Radiographic Diagnosis of Feline Heartworm Disease and Correlation to Other Clinical Criteria: Results of a Multicenter Clinical Case Study

W.R. Brawner, Jr
A.R. Dillon
C.K. Robertson-Plouch
J. Guerrero

College of Veterinary Medicine, Auburn University, AL
Merial, Limited, Iselin, NJ

ABSTRACT

Two-hundred fifteen cats with clinical signs consistent with feline heartworm disease (FHD) were entered into this clinical case study. In addition to physical examination, CBC, and heartworm antibody (Ab) and antigen (Ag) tests, thoracic radiographs were taken of 212 cats at initial examination. For cats that had a positive Ab or Ag test, or radiographic changes that could be associated with FHD, follow-up radiographs were taken at approximately 60 to 90 days after initial examination whenever possible. Each radiographic examination included VD, DV, and left lateral views, and each was read by the same board-certified radiologist who was blinded to heartworm serological results until after radiographic evaluation was completed. Criteria evaluated included heart size and shape, pulmonary artery enlargement, pulmonary parenchymal involvement, hyperinflation of lungs, tenting of the diaphragm, and pleural fluid accumulation. Summary interpretations and heartworm score were recorded. The heartworm score reflected the degree of suspicion of FHD based on radiographic signs: no radiographic signs of FHD; bronchointerstitial lung pattern only (consistent with but not specific for FHD); or pulmonary artery enlargement (with or without pulmonary or cardiac changes) mildly, moderately, or strongly indicative of FHD. Of 212 cats for which radiographs were taken at the initial examination, 38 (18%) had enlarged caudal lobar arteries indicative of FHD and 90 (42%) had bronchointerstitial pulmonary disease consistent with heartworms and/or enlarged caudal lobar arteries. Radiographic changes consistent with or indicative of FHD were evident in 9/22 cats (41%) presenting with gastrointestinal signs, 39/78 cats (50%) presenting with respiratory signs, and 41/80 cats (51%) presenting with both respiratory and gastrointestinal signs. Some cats presenting with only gastrointestinal signs had thoracic radiographic changes suggestive of FHD.

Eleven cats tested DiroCHEK® Ag positive, and radiographs were taken of 10. Of the 10 cats, 5 had radiographic changes indicative of FHD; one had changes consistent with FHD; and 4 cats showed no radiographic signs of FHD. Follow-up radiographs were taken of 6 of these 11 cats: 1/6 worsened in radiographic score, 3/6 improved in radiographic score, and 2/6 still demonstrated no radiographic signs of heartworm. Ninety-two cats tested Ab positive at initial examination, and radiographs were...
available for 91 of these cats. In 22/91 (24%), enlarged caudal lobar arteries indicated FHD. In 39/91 cats (43%) cats, radiographic signs consistent with or indicative of FHD were seen.

Of the 38 cats that had radiographic signs indicative of FHD, 22 (58%) were Ab positive on one or both tests. Seven (32%) had positive DiroCHEK Ag tests at initial or recheck examination. At recheck examinations, 2 cats that initially had radiographic signs indicative of FHD converted from DiroCHEK Ag negative to positive, confirming their infection with at least 1 sexually mature female heartworm. While many affected cats show pulmonary arterial enlargement and/or a bronchointerstitial pattern typical of FHD, some cats with serologic evidence of heartworms do not demonstrate any thoracic radiographic changes. Conversely, some cats show radiographic signs suggesting heartworm disease when concurrent serology is negative. These discrepancies may be caused by time between infection and examination, by differences in individual cats’ immune response to the presence of larval or adult stages of heartworm, or by aberrant migrations.

INTRODUCTION

Several papers have described radiographic changes characteristic of feline heartworm disease (FHD), which primarily consist of enlargement of the caudal lobar pulmonary arteries and bronchointerstitial pattern. However, none of the papers have utilized naturally occurring cases of heartworm in the cat, following their radiographic progress over time. Feline heartworm disease is a dynamic disease that may present itself to the veterinarian in various stages, influenced by the stage of the life cycle of the worm, the reaction of the cat to the parasite, and the live/dead status of the worm. Some evidence suggests that some pathologic changes resulting from heartworm can be permanent. Consequently, a better understanding of the variable radiographic appearance of FHD is of diagnostic and potentially prognostic value.

The objectives of this study were to identify cats with concurrent or previous FHD, and to characterize their radiographic presentation, correlate to other clinical findings, and follow their progress over a period of several months.

