Management of a Canine Distemper Virus Outbreak in a Shelter

Applicant I.D. Number: 7899028

Introduction

This case report describes the management of a canine distemper virus (CDV) outbreak at an animal shelter, and highlights the importance of early diagnosis of CDV in the management of canine infectious respiratory disease complex (CIRDC). Canine distemper virus is a highly transmissible infectious agent capable of producing clinical signs ranging from mild upper respiratory disease (e.g., "kennel cough") to severe, life-threatening multisystemic disease.[1–3] It is one of the many pathogens associated with CIRDC.[4] However, in addition to affecting the respiratory tract, CDV can also affect the immune, gastrointestinal, and neurologic systems, resulting in a wide array of clinical manifestations.[5] In animal shelters, the diagnosis of CDV is often delayed because initial clinical signs mimic those of more benign pathogens involved in CIRDC.[2] Delays in diagnosis often contribute to the spread of disease, which is further confounded when shelters fail to initiate aggressive and timely control measures because they do not recognize the severity of the disease threat posed by CDV. Through the use of isolation, diagnostic testing, risk assessment, and the creation of a sanitary environment for incoming dogs, this CDV outbreak was controlled without the use of or need for depopulation. Dogs on-site at the shelter, as well as dogs in foster, adopted homes and staff member homes were involved. Outbreak management began in May 2015 and resolved by October 2015.

Canine infectious respiratory disease complex is a transmissible, multifactorial condition commonly seen in settings where dogs are densely housed indoors, such as animal shelters.[1,4,6] It is an acute-onset infection, typically involving the upper respiratory tract. Various pathogens, as

well as environmental factors and host immunocompetence, contribute to the development of CIRDC.[7] Many of the pathogens involved in CIRDC cause mild clinical signs when acting alone, but can result in increased disease severity when combined with other pathogens and certain host and environmental factors associated with sheltering.[8,9] While CIRDC is not generally associated with high mortality, significant morbidity is common.[4]

Shelters densely house transient animal populations that typically have unknown medical and vaccination histories. Animals are continuously introduced into an environment with a rapid population turnover rate. Dense housing results in increased direct and indirect contact, as well as animal stress. In addition, biosecurity protocols within shelter settings may be inadequate, such as fomite prevention, cleaning and disinfection, vaccination, use of housing, disease recognition and reporting, and isolation of clinically affected animals. These environmental and host-related risk factors can contribute to increased infectious disease rates within shelters.[4,10,11]

Multiple bacterial and viral pathogens, acting alone, sequentially, or synergistically, are associated with CIRDC; however, the role of each pathogen within the complex pathogenesis of CIRDC has not been completely elucidated.[12] While some CIRDC pathogens can cause primary respiratory disease as sole agents, other pathogens are considered secondary, contributing to clinical signs when acting as co-pathogens. In addition, some pathogens can act as primary or secondary agents in CIRDC.[4,7] Bacterial pathogens implicated in CIRDC include *Bordetella bronchiseptica* (*B. bronchiseptica*), *Mycoplasma cynos* (*M. cynos*), and *Streptococcus equi* subspecies *zooepidemicus*. Viral pathogens include CDV, canine parainfluenza (CPiV), canine adenovirus type-2 (CAV-2), canine influenza (CIV H3N8 and H3N2), canine herpesvirus-1, canine reovirus, canine respiratory coronavirus (CRCoV), and canine

pneumovirus (CnPnV). Multiple secondary, opportunistic pathogens may also be associated with CIRDC.[7]

The incubation period for most CIRDC pathogens is typically three to four days, but can range from two days for CIV H3N8 to six weeks for CDV.[4,7] All CIRDC pathogens have a preclinical shedding period, complicating disease management within shelter settings. Clinical signs and shedding typically persist for five to ten days; however, some pathogens, such as *B. bronchiseptica, M.* cynos, and CDV, can shed for prolonged periods.[7] Infected respiratory secretions transmit disease through direct contact, fomites, and aerosolization up to 7.5 meters.[13] High-density environments, such as shelters, amplify exposure, susceptibility, and transmission of CIRDC.

