Canine influenza virus is an emerging, highly contagious, respiratory pathogen that has not previously been radiographically described. In this retrospective case series study, we describe the thoracic radiographic appearance of confirmed canine influenza virus in six dogs. Radiographic findings varied, but included abnormal unstructured interstitial (one) and unstructured interstitial and alveolar (five) pulmonary patterns, which were distributed cranioventral (four), diffuse (one), and caudodorsal (one). The right middle (five), left cranial (five), and right cranial (four) lung lobes were most commonly affected. Additionally, mild pleural effusion was present in one dog. Intrathoracic lymphadenopathy and cranial mediastinal widening/fluid accumulation were not detected in any dog. Canine influenza virus should be considered as a differential diagnosis for canine patients with respiratory signs and a cranioventral unstructured interstitial to alveolar pulmonary pattern.

Key words: canine, influenza, radiographs, virus.
method of sample collection were also recorded. Thoracic radiographs were independently reviewed by two board-certified veterinary radiologists (S.S., A.S.) using dedicated image-viewing software (Osirix, Pixmeo, Geneva, Switzerland). The results of independent reading sessions were compared and, where disagreement occurred, a consensus opinion was generated. Reviewers were aware of the patient’s diagnosis and allowed to adjust contrast and brightness of the images as would be done in the clinical setting. Radiographic characteristics recorded were the following: presence of lymphadenopathy, pleural effusion, cranial mediastinal widening/liquid accumulation, and abnormal pulmonary patterns. If present, pleural effusion was graded as mild (minimal displacement the lung lobes), moderate (heart and diaphragm partially obscured), or severe (heart and diaphragm completely obscured). Abnormal pulmonary patterns were classified as unstructured interstitial, structured/nodular interstitial, bronchial, and alveolar. The distribution of the abnormal pulmonary patterns was recorded as cranioventral, perihilar, caudodorsal, or diffuse. If diffuse, the changes were further subclassified as symmetric or asymmetric. The specific lung lobes affected were also recorded.

**Results**

Six dogs were identified that met the inclusion criteria with no dogs excluded. All six were diagnosed with canine influenza virus via positive polymerase chain reaction. Represented breeds were three mixed breeds and one of each of the following: Chow Chow, Beagle and St. Bernard. Dogs ranged in age from 5 to 12 years with a median of 9 years. There were four neutered males and two spayed females. Five of the six dogs presented for coughing, while one dog presented for lethargy and shallow breathing. Four dogs had a history of recently visiting a boarding/daycare facility with two dogs having known direct contact with dogs subsequently diagnosed with canine influenza virus. In regards to additional respiratory diagnostics, three of six patients were diagnosed with concurrent Mycoplasma pneumonia based on a positive polymerase chain reaction via a transtracheal wash (1) or pharyngeal swab (2). All six dogs had a respiratory polymerase chain reaction panel, which, in addition to canine influenza virus and Mycoplasma, also tested for Bordetella bronchiseptica, canine adenovirus 1 and 2, canine distemper virus, and coronavirus; all of which were negative.

Reviewers identified abnormalities on all thoracic radiographic studies, which were obtained using a portable X-ray generator (MinXray HF8015, MinXray Inc., Northbrook, IL) and digital radiography system (Eklin Mark V, Sound Eklin, Carlsbad, CA) using a technique of 74–88 kV, 50 mA, and 0.15 s. While none of the dogs had radiographically apparent lymphadenopathy or cranial mediastinal widening/effusion, one dog was identified with pleural effusion, which was graded as mild. This dog was also positive for Mycoplasma. One dog had an unstructured interstitial pattern, while the remaining five dogs had two pulmonary patterns present, unstructured interstitial and alveolar (Fig. 1). No dog was identified with a structured interstitial or bronchial pattern. The distribution of the pulmonary patterns was cranioventral in four dogs, diffuse in one, and caudodorsal in one. None of the dogs had a perihilar distribution. The one dog with a diffuse pulmonary pattern was further classified as asymmetric being more severe in the right lung lobes (Fig. 2). The dog with a caudodorsal distribution of an unstructured interstitial pattern had a cranioventral alveolar pattern on follow up thoracic radiographs 3 days later. No other dog had follow up radiographs for comparison. In all dogs, multiple lung lobes were affected. The left cranial, left caudal, right cranial, right middle, and right caudal lungs were affected in two dogs; one with a cranioventral distribution, and another with a diffuse distribution. Two dogs had abnormal pulmonary patterns in the right cranial, right middle, and left cranial lung lobes; both with a cranioventral distribution. The right middle and left cranial lung lobes were affected in one dog with a cranioventral distribution. The caudodorsal unstructured interstitial pattern affected the right and left caudal lung lobes in one dog.

**Discussion**

In this study, the thoracic radiographic characteristics identified in dogs with canine influenza virus were variable. The most commonly observed characteristics were a cranioventral distribution of unstructured interstitial and alveolar patterns, with multiple lung lobes affected. Canine influenza virus should therefore be considered as a differential diagnosis in canine patients with these characteristics. In this sample of six dogs, it is unknown whether age, breed, or sex could have been risk factors for developing clinical signs. All included dogs in this study were middle aged or older. All six dogs had presenting clinical signs of nonspecific respiratory disease including those previously documented with canine influenza virus. In addition, all dogs in this study were pets with a recent history of either visiting a boarding/daycare facility (four dogs) or having direct contact with dogs subsequently diagnosed with canine influenza virus (two dogs) thus making transmission of the disease more likely.