MATERIALS AND METHODS

As reported in an overview of this study, veterinarians from 15 private practices in Florida, South Carolina, Tennessee, and Texas were asked to participate in the survey by contributing data on cats presenting to their practices with signs of heartworm, including respiratory signs (coughing and dyspnea), and gastrointestinal signs (pattern of intermittent vomiting). The clinical database included signalment and clinical examination findings, environmental data, CBC, Knott, DiroCHEK® antigen (Ag) test, antibody (Ab) tests by Animal Diagnostics and Heska laboratories, and thoracic radiographs.

Thoracic radiographs also were taken at the initial examination. Each radiographic examination included left lateral, VD, and DV views, and were submitted to the same board-certified radiologist for evaluation. The radiologist was blinded to heartworm serological results until after radiographic evaluation was complete.

Each set of radiographs was evaluated for heart size and shape, cranial and caudal pulmonary lobar artery enlargement, presence of bronchointerstitial disease, pulmonary edema, pulmonary consolidation or nodular opacities, hyperinflation of lungs, tenting of the diaphragm, and pleural fluid accumulation. From this evaluation, summary interpretations were given for each case. The radiologist, on completion of each evaluation, gave each case a heartworm score. The heartworm score reflected the degree of suspicion of FHD based on ra-
diagnostic signs (Table 1).

For cats that were Ab positive, or had radiographic scores suggestive of FHD at the initial examination, follow-up radiographs were taken approximately 60 to 90 days later, whenever possible. These radiographs were evaluated by the radiologist in the same manner as described above.

RESULTS

As a prerequisite for entry into the study, all cats submitted to the study showed clinical signs of heartworm. Of the 215 cats presented, 94 (44%) were Ab positive by one or both tests, and 13 cats were Ag positive at the initial and/or follow-up examination.

Radiographs were obtained at the initial presentation for 212 of the 215 cats admitted into this study. The results presented here will be limited to these 212 cats.

On initial examination 144 of the 212 cats, (68%) had either radiographic signs suggestive of or consistent with FHD, or positive Ab titer. Thirty-eight of the 212 cats (18%) showed radiographic signs suggestive of FHD (score 1, 2, or 3) and an additional 52 cats exhibited a bronchointerstitial pulmonary pattern consistent with FHD. Combining those two groups, 90 (42%) showed radiographic signs that suggested the possibility of FHD (score >0). Among these 90 cats, 60% had positive antibody titers. Of the 38 cats that had radiographic signs suggestive of FHD, 22 (58%) were positive by one or both Ab tests. Seven (32%) had a positive Ag test at either the initial or follow-up examination.

Radiographic signs were not suggestive or consistent with heartworm disease in 122 of the 212 cats. Cardiac or pulmonary disease not related to FHD was diagnosed in 34 cats. Hypertrophic cardiomyopathy was the most common disease other than FHD seen in these cats.

Cats with a positive Ab test, or positive radiographic signs, were requested to return for follow-up examination. Of the 145 cats that fit this criteria, 81 were examined and radiographed approximately 60 to 90 days following the initial examination, allowing a comparison of the radiographs taken at the different times to monitor the progress of the individual cat’s condition.

Presenting Signs

Radiographic changes consistent with, or suggestive of, FHD were evident in 9/22 cats

<table>
<thead>
<tr>
<th>Score</th>
<th>Definition</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No radiographic sign of FHD</td>
<td>No radiographic changes consistent with FHD</td>
</tr>
<tr>
<td>0.5</td>
<td>Consistent with but not specific for FHD</td>
<td>Increased bronchointerstitial opacity only</td>
</tr>
<tr>
<td>1</td>
<td>Mildly indicative of FHD</td>
<td>Caudal lobar artery enlargement with or without pulmonary or other abnormalities</td>
</tr>
<tr>
<td>2</td>
<td>Moderately indicative of FHD</td>
<td>Caudal lobar artery enlargement with or without pulmonary or other abnormalities</td>
</tr>
<tr>
<td>3</td>
<td>Strongly indicative of FHD</td>
<td>Caudal lobar artery enlargement with or without pulmonary or other abnormalities</td>
</tr>
</tbody>
</table>
Presenting with only gastrointestinal (GI) signs, 39/78 cats (50%) presenting with only respiratory signs, and 41/80 cats (51%) presenting with both respiratory and GI signs. Thirty-three of the cats presenting with only respiratory signs returned for a recheck, and 28 of these had a positive radiographic score at the follow-up exam. Of the cats initially presenting with GI signs only, 18 returned, and 6 of these were positive radiographically at the recheck. Of the cats presenting with both respiratory and GI signs, 30 returned and 19 of these had a positive radiographic score at the follow-up exam.