Clinical signs of CIRDC include a paroxysmal harsh cough, sneezing, nasal and ocular discharges, and fever. Although signs are typically mild, self-limiting, and resolve with supportive care, severe disease can occur with certain pathogens (CDV, CIV, and *Streptococcus equi* subspecies z*ooepidemicus*), with coinfection by multiple pathogens, or in young or immunocompromised dogs.[4,13] All pathogens associated with CIRDC initially cause overlapping, nonspecific clinical signs. Accordingly, specific etiologic diagnoses cannot be made based on typical clinical signs in individual patients. In shelter settings, population disease patterns and unexpected or unusually severe clinical signs can raise the index of suspicion for certain pathogens. For example, puppies developing neurologic signs during a shelter outbreak of CIRDC should raise a strong suspicion of CDV.

While many CIRDC cases are self-limiting, obtaining etiologic diagnoses is indicated if affected dogs are not responding to supportive care or are showing systemic clinical signs, or when disease prevalence increases (i.e. outbreaks).[14] A definitive diagnosis helps guide effective

treatment plans and control measures in shelter outbreaks. In an outbreak, sufficient numbers of acutely affected dogs should be sampled for pathogen testing to provide data that is representative of the larger affected population.[4,15] A common recommendation is to sample 10-30% of the acutely affected population; at minimum, three to five acutely affected dogs should be sampled.[2,15]

Diagnostic tests are available for all known CIRDC pathogens, but sensitivity and specificity of tests vary depending on the pathogens involved, the source of the sample, and the timing of sample collection. For example, many viral respiratory pathogens have peak shedding periods early in the course of disease, so timing of sample collection that does not coincide with this period may result in false negative results. Some diagnostic tests are very sensitive and the small quantity of viral or bacterial nucleic acid needed for pathogen detection can readily be cross-contaminated if personal protective equipment (PPE) is not properly used by those collecting samples. Samples should be collected from respiratory tract areas most severely affected, including the nasal, oropharyngeal, and/or conjunctival epithelium. If lower airway disease is present, a transtracheal wash specimen is preferred.

Commercially available diagnostic options include culture and sensitivity, serology, polymerase chain reaction (PCR), and histopathology. Polymerase chain reaction testing is the most practical option for pathogen detection, because commercial veterinary diagnostic laboratories offer PCR respiratory panels targeted to CIRDC. False negatives can occur due to transient or low-level shedding of respiratory pathogens.[7] False positives can occur due to recent vaccination with a modified live virus (MLV) product or if samples are contaminated during an outbreak.[13] Some laboratories offer quantitative real-time PCR to differentiate vaccination from field strain infection. Positive results also can be seen in nonclinical dogs, confounding

diagnostic and management decisions. Accordingly, the mere presence of a pathogen does not indicate causation. If the same pathogen is found in several dogs, the suspicion of a causative relationship is raised, but is not definitively ruled in. In an outbreak, necropsy and histopathology can be important to confirm both the presence and the role of involved pathogens.[7]

Treatment of CIRDC is primarily supportive, including nursing care, adequate ventilation, strategies to reduce barking and prevent tracheal irritation, and appropriate nutrition and hydration. In contrast to dogs in private homes, affected dogs in shelters may require antibiotic therapy due to the additional environmental risk factors associated with the shelter setting. Antibiotic selection is based on the suspicion of the presence of primary or secondary bacterial pathogens.[7,13]

Canine infectious respiratory disease complex is a multifactorial condition, requiring a multifaceted preventive approach. Prevention focuses on decreasing exposure to CIRDC pathogens within the shelter setting, as well as supporting the health status and immunocompetence of shelter animals. Because CIRDC is highly transmissible, shelters that are "crowded," or operating beyond their capacity to adequately care for all animals in their custody, have higher rates of CIRDC.[4] In addition, an increase in shelter length of stay (LOS), which contributes to crowding, results in increased disease rates.[16] In one study, investigators reported a 3% increase in risk for CIRDC for each additional day a dog spent in the shelter.[17] Accordingly, reducing crowding and LOS are powerful tools for CIRDC prevention. Additional preventive strategies include prompt disease recognition and isolation of affected dogs, management tools designed to reduce stress, appropriate use of housing, adequate cleaning and disinfection practices, fomite control, appropriate husbandry, and proper vaccination protocols. Commercial

vaccines against certain CIRDC pathogens are available, including CDV, CPiV, CAV-2, *B. bronchiseptica,* and CIV strains H3N2 and H3N8.

