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Heartworm disease in canines

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Abstract. Heartworm disease is a parasitic disease caused by Dirofilaria immitis that affects the pulmonary arteries in canines, causing circulatory disturbances and breathing difficulties. The disease is transmitted through mosquito bites and the worms mature in the heart, lungs, and associated blood vessels of canines. Wolbachia, an endosymbiont bacteria present in D. immitis, triggers the canine immune response leading to acute and chronic inflammation in the heart and lung vasculature. The primary lesions in pulmonary arteries and lung parenchyma, along with the proliferation of the worms, result in severe pulmonary hypertension and congestive heart failure if left untreated. Though dogs of any age, breed, or sex may be affected, the disease is rare in dogs less than one year of age due to the time required for larval maturation into adult heartworms.

Keywords: Heartworm, Dirofilaria immitis, pulmonary

1. Introduction

Heart allows gas exchange in extremities by pumping oxygenated blood to the capillaries and bringing deoxygenated blood back to the lung in canines as in other vertebrates. Heartworm disease is a serious and potentially fatal condition that primarily affects dogs. It is a parasitic disease caused by *Dirofilaria immitis,* a filarial nematode parasite [1]. The parasite causes pathology in the pulmonary arteries in canine heart by triggering inflammation and obstruction, causing circulatory disturbances, and breathing difficulties.

2. Pathology

2.1. Etiology

Heartworm disease is a complex condition caused by a nematode parasitic worm called *Dirofilaria immitis*. The worms are acquired by dogs in the form of sheathless larvae through transmission via mosquitoes, an intermediate host. On the contrary, *D. immitis* mature, mate and reproduce in their definite host--canines. Compared to the larvae that live in mosquitoes, adult worms live as obligate endoparasites--they must live in the heart, lungs and associated blood vessels of canines to survive.

2.2. Pathogenesis

D. immitis larvae is transmitted to canines by the intermediate hosts, including mosquitoes and fleas [2]. As the parasites mature and migrate to the pulmonary arteries in the canine hosts, dogs' immune

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response to the infection is triggered via several pathways, resulting in vascular inflammation. One of the most well studied triggers to the canine immune response is the endosymbiont bacteria Wolbachia in *D. immitis*. Wolbachia is associated with the activation of the innate immune system and thus the up regulation of pro-inflammatory cytokines. The acute and chronic inflammation in the heart and lung vasculature lead to the primary lesions in pulmonary arteries and lung parenchyma. As the vascular lesions progress, the vasculature gets obstructed further by both the scar tissue (caused by chronic lesions in the vasculature) and the proliferation of the worms, resulting in pulmonary hypertension and consequently congestive heart failure if not treated.

The life cycle of *D. immitis* involves several crucial stages. It begins with an infected mosquito, which serves as an intermediate host, feeding on the blood of an already infected dog. During this feeding process, the mosquito ingests small larvae, known as sheathless larvae or microfilariae, present in the dog's bloodstream.

Inside the mosquito, these larvae undergo a maturation process and develop into infective larvae. When the mosquito subsequently bites another susceptible dog, it injects these infective larvae into the dog's skin. These larvae then actively penetrate the dog's tissues and gradually migrate through the bloodstream.

Over time, these larvae make their way to the heart, lungs, and associated blood vessels, where they mature into adult worms. It is within these vital organs that the adult *D. immitis* find their definite host - canines, including dogs, wolves, foxes, and other related species.

The adult worms in their definitive host are sexually dimorphic, with males and females. They mate and reproduce, producing tiny offspring called microfilariae. These microfilariae circulate within the bloodstream of the infected dog, ready to infect another mosquito that bites the dog, thereby continuing the life cycle.

Unlike the larvae that live within mosquitoes, adult worms are obligate endoparasites, meaning they have evolved to exclusively survive within the heart, pulmonary arteries, and associated blood vessels of canines. They anchor themselves to the walls of these vital organs, disrupting the blood flow and causing significant damage.

If left untreated, the presence of these adult worms can lead to severe cardiovascular complications, including heart failure, pulmonary hypertension, and ultimately, death.