**Initial Versus Follow-up Radiographs**

Of the 81 cats successfully recruited for recheck examination, 24 had worsened in radiographic score, 13 had improved, and 44 had no change. Of those cats whose radiographic scores changed from the initial exam, 8 of them changed more than one place on the radiographic score scale. Three of these cats improved in radiographic appearance, while 5 of the cats worsened. Of the 30 cats initially showing no radiographic changes consistent with heartworm, 13 of them worsened to a score of 0.5 on recheck examination.

**Radiographs Versus Antigen-positive Cases**

Through the course of the study, 13 cats tested Ag positive. Eleven of them were Ag positive on initial examination. At the follow-up examination, two cats that initially had radiographic signs suggestive of FHD converted from Ag negative to positive, confirming the initial radiographic diagnosis of existing heartworm disease.

At the initial examination, radiographs were taken of 10 of the 11 Ag-positive cats. Of these 10, 5 had radiographic changes suggestive of FHD (score 1, 2, or 3), one had changes consistent with FHD (score 0.5), and 4 showed no radiographic signs of FHD (score 0). Follow-up radiographs were taken of 6 of these 11 cats. While half of the cats had improved in radiographic score, 1 of the 6 worsened in radiographic score, and 2 of the 6 still demonstrated no radiographic signs of heartworm.

**Antibody-positive Cases**

Radiographs were available for 91 of the Ab-positive cats. In 22/91 (24%), enlarged caudal lobar arteries suggested FHD (score 1, 2, or 3). In 39/91 cats (43%), radiographic signs consistent with, or suggestive of, FHD were seen. Seven of the 91 Ab-positive cats showed radiographic signs characteristic of hypertrophic cardiomyopathy, 6 showed other radiographic

---

**Table 2. Radiographic Scores of Cats Submitted**

<table>
<thead>
<tr>
<th>Radiographic Score</th>
<th>No. cats</th>
<th>No. antibody positive by one or both tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6 (3%)</td>
<td>5/6 (83%)</td>
</tr>
<tr>
<td>2</td>
<td>14 (7%)</td>
<td>10/14 (71%)</td>
</tr>
<tr>
<td>1</td>
<td>18 (8%)</td>
<td>8/18 (44%)</td>
</tr>
<tr>
<td>0.5</td>
<td>52 (25%)</td>
<td>17/52 (33%)</td>
</tr>
<tr>
<td>0</td>
<td>122 (58%)</td>
<td>53/122 (43%)</td>
</tr>
</tbody>
</table>

---

**Table 3. Cats with Radiographic Signs of FHD (Score 0.5, 1, 2, or 3) on Initial and Recheck Examination**

<table>
<thead>
<tr>
<th>Positive Radiograph Score at:</th>
<th>Respiratory</th>
<th>Gastrointestinal</th>
<th>Respiratory and Gastrointestinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial examination</td>
<td>39/78 (50%)</td>
<td>9/22 (41%)</td>
<td>41/80 (51%)</td>
</tr>
<tr>
<td>Recheck examination</td>
<td>28/33 (85%)</td>
<td>6/18 (33%)</td>
<td>19/30 (63%)</td>
</tr>
</tbody>
</table>
abnormalities not related to FHD, and 26 showed no abnormal radiographic findings. Cats with a higher radiographic score were more likely to exhibit a positive antibody titer, although 42% of the cats with no radiographic signs of FHD were positive on one or both antibody tests (Table 4).

Among cats that were negative on both Ab tests, 13% showed radiographic signs of FHD and among cats that showed positive Ab titers, 46% showed no radiographic signs of FHD. These discrepancies were not unexpected because the time of seroconversion after infection and the duration of positive Ab titer have not been definitively established.

<table>
<thead>
<tr>
<th>Table 4. Cats Whose Radiographic Scores Changed More than One Place on the Radiographic Score Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiographic Score</strong></td>
</tr>
<tr>
<td><strong>No. Cats</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

Immunological changes and visible radiographic changes may not always occur at the same time. Thirteen percent of the Ab-negative cats had radiographic signs of FHD. These may be representative of individual variation in immune response, or of cats that are at varying disease stages when these parameters are not both positive. Forty-six percent of the Ab-positive cats had no radiographic signs associated with heartworm. This may represent cats for which anatomical changes visible on radiographs had not yet occurred, did not occur, or were sub-radiographic in nature.

