Changes in Cardiopulmonary Values after Heartworm Removal from Pulmonary Artery using Flexible Alligator Forceps

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(Received 12 November 1987/Accepted 29 January 1988)

ABSTRACT. Radiograph, arteriograph, echocardiogram, electrocardiogram and cardiopulmonary values were obtained in dogs with dirofilariaisis before and after heartworm removal with a flexible alligator forceps. After heartworm removal, the following results were obtained: 1) Dilations of the pulmonary artery, the right ventricle and the right atrium reduced on radiograph and ultrasonic echocardiogram; 2) tortuosity of the pulmonary artery was reduced, and pruning of the peripheral arteries improved on arteriogram; 3) electrocardiographic findings indicated the correction of right axis deviation in mean electric axis in frontal plane and decreases of voltages; 4) pulmonary arterial and right ventricular pressures fell (improvement of pulmonary hypertension); 5) right cardiac output decreased; 6) heart rate tended to decrease; and 7) total pulmonary arterial resistance decreased. These results indicated that pulmonary arterial resistance and blood flow volume might be reduced, thus decreasing the burden on the heart. It was considered that not only lesions of the pulmonary arteries but also heartworms themselves in the pulmonary artery play an important role in affecting right heart hemodynamics.—KEY WORDS: canine dirofilariaisis, cardiopulmonary value, flexible alligator forceps, heartworm removal.


The current treatment of heartworm-infected dogs is the surgical heartworm removal by thoracotomy [7, 11] or internal adulticidal treatment [5, 10]. Recently, the authors developed a flexible alligator forceps; a new instrument for heartworm removal from the pulmonary artery through the jugular vein without thoracotomy in dogs [8]. Almost all heartworms (over 90%) could be removed from the pulmonary artery, and no significant harm was found by the treatment with this forceps [8]. As different from thoracotomy or adulticidal treatment, heartworm removal with this forceps through the jugular vein does not disturb the hemodynamics of dogs. Therefore, the efficacy of heartworm removal for hemodynamics can be studied with accuracy in a short period after heartworm removal. The present study describes the changes in cardiopulmonary values after heartworm removal with a flexible alligator forceps in dogs with heartworm disease. After heartworm removal, the cardiopulmonary values were improved significantly.

MATERIALS AND METHODS

Twenty-four dogs with subclinical to mild naturally infected dirofilariaisis, 5 outpatients of the Veterinary Hospital, University of Gifu, and 19 dogs introduced from the regional dog ponds, were used. These dogs weighed from 5.5 kg to 18.0 kg, consisting of 14 females and 10 males. The presumed age of dogs was from 2 to 10 years old. Electrocardiography and radiography were made in all conscious dogs, and measurements of cardiac output and pressures in the right heart were undertaken in 16 experimental dogs under general anesthesia before and 1 and 4 weeks after heartworm
removal. Two-dimensional and M-mode echocardiographies were done with an ultrasonic convex array scanner (EUB-40, Hitachi Medical Corp. Tokyo). The 6-lead electrocardiograms (I, II, III, aVR, aVL, and aVF) were recorded in right lateral recumbency. Left-lateral and dorso-ventral thoracic radiographs were obtained from each dog. Arteriography was performed before and 4 weeks after heartworm removal. As the contrast medium, about 60% of methohizocid (Isopaque, Torii & Co., Ltd., Tokyo) was used. The experimental dogs were anesthetized by intramuscular injection of 0.25–0.5 mg/kg body weight of diazepam (Cercine, Takeda Chemical Industries, Ltd., Osaka) and 2.0–5.0 mg/kg body weight of ketamine hydrochloride (Ketalar, Sankyo Co., Ltd., Tokyo) for measurements of cardiopulmonary values.

The heartworm removal from the pulmonary artery through the jugular vein was performed according to our previous report [8]. A Swan-Ganz flow directed pediatric thermodilution catheter (93–132–5F, Edwards Lab., Santa Ana, U.S.A.) was inserted into the pulmonary artery and the right ventricle. The catheter position was verified by fluoroscopy. The catheter was connected with a blood pressure transducer and a multi purpose polygraph for measurement of pulmonary arterial and right ventricular pressures. The 0-reference was placed at the midpoint of thoracic thickness at the 3rd intercostal space. A thermodilution amplifier and a cardiac output computer were used for measurement of right cardiac output. Cardiac index (cardiac output/kg body weight), stroke volume (cardiac output/heart rate), stroke index (stroke volume/kg body weight) and total pulmonary resistance (60 mean pulmonary arterial pressure 1332/cardiac index) were calculated from each parameter. A paired t-test was used to compare the means, which were considered significantly different at p<0.05.

At the completion of each experiment, the dogs were euthanatized, and the number of remaining heartworms were counted.