The prognosis for CIRDC is typically good, but depends on the causative agents, as well as the environmental and host factors involved. Shelters with adequate management of environmental risk factors have reduced severity and prevalence of disease.

Of the CIRDC pathogens, one viral agent, CDV, and two bacterial agents, *B. bronchiseptica,* and *M. cynos,* were identified in this shelter outbreak. The many strains of *B. bronchiseptica,* a gram-negative, aerobic coccobacillus, vary in virulence and host specificity, causing respiratory disease in dogs and cats, as well as a number of wildlife species. This pathogen was recognized as a primary cause of respiratory disease in dogs in the 1970s, but has been isolated from both clinically affected and nonclinical dogs. It is established as both a primary and secondary agent in CIRDC and is a prevalent CIRDC pathogen in the shelter setting; however, *B. bronchiseptica's* complex pathogenesis complicates its role in causing comorbidity with other CIRDC pathogens. It is primarily transmitted via aerosolization, but contaminated fomites and water sources may also be important. Upon entry into a host, it adheres to respiratory cilia and secretes toxins that damage the respiratory epithelium, induce ciliostasis, and impair phagocyte function. The resulting altered cell function and inflammation lead to compromised mucociliary clearance that predisposes its host to opportunistic viral and bacterial infections. Survival inside impaired phagocytes can result in a persistent infection. Clinical signs of *B. bronchiseptica* infection are similar to those of other CIRDC pathogens, but may be more severe in puppies and immunocompromised dogs.[7] Diagnosis of *B. bronchiseptica* is achieved through aerobic bacterial culture or PCR assays. Intranasal vaccination against *B. bronchiseptica* can result in false positive PCR results for three weeks post-vaccination.[18] In the

shelter setting, susceptibility testing is typically not performed, due to financial limitations. Accordingly, if *B. bronchiseptica* is suspected and overt bacterial pneumonia is not present, doxycycline is the treatment of choice.[4] If pneumonia is present, an alternative broad-spectrum antibiotic combination that can preferably be administered intravenously is recommended.[19] Prevention of *B. bronchiseptica* is similar to that of other CIRDC pathogens, but includes a specific vaccination strategy in the shelter setting. Both avirulent mucosal and inactivated parenteral vaccines are commercially available for *B. bronchiseptica*. However, due to its rapid onset of immunity, as well as its ability to elude interference by maternally derived antibodies (MDA), mucosal vaccination, either through an intranasal or oral formulation, should be performed.[7] Ideally, vaccination should be performed prior to shelter admission or, if not possible, immediately upon entry into a shelter.[20,21] Routine disinfectants used in the shelter setting will inactivate *B. bronchiseptica.*[4]

Mycoplasma cynos was the other bacterial CIRDC pathogen identified in this shelter outbreak. Mycoplasmas belong to the bacterial class Mollicutes, distinctive due to their lack of cell walls.[22] Various mycoplasmas have been isolated from the respiratory tract of both nonclinical and diseased dogs, but *M. cynos* is the only species that is commonly associated with respiratory disease.[23] It has been associated with pneumonia, loss of respiratory epithelial cilia, and alveolar infiltration with neutrophils and macrophages, but it is uncertain whether *M. cynos* is able to cause such pathological changes alone or when functioning as a coinfectious respiratory agent.[9] In one shelter study, investigators reported that *M. cynos* was associated with increased CIRDC severity, but further research was needed to understand the interaction between *M. cynos* and other CIRDC pathogens.[23] Accordingly, it remains unclear whether *M. cynos* is a primary or secondary pathogen in CIRDC. Due to limited research into the specific pathogenesis

