Open Heart Surgery Applications in Dogs Suffering from Natural Infection of Dirofilaria immitis*

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Abstract: This study includes 6 dogs naturally infected with Dirofilaria immitis of different ages and sexes. Clinical, radiographical, blood gas and blood biochemical evaluations were examined in the preoperative period. Microfilariae were determined in 6 cases with a modified Knott test. Cardiopulmonary bypass (CPB) and open-heart surgery were carried out.

Animals were prepared for cannulation under general anesthesia. The heart was approached by right lateral thoracotomy. The femoral artery and vena cavae were cannulated before CPB. During the operation, arterial blood pressure and the heart rate were monitored and blood gas values were continuously observed. Before and 1 hour after the operation cardiac output was monitored. Mean operation time was 155 ± 35 minutes, and cross-clamp time was 34 ± 9 minutes. A total of 12 ± 5 mature Dirofilaria immitis were collected from the right heart and the pulmonary artery.

Radiographical evaluation showed that the heart was hypertrophic in all cases and right heart dilatation was seen in one case. In blood gas analysis, an increase in pCO₂ and decreases in pO₂, HCO₃ and pH were observed.

One dog was extubated for 1 hour, while the remaining 5 dogs were extubated for 3 hours after the operation. One dog was followed for 1.5 years whereas the others were followed for 6 months after surgery.

No complications occurred during the operation, but premature ventricular contractions were observed in all cases. Arterial blood pressure and cardiac output decreased significantly when compared to preoperative values 1 hour after the operation. The heart rate increased significantly. In two cases, a postoperative superficial infection was identified.

Two dogs were still infected with microfilariae two weeks after the operation. Ivermectin was administered and the microfilariae were destroyed two months after this medication.

All dogs tolerated the CPB and open-heart surgery procedures well.

Key Words: Dirofilaria immitis, cardiopulmonary bypass, dog

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**Introduction**

*Dirofilaria immitis* is a nematode. It is a frequently seen parasite in dogs and in other species such as cats, foxes, bears, wolves, and horses and rarely in humans (1-6).

The mature form of the parasite lives in the right ventricle of the heart or in the pulmonary artery (1,3,4,6,7). The female forms release several thousand larvae into the blood (1,4,6,8).

Environmental factors like temperature, mosquitoes, and aging play an important role in *D. immitis* infection in dogs (9).

The infection risk increases at the age of 4-7 years. Male dogs carry a higher risk almost twice as much as females of succumbing to such parasites (1,10-12). Elderly dogs, those 8 or 9 years old, have a decreased risk of infection although this may be because most deaths occur by this age. In addition the immune system prevents the maturation of the parasites in this age group (1,10).

Infected dogs sometimes do not show any clinical signs. The initial signs of infection are restricted movements and weight loss followed by coughing, respiratory difficulties and chest pains (1,2,4,13-15). Pulmonary edema, right heart insufficiency and ascites worsen the clinical situation (1,13,14). Following severe and long-lasting infections, pulmonary vascular disorders occur and end in pulmonary hypertension. In addition, intimal hyperplasia, thromboembolic events, arterial wall injury and parenchymal lesions are all associated with pulmonary hypertension (1,13,15-17).

The increased vascular resistance leads to acute right heart failure (1,13). Pulmonary hypertension was the main cause of the symptoms in the infected dogs. Heart murmurs can be heard along with signs of hypertension and ascites (1,17). The massive presence of live parasites in the pulmonary artery prevent blood flow and increase blood pressure (1,13,17).

Imbalanced blood gases, increased hepatic enzyme levels, loss of liver functions, proteinuria and uremia can be seen in dirofilariasis with pulmonary, cardiac and hepatic disorders. In severe cases, the $pO_2$ level is 40.0 mmHg, although healthy subjects have 55.3 mmHg (1,18).

In physical examination, the paradoxial second heart sound due to the delay of the evacuation of the right ventricle, a harsh respiration sound and laboratory tests, such as leukocytosis and the existence of microfilaremia in the blood can be observed for diagnosis (1,19). Immunological tests are very accurate for diagnosis. Right heart and pulmonary artery dilatation is related to pulmonary hypertension (1,20). The degree of the illness can be determined by using two-dimensional echocardiography (1,21).

There are medical and surgical treatment methods for *Dirofilaria immitis*. The most radical method for the treatment of mature forms is surgery. Jugular venotomy (21-25), pulmonary arteriotomy (26-28), removal of parasites from the right ventricle (28), inflow occlusion and right ventriculotomy (28) and extracorporeal circulation (29) are among the surgical methods available.