3. Signalment and History

Heartworm disease can affect dogs of any age, breed, or sex. However, it is relatively rare in dogs that are less than one year old. This is because it takes a considerable amount of time for the microfilariae, or the larval stage of the heartworms, to develop into adult heartworms after a dog is infected.

The life cycle of heartworms in dogs involves several stages. When an infected mosquito bites a dog, it transfers the infective larvae into the dog's bloodstream. These larvae then migrate through different tissues in the dog's body for about 2 to 3 months until they reach the heart and adjacent blood vessels. Here, they continue to grow and develop into adult heartworms, which can reach lengths of up to 12 inches.

The time it takes for the microfilariae to mature into adult heartworms is estimated to be around 5 to 7 months. During this time, the larvae undergo several molts and transformations within the dog's body. As a result, heartworm disease is less commonly seen in dogs under one year old, as they have not yet had sufficient time for the larvae to reach maturity.

It is important to note, however, that while younger dogs may have a lower incidence of heartworm disease, they are still susceptible if they are exposed to infected mosquitoes. Therefore, preventive measures, such as administering regular heartworm preventives and minimizing exposure to mosquitoes, are crucial for all dogs regardless of age.

For older dogs, the risk of heartworm disease increases with time, as they have had more opportunities to be bitten by infected mosquitoes. Regular testing and preventive measures are recommended to detect and prevent heartworm infection in these dogs. By identifying and treating

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heartworm disease early on, we can minimize the potential complications and ensure the best possible outcome for our furry companions.

In conclusion, heartworm disease can affect dogs of any age, breed, or sex, but it is relatively rare in dogs less than one year old due to the time required for the microfilariae to mature.

4. Clinical anatomy

Sitting within the middle mediastinum, the main pulmonary artery and the subsequent right and left pulmonary arteries arise from the right ventricle of the four-chambered heart and transport deoxygenated blood to the lungs [3]. The pulmonary arteries are crucial to pulmonary circulation.

After systemic circulation, the blood is oxygen-poor and needs to go through pulmonary circulation to gain oxygen from the lungs through gas exchange. The oxygen-depleted blood enters the right atrium via vena cava. The right AV valve controls the direction of blood flow and ensures that the blood moves correctly to the right ventricle. The pulmonic valve opens to allow blood to flow from the right ventricle through the pulmonary artery to the lungs where it will receive oxygen. The pulmonic valve also prevents the back flow of blood from the pulmonary artery to the right ventricle. After gas exchange at alveoli in the lungs, the oxygenated blood flows back to the left side of the heart and can supply oxygen to the rest of the body.

5. Clinical signs

As the proliferating worms and progressing vascular disease advance, obstruction in the pulmonary arteries occurs and thus, pulmonary circulation is blocked. Subsequently, the right ventricle becomes congested with blood waiting to be pumped into the pulmonary circulation, causing the pulmonary artery to enlarge in size. Chronically, the pooled blood in the pulmonary arteries leads to pulmonary hypertension. In addition, impaired pulmonary circulation leads to insufficient somatic oxygen. As a result, the heart compensates by pumping faster to allow for sufficient gas exchange. *D. immitis* can also cause inflammation in heart valves, further worsening workload on the heart due to less-than-ideal stroke volume. As a result, affected canines present as congestive heart failure in the long term: clinical signs include soft dry cough, chronically increased heart rate, labored breathing, weakness, shortness of breath, and loss of stamina. In advanced cases, congestive heart failure may cause the abdomen and legs to swell from fluid accumulation. There may also be evidence of weight loss, poor condition, and anemia. Severely infected dogs may die suddenly during exercise or excitement.

6. Diagnosis

Diagnosis of heartworm disease in dogs involves multiple steps and tests. The primary test for diagnosing heartworm disease is the heartworm antigen test (HWD). This test detects the presence of circulating heartworm antigens that are released by mature female worms. A positive result indicates that the dog is infected with heartworms.