of *M. cynos*, comparisons to other, more frequently studied mycoplasmas, are used to predict its pathogenesis. Transmission of *M. cynos* occurs via droplets from infected nasal and ocular discharges and saliva. It is unknown how long *M. cynos* can persist in the environment, but it has been isolated from shelter aerosols in one study, while another shelter study genetically identified local persistence of the same *M. cynos* strain in the environment even after a break of several months.[23,24] Colonization by mycoplasmas require adherence to host cells. Invasion of deeper tissues and disease occurs due to immunosuppression or disruption of normal host barriers.[22] A recently identified enzyme in *M. cynos*, sialidase, likely contributes to a direct toxic effect on host cells and host defense mechanisms.[25] Mycoplasmas can evade the host immune system and persist in tissues for prolonged periods. Because they are fastidious organisms, diagnosis of mycoplasmas through culture requires special handling and media. Diagnosis through PCR is more sensitive and allows for sequencing of species. Treatment of *M. cynos* involves specific antibiotic therapy, which is typically doxycycline. Prevention of mycoplasma infection is similar to that of other CIRDC pathogens; however, a vaccine against *M. cynos* is currently not available. Routine disinfectants inactivate mycoplasmas that persist in the environment.[22]

Doxycycline is commonly used in the shelter setting for supportive treatment of CIRDC, because of its effectiveness against a broad spectrum of organisms, including CIRDC pathogens *M. cynos* and *B. bronchiseptica*; its relatively low cost; its option for oral once daily dosing; and its minimal adverse effects when given with food.[7] Doxycycline belongs to the group of bacteriostatic, time-dependent tetracycline antibiotics that have a broad spectrum of activity against gram-positive and gram-negative bacteria, some anaerobes, and some atypical and intracellular pathogens. Tetracyclines inhibit bacterial protein synthesis by reversibly binding to

30S ribosomal subunits of susceptible organisms, such as *Mycoplasma* species, *B. bronchiseptica, Chlamydia* species, and *Rickettsia* species. Doxycycline is well-absorbed from the GI tract and is more lipophilic than older tetracyclines, resulting in better tissue and fluid penetration of the lungs, bronchial secretions, liver, kidney, prostate, and, to some extent, the CNS. It undergoes hepatic metabolism and is excreted into feces in an inactive form.[26] Doxycycline is a longer-acting tetracycline, and its long half-life permits once daily dosing. It has both anti-inflammatory and immunomodulatory properties.[27] Doxycycline has fewer adverse effects compared with other tetracycylines, but the most commonly reported adverse effects are vomiting, diarrhea, and anorexia. These adverse side effects can be reduced, without significantly reducing drug absorption, by administration with food. Compared with other tetracyclines, doxycycline is less likely to interfere with skeletal development or result in discoloration of teeth in growing animals.[26] Oral dosing should be followed with water or food to prevent adverse esophageal effects. Intravenous preparations of doxycycline are available, but are more expensive than oral formulations and must be given slowly over one to two hours.[26,27]

Canine distemper virus was the only viral pathogen identified in this outbreak. Of the pathogens associated with CIRDC, CDV is distinctive because it can cause severe multisystemic disease. Canine distemper virus is an enveloped, non-segmented, single-stranded ribonucleic acid virus that belongs to the genus *Morbillivirus* of the family Paramyxoviridae.[5] It is closely related to the measles virus of primates and the rinderpest virus of ruminants. Dogs are its primary host and can act as reservoirs of infection for mammalian wildlife, including other Canidae such as coyotes, foxes, and wolves; Procyonidae such as raccoons and pandas; Mustelidae such as ferrets, minks, skunks, and otters; and large wild Felidae such as lions, tigers, leopards, and jaguars.[28,29] Raccoons can act as reservoirs of infection for susceptible dog

populations and, as an urban-adapted wildlife species, they are of significant concern to shelters. Animal control officers may be called to respond to public complaints about raccoons, creating opportunities for interactions between raccoons and dogs. At least one documented CDV outbreak in a shelter has been related to the transportation of infected raccoons and dogs within the same animal control vehicle.[30]