Three of the six dogs had concurrent Mycoplasma spp. pneumonia diagnosed via polymerase chain reaction on fluid from either a transtracheal wash or pharyngeal swab. Secondary bacterial or mycoplasma infections have been documented in dogs with more severe canine influenza
Fig. 1. Left-right lateral (A), right-left lateral (B), and ventrodorsal (C) radiographs of an 11-year-old mix breed dog with canine influenza virus and an unstructured interstitial (left cranial lung lobe) to alveolar (right middle lung lobe) pulmonary pattern.

However all dogs in this study survived to discharge consistent with the previously noted low mortality rate. While a normal inhabitant of the canine upper respiratory tract, *Mycoplasma* spp. have been documented as a primary cause of pneumonia or as a coinfection. It is unknown if the positive polymerase chain reaction results for *Mycoplasma* in two of the three dogs in this study indicated true disease or normal flora based on sample location (pharyngeal). Thus possible effects of coinfection with *Mycoplasma* spp. on the radiographic findings in this sample of dogs remain unclear. A prior case series of 17 dogs with *Mycoplasma* spp. pneumonia identified a variety of radiographic changes including pleural effusion; tracheal collapse; and interstitial, bronchial, alveolar, and mixed pulmonary patterns.

Radiographically, lymphadenopathy, and mediastinal widening/effusion were not identified in any of the dogs. Mild pleural effusion was noted in one dog. While lymphadenopathy, mediastinal fluid/hemorrhage, and pleural effusion have been reported in dogs with pneumonia, it is unknown whether these findings are related to the underlying infectious agent, duration of infection or other patient factors. Pulmonary patterns identified in this study are consistent with prior studies that suggest interstitial and
alveolar are the most common pulmonary patterns for both bacterial and viral pneumonia.\textsuperscript{6,9,10,12–14} It has been noted that pulmonary changes initially start as an interstitial pattern and, as the disease progresses, the pattern becomes alveolar.\textsuperscript{10,12} The progression of disease would explain why both interstitial and alveolar patterns were identified in all but one dog in this study. The one dog in this study with an initial unstructured interstitial pattern did however go on to develop an alveolar pattern on follow up radiographs 3 days later.

A cranioventral distribution of the pulmonary patterns was most common (four dogs), with one having diffuse
asymmetric changes and another with a caudodorsal distribution. This is consistent with prior studies that suggest dogs with bacterial pneumonia or with viral and bacterial coinfections, including *Mycoplasma* spp. have radiographic findings similar to aspiration pneumonia, in that the pulmonary changes are most common in the cranioventral aspect of the lungs.\(^6,13\) This is thought to be due to the effects of gravity on the causative organism.\(^14\) A diffuse distribution of abnormal pulmonary patterns has been thought to suggest more severe disease,\(^10,12\) or viral pneumonia.\(^13\) The patient with a caudodorsal distribution of the abnormal pulmonary pattern had a cranioventral distribution on follow-up radiographs 3 days later and thus the difference may be due to the duration or severity of disease. This is the same dog that had only an unstructured interstitial pattern.

In all dogs, multiple lung lobes were affected with the right middle (five dogs), left cranial (five dogs) and right cranial (four dogs) lung lobes being most common. This is similar to dogs with aspiration pneumonia and both bacterial and viral pneumonia, as multiple lung lobes are usually affected, specifically the right middle, right cranial and left cranial lung lobes.\(^6,14\) No dog in this study had a history or documented clinical signs of vomiting/regurgitation and thus aspiration pneumonia was thought to be unlikely, but can not be completely ruled out.

The primary limitation of this study was the retrospective design. This prohibited follow-up thoracic radiographic studies from being obtained in all patients and correlation with clinical response. In addition, some infected dogs may not have been tested for canine influenza virus and thus not included in the study. Another limitation was the small number of dogs identified for inclusion, which precluded analysis of possible covariants such as age, sex, breed, or concurrent diseases. Larger prospective studies are recommended to further evaluate the thoracic radiographic appearance of canine influenza virus and to assess any correlations with clinical response.

In conclusion, canine influenza virus should be included as a differential diagnosis in canine patients with unstructured interstitial and alveolar pulmonary patterns. While viral pneumonias may have been reported to have a caudodorsal, diffuse, or cranioventral distribution; this study would suggest that a cranioventral unstructured interstitial to alveolar pattern may be common in dogs affected by canine influenza virus.

### LIST OF AUTHOR CONTRIBUTIONS

**Category 1**

(a) Conception and Design
- Scott Secrest and Ajay Sharma

(b) Acquisition of Data
- Scott Secrest and Ajay Sharma

(c) Analysis and Interpretation of Data
- Scott Secrest and Ajay Sharma

**Category 2**

(a) Drafting the Article
- Scott Secrest and Ajay Sharma

(b) Revising Article for Intellectual Content
- Scott Secrest and Ajay Sharma

**Category 3**

(a) Final Approval of the Completed Article
- Scott Secrest and Ajay Sharma

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