The initial use of open-heart surgery for *D. immitis* infection in 6 dogs in Turkey is reported in this paper.
Materials and Methods

Six dogs of different ages, breeds and sexes were used in the study. The mean weight of the animals was 28 ± 5 kg. The study was carried out in accordance with the ‘Principles of Laboratory Animal Care’ and ‘Guide for the Care and Use of Laboratory Animals’ (NIH Publication No.80-23, revised 1985) following the approval of our ethics committee.

The dogs were first admitted to the internal medicine department. The clinical examination and modified Knott test confirmed the diagnosis as D. immitis infection, and the dogs were referred to the surgery department.

Preoperative Preparation

The animals were not allowed to eat 24 hours before surgery. If they had ascites or pericardial tamponade, they were drained before surgery. Cefazolin sodium (20 mg/kg) was infused intravenously 12 hours before and again just before the operation.

Anesthesia Protocol

An 18 G catheter was placed in the vena cephalica antebrachii and 10 ml/kg per hour of ringer lactate solution was given before the operation. The left lateral side of the thorax and left femoral regions were clipped and disinfected before surgery. Premedication was made with atropin sulfate (0.04 mg/kg, subcutaneous injection) 45 min prior to surgery. The animals were sedated with xylazine HCl (2 mg/kg i.m.) 30 min. after premedication. To induce anesthesia, a combination of fentanyl citrate (5 mcg/kg), thiopental sodium (15 mg/kg) and atracurium (90 mcg/kg) were given intravenously 12 hours before and again just before the operation.

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The operation side was prepared for aseptic surgery. The left femoral artery and venae were catheterized. An arterial line was used for blood pressure measurements and blood gas analyses and was connected to the monitor with a transducer. Electrocardiography (ECG) electrodes were also placed on the extremities and ECG was monitored. Blood pressure was continuously monitored with the multichannel monitor. A swan-ganz thermodilution catheter was placed in the pulmonary artery via the femoral venae for cardiac output monitoring as reported by Sartas et al. (30).

Cardiopulmonary Bypass (CPB) Procedure

Prime solution

A 1.5-I ringer lactate solution, 44 mEq sodium bicarbonate and a 1 ml/kg, 20% mannitol solution were used for the initiation of the circulation in CPB. 5000 IU heparin was added for anticoagulation and ACT was held above 480 s.

Thoracotomy and Cannulation

The fourth right intercostal space was used for the thoracotomy and the ribs were separated. Pericardectomy was done carefully while protecting the phrenic nerves, and the pericardium was attached to the thorax with 3/0 silk sutures (Figure 1). The ascending aorta was prepared with purse string sutures (4/0 polypropylene (Prolen)) for the aortic catheterization. A right atrium was used for venous cannulation with 2/0 vicryl sutures. Heparin (300 U/kg) and a total dose of 250 mg methylprednisolon (Prednol) were infused before cannulation.

Cannulation

The arteria femoralis was used for arterial cannulation and an 18 Fr arterial cannula was used. Two venous cannulas were inserted into the vena cava caudalis and cranialis via the right ventricle. A 12 G infusion cannula was inserted into the ascending aorta for cardioplegic infusion with the Y-shaped connection for air evacuation before declamping (Figure 2).

Cardioplegic Solution Application

A + 4 °C crystalloid cardioplegic solution was used to stop the heart in order to protect it during the ischemic period. The solution contained 27 m Eq Na⁺, 30 m Eq K⁺, 57 m Eq Cl⁻, 6 m Eq Mg²⁺, 6 m Eq SO₄, 4 m Eq Tromethamine and 50 g Dextrose monohydrate (31).

Cardiopulmonary Bypass

A Debeakey pump and membrane oxygenator were used for the CPB. Arterial and venous connections were made with the pump. The flow was adjusted to 2.5 l/m² per minute and was increased until the arterial blood pressure exceeded 60 mmHg. All of the dogs were cooled down to 28 °C rectal temperature.

Cardiac Arrest

After placing the cross-clamp on the aorta, 1 l cold (+4 °C) crystalloid cardioplegic solution (St. Thomas) was infused for rapid cardiac arrest.
Intracardiac Surgery

A right ventriculotomy was performed by creating a 4-6 cm incision from the lateral wall to the apex, and the exposure was obtained. Mature *Dirofilaria immitis* were visible both in the right ventricle and in the pulmonary artery. After removing the parasites from the heart, the ventricle was closed with double layer sutures. The first layer was simple and interrupted sutures, the second one was continuous with 3/0 prolene sutures. The last suture was completed by compressing the right ventricle. Then the aortic clamp was removed and the heart was defibrillated. The remaining air was aspirated.