RESULTS

Heartworm echoes were observed only in the pulmonary arteries in all the dogs before heartworm removal (Fig. 1). From 13 to 106 heartworms were removed from the pulmonary artery of dogs, and mean removal efficacy in 19 dogs was 90.4±7.1 (SD)%. After removal, almost all heartworm echoes disappeared (Fig. 2). On radiograph (Figs. 3 and 4) and pulmonary arteriograph (Figs. 5 and 6), the dilations or enlargements of the main pulmonary artery, the lobar vessels, the right ventricle and the right atrium reduced till 4 weeks after heartworm removal. Because of decreased lung density, the vessels were observed clearly. On arteriogram, the dilation and tortuousness of the pulmonary arteries were reduced, and pruning of the peripheral arteries improved after heartworm removal. The dimension of the main pulmonary artery measured by M-mode echocardiography was significantly reduced 1 and 4 weeks after removal (Table 1).

Table 2 shows the electrocardiographic findings before and after heartworm removal. The mean electrical axis in the frontal plane was +89.3±33.3 degrees before removal. The axis did not change significantly 1 week after removal, but it shifted counterclockwise significantly (+81.1±27.4 degrees) 4 weeks after removal. Although within normal limits, the voltages of P, Q and R waves decreased significantly after heartworm removal.

Table 3 shows the pressures in the pulmonary artery and the right ventricle before and after heartworm removal. Systolic, mean and diastolic pulmonary arterial pressures and systolic right ventricular pressure fell 1 week after heartworm removal.
Fig. 1. Echocardiogram before heartworm removal.
Many heartworm echoes were observed in the pulmonary artery.

Fig. 2. Echocardiogram after heartworm removal.
No worms can be observed in the pulmonary artery.

Fig. 3. Radiograph before heartworm removal.

Fig. 4. Radiograph 4 weeks after heartworm removal.

Moreover, these pressures fell 4 weeks after removal. Diastolic right ventricular pressure did not change significantly after heartworm removal.

Table 4 shows the heart rate. The heart rate in conscious dogs decreased significantly after heartworm removal. The heart rate under anesthesia tended to decrease, but it was not statistically significant.

Table 5 shows cardiac output and total
pulmonary resistance. One week after removal, although not statistically significant, the cardiac output, cardiac index and stroke volume tended to decrease. The decreases in these parameters became statistically significant 4 weeks after removal. Total pulmonary resistance decreased significantly 1 and 4 weeks after heartworm removal.

**DISCUSSION**

In the present study, the following results were obtained after heartworm removal: 1) dilations of the pulmonary artery, the right ventricle and the right atrium were reduced morphologically on radiograph and ultrasonic echocardiogram; 2) tortuosity of the pulmonary artery was reduced, and pruning of the peripheral arteries improved on arteriogram; 3) electrocardiographic findings indicated the improvement of right axis deviation in mean electric axis in frontal plane and decreases of voltages; 4) pulmonary arterial and right ventricular pressures fell (reduced pulmonary hypertension); 5) right cardiac output decreased; 6) the heart rate tended to decrease; and 7) total pulmonary arterial resistance decreased. These
Table 2. Electrocardiographic findings before and after heartworm removal

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>Before Mean</th>
<th>Mean SD</th>
<th>1 week after Mean</th>
<th>Mean SD</th>
<th>4 weeks after Mean</th>
<th>Mean SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean axis (degree)</td>
<td>24</td>
<td>89.3 (212-53)</td>
<td>33.3 (0.30-0.07)</td>
<td>91.4 (205-43)</td>
<td>30.0 (0.27-0.03)</td>
<td>81.1 (0.28-0.05)</td>
<td>27.4 (187-39)</td>
</tr>
<tr>
<td>P wave (mV)</td>
<td>24</td>
<td>0.163 (0.69-0)</td>
<td>0.056 (0.69-0)</td>
<td>0.137 (0.69-0)</td>
<td>0.065 (0.69-0)</td>
<td>0.140 (0.69-0)</td>
<td>0.057 (0.69-0)</td>
</tr>
<tr>
<td>Q wave (mV)</td>
<td>24</td>
<td>0.156 (0.69-0)</td>
<td>0.167 (0.69-0)</td>
<td>0.126 (0.69-0)</td>
<td>0.109 (0.69-0)</td>
<td>0.078 (0.69-0)</td>
<td>0.079 (0.69-0)</td>
</tr>
<tr>
<td>R wave (mV)</td>
<td>24</td>
<td>0.74 (1.6-0)</td>
<td>0.37 (1.6-0)</td>
<td>0.66 (1.6-0)</td>
<td>0.28 (1.6-0)</td>
<td>0.64 (1.6-0)</td>
<td>0.26 (1.6-0)</td>
</tr>
<tr>
<td>S wave (mV)</td>
<td>24</td>
<td>0.018 (0.25-0)</td>
<td>0.056 (0.25-0)</td>
<td>0.017 (0.25-0)</td>
<td>0.037 (0.25-0)</td>
<td>0.015 (0.25-0)</td>
<td>0.041 (0.25-0)</td>
</tr>
<tr>
<td>T wave (mV)</td>
<td>24</td>
<td>0.23 (0.74-0)</td>
<td>0.18 (0.74-0)</td>
<td>0.18 (0.74-0)</td>
<td>0.12 (0.74-0)</td>
<td>0.23 (0.74-0)</td>
<td>0.24 (0.74-0)</td>
</tr>
</tbody>
</table>

