Dow SW, Rosychuk RA. Pulmonary thromboembolism associated with immune-mediated hemolytic anemia in dogs: ten cases (1982-1987). *J Am Vet Med Assoc* 1989;195:246-250.
- Kumar SA, Vardhan SH, Arun RA, Kumar SS. C-reactive protein, inflammation and coronary heart disease. *EJH* 2015;67:89-97.
- Lennon EM, Hanel RM, Walker JM, Vaden SL. Hypercoagulability in dogs with protein-losing nephropathy as assessed by thromboelastography. *J Vet Intern Med* 2013;27:462-468. DOI:10.1111/jvim.12067.
- Lowe GD, Rumley A, Woodward M, Morrison CE, Philippou H, Lane DA, Tunstall-Pedoe H. Epidemiology of coagulation factors, inhibitors and activation markers: the Third Glasgow MONICA Survey. I. Illustrative reference ranges by age, sex and hormone use. *Br J Haematol* 1997;97:775-784.
- Lynelle RJ, Michael RL, Dale CB. Pulmonary Thromboembolism in 29 Dogs: 1985-1995. *J Vet Intern Med* 1999;13:338-345.
- McCall JW, Genchi C, Kramer LH, Guerrero J, Venco L. Heartworm disease in animal and humans. *Adv Parasitol* 2008;66:193-285. DOI:10.1016/S0065-308X(08)00204-2
- Méndez JC, Carretón E, Martínez S, Tvarijonavičiute A, Cerón JJ, Montoya-Alonso JA. Acute phase response in dogs with *Dirofilaria immitis*. *Vet Parasitol* 2014;204:420-425. DOI:10.1016/j.vetpar.2014.05.016.
- Montoya JA, Carretón EG. *Dirofilariosis* pautas de manejo clínico (*Dirofilariosis* clinical management guidelines). Barcelona: Multimedica; 2012. ISBN: 9788496344440.
- Murata H, Shimada N, Yoshioka M. Current Research on Acute Phase Proteins in Veterinary Diagnosis: An Overview. *Vet J* 2004;168:28-40. DOI:10.1016/S1090-0233(03)00119-9.
- Nelson OL, Andreasen C. The utility of plasma D-dimer to identify thromboembolic disease in dogs. *J Vet Intern Med* 2003;17:830-834.
- Oyama MA, Sisson DD. Cardiac troponin-I concentration in dogs with cardiac disease. *J Vet Intern Med* 2004;18:831-839.
- Respass M, O'Toole TE, Taeymans O, Rogers CL, Johnston A, Webster CR. Portal vein thrombosis in 33 dogs: 1998-2011. *J Vet Intern Med* 2012;26:230-237. DOI:10.1111/j.1939-1676.2012.00893.x
- Schreiber MA, Differding J, Thorborg P, Mayberry JC, Mullins R. Hypercoagulability is most prevalent early after injury and in female patients. *J Trauma* 2005;58:475-480.
- Serrano-Parreño B, Carretón E, Caro-Vadillo A, Falcón-Cordón S, Falcón-Cordón Y, Montoya-Alonso JA. Pulmonary hypertension in dogs with heartworm before and after the adulticide protocol recommended by the American Heartworm Society. *Vet Parasitol* 2017a;236:34-37. DOI:10.1016/j.vetpar.2017.02.001.

Serrano-Parreño B, Carretón E, Caro-Vadillo A, Falcón-Cordón Y, Falcón-Cordón S, Montoya-Alonso JA. Evaluation of pulmonary hypertension and clinical status in dogs with heartworm by Right Pulmonary Artery Distensibility Index and other echocardiographic parameters. *Parasit Vectors* 2017b;10:2-6. DOI:10.1186/s13071-017-2047-2.

Simón F, Mar Siles L, Morchón R, González MJ, Mellado I, Carretón E, Montoya JA. Human and Animal Dirofilariasis: the Emergence of a Zoonotic Mosaic. *Clin Microbiol Rev* 2012;25:507-544. DOI:10.1128/CMR.00012-12.

Stokol T. Plasma D-dimer for the diagnosis of thromboembolic disorders in dogs. *Vet Clin North Am Small Anim Pract* 2003;33:1419-1435.

Thawley VJ, Sánchez MD, Drobatz KJ, King LG. Retrospective comparison of thromboelastography results to postmortem evidence of thrombosis in critically ill dogs: 39 cases (2005-2010). *J Vet Emerg Crit Care* 2016;26:428-436. DOI:10.1111/vec.12441.

Tracy RP. Inflammation in Cardiovascular Disease: Cart, Horse or Both—Revisited. *Journal of the American Health Association*. 2002;22:1514-1515. DOI:10.1161/01.ATV.0000035403.39442.DB

•Rodrigo De Laval Galvis, Faculty of Veterinary Medicine, University of Cordoba, Colombia, Avenue 6 No. 76-103, Montería, Córdoba. Email: rdelavalgalvis42@correo.uni-cordoba.edu.co.

•Jorge Guzmán Rodríguez, Faculty of Veterinary Medicine, University of Cordoba, Colombia, Avenue 6 No. 76-103, Montería, Córdoba. Email: Jorgeguzmanmvz@gmail.com

•Ariel Mendoza Duarte, Faculty of Veterinary Medicine, University of Cordoba, Colombia, Avenue 6 No. 76-103, Montería, Córdoba. Email: vetsharpey@gmail.com

•Amanda Ramos Riquett, Department of Veterinary Medicine, UDCA University, Colombia, Street 31 No. 18b - 17 (Avenida Pié del Cerro)Cartagena, Colombia, Email: amandaka\_mvz@hotmail.com

•María de la Puente, Department of Veterinary Medicine, UDCA University, Colombia, Colombia, Street 31 No. 18b - 17 (Avenida Pié del Cerro), Email: crisdlp93@hotmail.com

•Maria Badillo Viloría, Faculty of Biomedical Sciences, Simón Bolívar University, Colombia, Street 58 #55-132, Barranquilla, Colombia, Email: Mbadillo3@unisimonbolivar.edu.co

## Authors

•Mario de la Puente, Research Group I.A, Universidad del Norte, Colombia, Km 5 Via Puerto Colombia, Colombia, Email: mde-lapuate@uninorte.edu.co.

**Citation** de la Puente M, De Laval Galvis R, Rodríguez RG, Duarte AM, Riquett AR, de la Puente M, Viloría MB. Use of biomarkers as prognostic indicators in dogs with natural heartworm. *HVM Bioflux* 2018;10(3):99-103.

**Editor** Stefan C. Vesa

**Received** 18 May 2018

**Accepted** 26 June 2018

**Published Online** 19 July 2018

**Funding** None reported

**Conflicts/  
Competing  
Interests** None reported