Once the dog’s body temperature heated up to the 37 °C, CPB was terminated. The necessary positive inotropic agent dobutamine was started to bring the systemic blood pressure above 80 mmHg, the cannulas were taken

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**Figure 1.** View of the Heart after Pericardiectomy.

**Figure 2.** Cardiopulmonary Bypass Procedure and Cannulation.
out, 7/0 and 4/0 prolene were used to repair the arterio femoralis and the right atrium. The blood that remained in the reservoir was placed in plastic bags and infused. Acid-base disturbances were balanced by infusing bicarbonate solutions. The heparin that was initially infused was reversed with protamine sulfate (4.5 mg/kg) (32). A normal heart rhythm was maintained by using arrhythmal infusion. The dogs were defibrillated when ventricular fibrillation occurred.

**Thorax Closure**

Hemostasis was corrected by either coagulation or ligatures. A 32 Fr thorax drain was located after the closure. The ribs were closed by three separate sutures. Muscles, above the ribs, were closed with 0/0 vicryl. Skin was closed with interrupted sutures using 2/0 prolene. Thorax drainage was continued until satisfactory intrathoracic pressure and hemorrhage were achieved. Positive pressure ventilation was used during this period.

**Postoperative care**

In the postoperative period, positive pressure ventilation was continued until the drain was removed. Mepheridin hydrochloride (25-50 mg iv) and morphine sulfate (10 mg iv) were administered for sedation and postoperative pain management.

**Statistical Analysis**

All values were presented as the mean ± standard deviation. The difference among the pre and postoperative values were determined by Student’s t-test. The significance level was set at \( P < 0.05 \) (33).

**Results**

**Preoperative Clinical Findings**

Clinical examination of the infected dogs revealed a tricuspid valve murmur during auscultation. Five cases had respiratory distress and exercise intolerance. Two cases had severe ascites and one had cachexia.

**Hematological Findings**

The mean RBC, WBC, MCV, HCT and Hb values are shown in Table 1. RBC was found below the limit and WBC was significantly high (Table 1).

**Blood Gas Analysis**

Preoperative blood gas analysis results were presented as mean ± standard deviation and shown in Table 2; pH values were found at the lower border, \( PCO_2 \) was above the reference values, and \( PO_2 \) was low. \( HCO_3 \) level and base access values were also low (Table 2).

**Radiological Findings**

Two-way radiographical investigation revealed that 4 cases had heart dilatation of different sizes and one of them had severe dilatation (Figure 3).

**Intraoperative Findings**

The total operation duration was 155 ± 35 min and cross-clamp time was 34 ± 9 min. All dogs tolerated the operation well. One dog had severe heart dilatation, parallel to the preoperative findings as shown in picture 1. The mean of 12 ± 5 piece of mature forms of *Dirofilaria immitis* (Figure 4) were extracted from the right ventricle and pulmonary artery of each case.

**Postoperative Findings**

One of the cases was extubated one hour after surgery and the others were extubated three hours after surgery. All dogs had premature ventricular extrasystole, which was balanced by using lidocaine hydrochloride.

### Table 1. Blood profile in Dogs with Dirofilariosis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Value</th>
<th>Obtained Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC (10⁶/mm³)</td>
<td>5.5-8.5</td>
<td>5.62 ± 1.28</td>
</tr>
<tr>
<td>MCV (m)</td>
<td>60-77</td>
<td>65.5 ± 12.31</td>
</tr>
<tr>
<td>HCT (%)</td>
<td>37-55</td>
<td>40.17 ± 10.78</td>
</tr>
<tr>
<td>WBC (10³/mm³)</td>
<td>6-17</td>
<td>19.72 ± 2.64</td>
</tr>
<tr>
<td>Hb (g/dl)</td>
<td>12-18</td>
<td>2.55 ± 2.61</td>
</tr>
</tbody>
</table>

### Table 2. Preoperative blood gas analyses in dog with Dirofilariosis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Value</th>
<th>Obtained Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH (-log H⁺)</td>
<td>7.31-7.42</td>
<td>7.318 ± 0.03</td>
</tr>
<tr>
<td>PCO₂ (mm Hg)</td>
<td>29-42</td>
<td>48.3 ± 4.32</td>
</tr>
<tr>
<td>PO₂ (mm Hg)</td>
<td>80-100</td>
<td>55 ± 4.69</td>
</tr>
<tr>
<td>HCO₃ (mmol/l)</td>
<td>20-25</td>
<td>18.93 ± 1.16 O₂</td>
</tr>
<tr>
<td>Sat (%)</td>
<td>80-100</td>
<td>72.17 ± 0.47</td>
</tr>
<tr>
<td>BD (mmol/l)</td>
<td>-4.0</td>
<td>-7.4 ± 2.78</td>
</tr>
</tbody>
</table>
The mean arterial blood pressure, cardiac output and heart rate values were statistically different at the first postoperative hour according to preoperative values. The preoperative and first postoperative mean arterial blood pressure values were 95 ± 8 mmHg and 75 ± 7 mmHg respectively (P < 0.002). Cardiac output was measured at 3.3 ± 0.48 l/min preoperatively and decreased to 2.25 ± 0.48 l/min postoperatively after the first hour (P < 0.01). The heart rate also increased from 133 ± 12 / min to 163 ± 9 / min at the postoperative first hour (P < 0.002).