a) Standard deviation.
b) c) Significantly different from before removal; each asterisk indicates at p<0.05 (b) and at p<0.01 (c), respectively.
d) Range (Maximum-Minimum).

Table 3. Pressures in the pulmonary artery and the right ventricle before and after heartworm removal

<table>
<thead>
<tr>
<th>Item</th>
<th>Phase</th>
<th>n</th>
<th>Before Mean</th>
<th>Mean SD</th>
<th>1 week after Mean</th>
<th>Mean SD</th>
<th>4 weeks after Mean</th>
<th>Mean SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic</td>
<td>Pulmonary</td>
<td>19</td>
<td>53.0 (91.2-32.6)</td>
<td>16.2 (91.2-32.6)</td>
<td>33.8 (57.5-15.5)</td>
<td>11.2 (57.5-15.5)</td>
<td>27.2 (42.0-14.6)</td>
<td>8.3 (42.0-14.6)</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>Mean</td>
<td>19</td>
<td>35.4 (54.6-23.3)</td>
<td>9.6 (54.6-23.3)</td>
<td>21.6 (33.9-11.1)</td>
<td>6.8 (33.9-11.1)</td>
<td>17.7 (30.8-8.4)</td>
<td>6.4 (30.8-8.4)</td>
</tr>
<tr>
<td>Diastolic</td>
<td></td>
<td>19</td>
<td>26.5 (42.0-16.3)</td>
<td>7.2 (42.0-16.3)</td>
<td>15.5 (25.9-6.6)</td>
<td>5.2 (25.9-6.6)</td>
<td>12.8 (25.2-5.4)</td>
<td>5.7 (25.2-5.4)</td>
</tr>
<tr>
<td>Right ventricular pressure (mmHg)</td>
<td>Systolic</td>
<td>19</td>
<td>51.8 (88.5-32.1)</td>
<td>15.5 (88.5-32.1)</td>
<td>33.1 (57.0-13.8)</td>
<td>10.5 (57.0-13.8)</td>
<td>26.2 (44.0-14.7)</td>
<td>8.1 (44.0-14.7)</td>
</tr>
<tr>
<td>Diastolic</td>
<td></td>
<td>19</td>
<td>−4.3 (1.2-12.3)</td>
<td>3.2 (1.2-12.3)</td>
<td>−3.8 (−0.5−8.8)</td>
<td>2.7 (−0.5−8.8)</td>
<td>−3.2 (−0.2−6.3)</td>
<td>2.0 (−0.2−6.3)</td>
</tr>
</tbody>
</table>

a) Standard deviation.
b) Significantly different from before removal at p<0.01.
c) Range (Maximum-Minimum).
Table 4. Heart rate before and after heartworm removal

<table>
<thead>
<tr>
<th>Item</th>
<th>State of dog</th>
<th>n</th>
<th>Before (Mean±SD)</th>
<th>1 week after (Mean±SD)</th>
<th>4 weeks after (Mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>Conscious</td>
<td>19</td>
<td>127 (175–80)</td>
<td>110 (190–56)</td>
<td>96 (167–63)</td>
</tr>
<tr>
<td>(beat/min)</td>
<td>Anesthetized</td>
<td>19</td>
<td>169 (210–120)</td>
<td>159 (215–123)</td>
<td>156 (213–113)</td>
</tr>
</tbody>
</table>

a) Standard deviation.
b) Significantly different from before removal; each asterisk indicates at p<0.05 (b) and p<0.01 (c), respectively.
d) Range (Maximum-Minimum).