In addition to the HWD test, a conversation with the pet owner is crucial in helping the veterinarian determine if the dog has been exposed to infected mosquitoes, which are the intermediate hosts of heartworms. Knowing the dog's exposure history can provide valuable information for the diagnosis.

Radiographs, or X-rays, can also be taken to examine the dog's heart. These images can reveal any abnormalities that develop in the early stages of the disease. In approximately 85% of heartworm disease cases, radiographic findings show an increased size of the pulmonary artery and an enlarged right ventricle of the heart. [4]

To further support the diagnosis, additional tests may be conducted. These include microfilaria testing, blood smear examination, and electrocardiogram (ECG). Microfilaria testing involves the examination of a blood sample to detect the presence of microfilariae, which are immature heartworms. Blood smear examination can also help identify the presence of microfilariae. An ECG is a recording of the electrical activity of the heart and can provide additional information about the dog's cardiac health.

By combining the results of these various tests and examinations, veterinarians can accurately diagnose heartworm disease in dogs and determine the appropriate treatment plan. It is important to

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diagnose heartworm disease as early as possible to prevent further complications and ensure the well-being of the affected dog.

7. Treatment

Treating heartworm disease in dogs is a complex and careful process because the disease involves parasites that exist in different life stages within the canine host. The treatment must target the adult worms without causing undue harm to the dog, particularly considering that dying heartworms can create serious complications in the cardiovascular system.

7.1. Anti-parasitic Medications

The primary treatment for adult heartworms is an anti-parasitic medication called Melarsomine. This drug is designed to kill adult worms in the heart and adjacent vessels [5]. However, Melarsomine is not effective against the larval stages (microfilariae) of the parasite. The medication is typically administered via a series of deep intramuscular injections into the lumbar muscles. The veterinarian will assess the dog's health before determining the exact treatment schedule, which often consists of one injection followed by a period of rest, and then a set of two additional injections given 24 hours apart. This schedule is designed to reduce the risk of complications that can occur when a large number of worms die at once.

7.2. Surgery

In severe cases of heartworm infestation, surgical removal of the worms may be necessary, particularly when the worm burden is high and causing significant obstruction. This is usually an option when there is a risk of the dog not surviving the time it would take for the anti-parasitic medication to work.

7.3. Supporting Therapy

Alongside anti-parasitic treatment, veterinarians may prescribe supportive therapies. NSAIDs (nonsteroidal anti-inflammatory drugs) can help manage inflammation caused by the dying worms and surrounding tissue reaction. Corticosteroids are sometimes used to control inflammation and reduce allergic reactions to the death of the worms. Antibiotics (like doxycycline) target Wolbachia, a bacterial endosymbiont of heartworms, which is thought to play a role in inflammation and embolism associated with heartworm disease and its treatment.

7.4. Strict Rest

During and after treatment, strict rest is essential. The purpose of exercise restriction is to prevent a rapid increase in heart rate and blood flow, which can dislodge dying worms and lead to blockages in the pulmonary vessels (pulmonary thromboembolism). Restricted activity must continue for a period after the last injection, potentially for several weeks, to allow safe absorption of the dead worms.

Throughout the course of treatment, close monitoring is imperative to manage any adverse effects and to gauge the dog's response to therapy. Serial examination using diagnostics such as radiographs and follow-up heartworm tests is usually required to confirm the success of the treatment. Moreover, starting heartworm prevention is crucial to prevent new infections and to kill remaining microfilariae, thus, a year-round prophylaxis is typically recommended post-treatment.

With the completion of the treatment regimen and full rest, most dogs with heartworm disease can recover well, but the process is long and can be hard on the animal. Prevention is always the best approach and is significantly less risky and less expensive than treating the disease after it has developed.

8. Prognosis

The prognosis for dogs with heartworm disease varies significantly and depends on several factors like the severity of the infection, the stage at which the disease is diagnosed, and the dog's overall health. Regular physical examinations by a veterinarian can help detect clinical signs of heartworm disease early, which is crucial since the disease is progressive. During these exams, a vet may identify symptoms

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like a mild persistent cough, reluctance to exercise, fatigue after moderate activity, decreased appetite, and weight loss, which could suggest heartworm infection.