One dog had emphysema at the incision side of the thorax 9 days after the operation. The dog was operated on again and the incision line was sutured. Two dogs had superficial infections on the thorax incision line and one had an infection on the femoral incision line. All dogs were treated with a suitable antibiotic, and drainage was applied.

Two dogs still had microfilariae in their blood. All cases were treated with ivermectin on the 15th postoperative day and the ivermectin treatment was
repeated one month later. Two dogs were treated for anemia and they completely recovered within two months.

Five cases had 6-month follow-up control and one dog had an 18-month follow-up control. All dogs had negative Knott tests in the 6th month. One dog had a thoracic incision and an anterior extremity infection in the 7th month and was treated with a systemic antibiotic treatment.

**Discussion**

Observing clinical symptoms of *D. immitis* in dogs not difficult. Reluctancy in movement, weight loss, coughing, respiratory difficulties and chest pains are the signs of infected dogs (1,2,4,13-15). Heart murmurs, ascites and hypertension can also be seen during this period (1,17). All of our cases had a tricuspid valve murmur, while five had respiratory difficulties and intolerance toward exercise. These were similar to the literature (1,17). Pulmonary edema, right heart insufficiency and ascites adversely affected the cases and worsened the clinical situation in the dogs infected with dirofilariasis (1,13,14). Two of our dogs had severe ascites and one had severe right heart dilatation. Although five of the cases had respiratory difficulties and right heart dilatation was observed in the radiographic evaluation, they did not have clinical findings because of this situation.

The vena cava caudalis can sometimes be obstructed acutely with *D. immitis* and this is called caval syndrome. The dogs had anemia, hemoglobinemia and hemoglobinuria (1,13,14,21,34). None of our cases had caval syndrome, but RBC and Hb levels were below limits in preoperative evaluation. Right heart insufficiency could be observed due to the increase in vascular resistance and one of our cases had right heart dilatation (1,13).

Most of the infected dogs developed pulmonary hypertension and the clinical symptoms were observed. The massive presence of live parasites in the pulmonary artery prevents blood flow in turn increasing blood pressure (1,13,17). In our cases, although arterial blood pressure was high, it cannot be identified as arterial hypertension, indicating that parasites had not yet occluded the artery.

Blood gases were imbalanced when the dogs were severely affected. Although healthy dogs have 55.3 mmHg pO₂, the dogs in the study had 40.0 mmHg pO₂ in their venous blood (1,18).

In the study, the pH was low, the pCO₂ level was high and pO₂ was low in the blood gases during preoperative evaluation. In addition to these values, the HCO₃ level was low. The results were similar to the findings of Kitagawa et al. (18). These not only supported the intolerance towards exercise in the infected dogs, but also the collapse of respiration and circulation that developed during the infection.

The CPB can be effectively used in the dogs for several reasons such as the removal of cardiac parasites (31,35-37), the correction of ventricular and atrial septal defects (38), the correction of mitral valve repair (39) and experimental surgery.

Open-heart surgery and cardiopulmonary bypass affect homeostasis. It requires complex and advanced types of instruments and an educated staff. In humans, it is performed by using the ascending aorta for the arterial outflow and the right atrium for the venous inflow beside the median sternotomy. In dogs, lateral thoracotomy accompanies right atrial and femoral arterial cannulation (31).

In this study, surgery was carried out according to the literature and none of the cases had surgical complication during the cardiopulmonary bypass. In the postoperative evaluation, we did not have any complications due to coagulation or bleeding. We used membrane oxygenators and a non-hemic prime solution.

In this study, we did not experience any complications due to the open-heart procedure that was used for the first time in Turkey to treat dogs naturally infected with *D. immitis*. This surgical method can be safely used for treatment. In conclusion, cardiopulmonary bypass is a safe and successful approach for dogs and can be a treatment method for *D. immitis* infection but it is expensive and requires an educated staff.
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References