Table 5. Right cardiac output and total pulmonary resistance before and after heartworm removal

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>Before (Mean±SD)</th>
<th>1 week after (Mean±SD)</th>
<th>4 weeks after (Mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac output (l/min)</td>
<td>19</td>
<td>2.96 (6.81–1.99)</td>
<td>2.72 (4.2–1.66)</td>
<td>2.08 (2.96–1.36)</td>
</tr>
<tr>
<td>Cardiac index (ml/min/kg)</td>
<td>19</td>
<td>348 (607–166)</td>
<td>323 (505–200)</td>
<td>262 (398–130)</td>
</tr>
<tr>
<td>Stroke volume (ml/min/beat)</td>
<td>19</td>
<td>17.6 (37.3–11.1)</td>
<td>17.5 (34.2–10.6)</td>
<td>13.8 (23.4–7.4)</td>
</tr>
<tr>
<td>Stroke index (ml/min/beat/kg)</td>
<td>19</td>
<td>2.06 (3.75–1.10)</td>
<td>2.05 (3.59–1.26)</td>
<td>1.74 (2.88–0.70)</td>
</tr>
<tr>
<td>TPUR (dyn×sec×cm⁻²×kg⁻¹)</td>
<td>19</td>
<td>9249 (25420–4016)</td>
<td>5766 (9830–2421)</td>
<td>5611 (9289–1339)</td>
</tr>
</tbody>
</table>

a) n=18.
b) Standard deviation.
c) Significantly different from before removal; each asterisk indicates at p<0.05 (c) and p<0.01 (d), respectively.
c) Range (Maximum-Minimum).
f) Total pulmonary resistance.

findings indicated decreases of the resistance to blood flow and the volume of blood flow through the lung and reduce of the size of the right heart-pulmonary vessel system following the heartworm removal. The burden of the heart in pumping the blood was significantly reduced. The congestion of the systemic and pulmonary circulation might be resolved, and clinical signs such as coughing, labored respiration and intolerance for exercise might improve.

In general-type heartworm disease (dirofilariasis), the heartworms in the pulmonary artery and various lesions such as villial and proliferative lesions on the surface of the pulmonary arteries, obstructive fibrosis of the small arteries and granulomatous lesions with dead worms can coexist [1, 2, 9, 20].
Lesions of the lung were found to be more important for revelation of pulmonary hypertension than the presence of heartworms in the pulmonary artery [14]. In the present study, however, the dilations of the pulmonary artery were reduced, and pulmonary hypertension and signs of heartworm disease were improved significantly within a relatively short period after heartworm removal. Different from the hypothesis [16] approved currently, not only the lesions of the lung but also the heartworms themselves might play an important role in affecting the right heart hemodynamics (occurrence of pulmonary hypertension) in canine dirofilariasis.

It was reported that the central blood volume was less [13], and the cardiac index was not greater [15, 21] in heartworm infected dogs. However, it was also reported that the pulmonary arteries and the right heart dilated in heartworm-infected dogs [3, 4, 12, 17, 22]. These dilations were reduced and right cardiac output decreased after heartworm removal in the present study. Therefore, it may be appropriate to consider that the blood flow volume through the lung, namely right cardiac output, may be larger in heartworm-infected dogs in the slight to mild stage of the disease, and it decreased following removal of the burden. The cardiopulmonary values after heartworm removal in dogs with serious dirofilariasis will be described in a separate paper.

The availability of heartworm elimination has been recognized in practitioners. Though many problems were encountered (occasionally the dogs died), the surgical heartworm removal by thoracotomy or adulticidal treatment produced clinical improvement after the treatment [5, 7, 10, 11, 18, 19]. Because of this fact and the lack of other adequate methods, these two treatments have been used as the therapy of choice for heartworm disease. On the other hand, the operation with a flexible alligator forceps could remove the heartworms in the pulmonary artery with high efficacy and safety. After heartworm removal, circulatory disturbances with heartworm infection rapidly disappeared, and clinical recovery of the dogs was also rapid [6]. The heartworm removal with a flexible alligator forceps is very much as the therapy of choice in heartworm disease from the standpoint of right heart hemodynamics.

REFERENCES


要約

フレキシブル・アリゲーター鉛子による肺動脈内犬糸状虫摘出後の循環動態の変化：石原勝也・北川 均・佐々本栄英・横井宏枝（岐阜大学農学部家畜内科学講座）—フレキシブル・アリゲーター鉛子により肺動脈に寄生する犬糸状虫を摘出し、摘出後のX線像、心電図、右心系循環動態などの変化を観察・測定した。犬糸状虫摘出後、肺動脈、右心室及び右心房の拡張は縮小し、肺動脈の屈曲及び末梢肺動脈の切り詰め像は改善された。心電図では、平均電気軸における右軸変位の改善と各波の電位低下が認められた、肺動脈圧及び右心室圧は低下し、右心拍出量、心拍数及び総肺血管抵抗も減少した。これらの結果から、肺の血管抵抗の低下と血流量の減少、心臓負荷の軽減が示唆された。摘出後各パラメーターが短期間に改善された所見から、右心系循環動態の異常発現には、肺血管病変のみならず、犬糸状虫そのものも重要な役割を果たしていると考えられた。