Among the 90 cats exhibiting radiographic signs consistent with FHD, 60% had positive Ab titers. Among cats that were negative on both Ab tests, 13% showed radiographic signs of FHD, and among cats that showed positive Ab titers, 46% showed no radiographic signs of FHD. Disparities such as these are not unexpected because the time of seroconversion after infection and the duration of positive Ab titer have not been definitively established. It is also important to remember that the cats in this study were clinical patients that were naturally infected. Unlike most experimental studies, where all infective larvae are administered at the same time, natural infections may occur over an extended period of time such that the precise time of infection cannot be established.

Considering these variations, it is not unreasonable to expect that radiographically visible cardiovascular and pulmonary changes caused by heartworms might precede and/or persist after serologically detectable immune response. It must also be noted that significant anatomic changes in the heart, pulmonary arteries, or pulmonary parenchyma must be present for detection of FHD on thoracic radiographs. Functional abnormalities and subtle anatomic changes can be present but not detectable on radiographs. Also, radiographs represent a spe-
specific point in time. Cardiopulmonary response to heartworm infection is dynamic and radiographs may not show changes if they are made very early or very late in the course of the disease. For these reasons, complete correlation between radiographic signs of FHD and immunologic evidence of FHD throughout the course of the infection is unlikely.

Radiographic changes suggestive of FHD may occur before circulating Ab or Ag levels are detectable. In this study, two cats that were initially Ag negative but showed radiographic evidence (enlarged pulmonary arteries) suggestive of heartworm, then converted to Ag positive on recheck evaluation. This conversion to Ag positive confirmed the presence of at least one adult female worm. These data demonstrate that radiographic changes do not always parallel detectable Ab and Ag changes.

Radiographic changes of cardiomyopathy are similar to those seen in heartworm disease in some cases. The radiographic changes that occur in these diseases are well documented but careful observation may be necessary to avoid misdiagnosis in cats with dyspnea.

Although many of the radiographic evaluations remained stable on recheck evaluation, radiographic changes in heartworm-suspect cats can change over time. In this study, approximately 10% of the cats presented for a follow-up examination showed either significant resolution or progression of radiographic signs of FHD. Interestingly, a large number of cats showed clinical improvement after treatment with corticosteroids but did not show a significant decrease in the radiographic heartworm score. This observation can be explained by the fact that cats with any evidence of bronchointerstitial lung disease, but without pulmonary arterial changes were given a score of 0.5. In many of these cases, the severity of bronchointerstitial infiltrates decreased, but the heartworm score did not change. Other reports have shown that the radiographic appearance of the thorax changes over a period of months in cats with heartworm infection. It is likely that more changes would have been seen in this study if additional follow-up examinations had been made or if the follow-up examinations were made at a longer interval.

While many cats with FHD show pulmonary arterial enlargement and/or a bronchointerstitial pattern typical of FHD, some cats with serologic evidence of heartworms do not demonstrate any thoracic radiographic changes. Conversely, some cats show radiographic signs suggesting heartworm disease when concurrent serology is negative. These discrepancies are indicative of the dynamic nature of FHD. They may be caused by time between infection and examination, by differences in individual cats’ immune response to the presence of larval or adult stages of heartworm, or by aberrant migrations.

**CONCLUSION**

Radiographs allow assessment of the severity of cardiopulmonary changes when heartworm disease is present. Repeated follow-up radiography is a useful method to assess the progression or resolution of the pathologic changes caused by heartworms.

Feline heartworm disease is a dynamic syndrome in which either radiographic signs may precede serologic changes, or serologic changes may precede radiographic signs. The radiographic changes evident in the thorax detect the results of heartworm infection when a disease process causes significant physical alteration of organs or tissues to alter their radiodensity. However, this study suggests that radiographic and immunologic changes may not occur in the same time sequence.

Cats with GI signs only may have radiographic changes in the thorax suggestive of feline heartworm. Radiographic appearance of
cats with feline heartworm may improve or worsen over time. Feline heartworm disease is a dynamic disease that necessitates use of multiple diagnostic criteria to diagnose and differentiate it from many other diseases similar in appearance.

**ACKNOWLEDGMENT**

This article is reproduced with the permission of The American Heartworm Society. The material is copyrighted and is not to be reproduced in any manner without permission of The American Heartworm Society, Post Office Box 667, Batavia, IL 60510-0667 USA; 630-844-9676; www.heartwormsociety.org.

**REFERENCES**