The earlier the intervention, the better the prognosis for the dog. Effective early intervention includes the use of heartworm preventatives, which are designed to interrupt the development of larvae into adult heartworms. Common medications for heartworm prevention include:

- Ivermectin (Heartgard, Iverhart): A well-tolerated drug effective against the larval stages of heartworm when administered monthly.
- Milbemycin oxime (Interceptor, Trifexis): This is another monthly oral preventative that also treats intestinal worms.
- Selamectin (Revolution, Stronghold): Applied topically, this preventative is absorbed into the bloodstream and provides protection against heartworms and other parasites.
- Moxidectin (ProHeart, ProHeart 6, Simparica Trio): Available as a topical solution or as an injectable formulation, which can offer protection for 6 or 12 months with a single dose depending on the product [6].

The use of these medications can prevent heartworm disease when given as prescribed by a veterinarian. They are most effective before the dogs are infected or in the very early stages, as they do not treat the adult heartworms.

For dogs already infected with heartworms, the prognosis depends on the severity of the disease. Dogs with mild to moderate infections can often be treated successfully and can have a good prognosis if the disease is managed well and any follow-up recommendations are adhered to closely. In severe cases, particularly when heart failure or caval syndrome (where a mass of worms obstructs the blood flow from the heart) is present, treatment is riskier and the prognosis is guarded to poor.

Regular use of heartworm prevention, as well as annual screening for heartworm infection, is generally recommended for all dogs in areas where heartworms are prevalent. Prevention is key, as it is far more cost-effective and safer for the dog than treating the established disease. Moreover, adopting such strategies contributes to the overall health and longevity of the dog, ensuring it remains free of this potentially fatal disease.

9. Conclusion

Heartworm disease is an insidious condition that poses a significant threat to dogs of virtually any age or breed. The causative agent, *Dirofilaria immitis*, is a parasitic worm that is transmitted through the bite of an infected mosquito. The worms mature and reproduce within the host's body, specifically targeting the heart and lungs.

As the disease progresses, the immune system mounts a response to combat the invading worms. This immune response, along with the physical presence of the worms, can lead to inflammation of the vascular system and damage to the blood vessels. The growing number of these parasites within the heart and pulmonary arteries can significantly impair blood flow, leading to a condition known as pulmonary vascular disease. This diminished blood flow can disrupt pulmonary circulation, which is critical for effective gas exchange within the lungs.

When the heart and lungs struggle to overcome the physical obstruction caused by the heartworms, the organ systems attempt to compensate for the reduced functionality. However, as the disease advances and the burden of parasitic infestation grows, these compensatory mechanisms often fall short. The result can be the development of congestive heart failure, a condition in which the heart is unable to pump blood effectively, leading to fluid buildup in the lungs, the chest cavity, or the abdominal space. This fluid accumulation contributes to the breathing difficulties, coughing, and lethargy seen in affected dogs.

The consequences of advanced heartworm disease can be grave and irreversible. Treatment at this stage is complex, carries significant risk, and can be costly. The best strategy to prevent the disease from reaching such a critical state is through proactive measures and education. Dog owners should be vigilant for clinical signs that might suggest heartworm infection, such as coughing, fatigue after mild activity,

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decreased appetite, and weight loss. They should also ensure that their pets undergo regular veterinary check-ups, including annual heartworm testing, especially in regions where the disease is prevalent.

Preventative care is the most reliable method for protecting dogs from heartworm disease. Safe, effective, and easy-to-administer prophylactic medications are available to prevent larval heartworms from developing into adults. These preventives should be given as recommended by a veterinarian, typically once a month, year-round. Additionally, education initiatives that inform pet owners about the risks of heartworm disease, its transmission, and the importance of year-round prevention can greatly reduce the incidence of this debilitating disease.

In conclusion, heartworm disease is a preventable but potentially fatal condition. The joint efforts of veterinarians and dog owners in implementing routine prevention strategies, early detection, and timely treatment are essential in safeguarding the health and well-being of our canine companions.

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