A variety of CDV biotypes exist and at least six to eight major genetic lineages for field strains exist worldwide.[31] Pathogenicity differs among CDV strains. This characteristic, along with the age and immune status of the host, can cause clinical signs of CDV to differ significantly in animals.[3,32] Although vaccine strains of CDV belong to a different lineage than the field strains that circulate in North America, cross-neutralization studies convey that antigenic variations between these strains do not affect the protection induced by vaccination.[1,3] Consequently, the MLV vaccines developed in the 1950s remain highly effective in limiting infection and preventing disease.[1,2]

The incubation period of CDV is typically one to two weeks, but can be as long as six weeks.[2,3] Viral shedding of CDV can begin one week post-infection, before manifestation of clinical signs, and can persist 16 weeks post-infection but typically resolves more quickly.[5] Recovery from natural infection provides prolonged immunity. Based on CDV's long incubation period, quarantine of exposed dogs may not be feasible for resource-limited shelters in an outbreak scenario. Similarly, the possibility of a prolonged shedding period can make isolation challenging for shelters, as well. In addition to capacity and resource concerns, long-term confinement related to prolonged quarantine or isolation may compromise animal welfare by increasing emotional stress and potentially limiting enrichment opportunities.[33]

In infected animals, viral distemper particles are shed from all body secretions, but are most abundant in respiratory exudates. Both subclinically and mildly affected animals can shed virus, and it is estimated that between 25-75% of infected animals may shed virus but never show clinical signs of CDV.[2,5] In the shelter setting, animals that shed virus without manifesting clinical signs result in a chronic source of disease exposure where CDV is an unrecognized infectious agent. This is of particular importance in an outbreak scenario, as it renders depopulation of clinical animals an ineffective strategy for outbreak management.

Transmission occurs through direct contact between dogs or through particle aerosols or droplets.[34] Aerosolization can spread particles up to 7.5 meters, making this a significant transmission route in shelters where animals may be densely housed or are ineffectively segregated.[2,35] Fomite and environmental transmission is less common, because CDV remains infectious for only a few hours outside of its host; however, in a high-density shelter setting, this mode of transmission can be significant. As an enveloped virus, it is susceptible to most routine disinfectants, as well as ultraviolet light.[5] Risk factors for CDV infection include lack of vaccination, age, stress, and high-density settings.[2]

Upon entry into a new host, the virus initially replicates in lymphoid tissue in the upper respiratory tract and tonsils and is subsequently transported throughout the body via the lymphatics and blood.[34] Within a few days of infection, direct viral destruction of lymphocytes occurs, resulting in severe lymphopenia and immunosuppression.[36] A concurrent, transient fever occurs from three to six days post-infection, but often goes unrecognized in shelter settings. Immunosuppression can persist for several weeks, predisposing dogs to secondary infections. Prolonged immunosuppression in the shelter setting, where infectious pathogens may be

abundant, can predispose CDV-infected animals to other respiratory pathogens in the CIRDC, resulting in faster onset and increased disease severity.[2,5]

A second stage of viremia and fever occurs eight to nine days post-infection. Clinical manifestation of CDV at this point depends on the strain pathogenicity, host age and immune status, as well as the presence of concurrent infections.[32] Dogs with a strong immune response, including adequate CDV antibody titers and cell-mediated immunity, clear the virus and do not manifest clinical signs of disease. Dogs with intermediate levels of cell-mediated immunity and delayed antibody titers allow virus to spread to epithelial tissues and the central nervous system (CNS). Such dogs may recover from acute illness with a rise in antibody titers, but do not eliminate the virus completely, resulting in chronic manifestations of disease which can involve the CNS, uvea, lymphoid organs, and footpads.[34] These dogs may continue to shed virus, as well. In dogs that fail to immunologically respond, the virus spreads to multiple tissues, including the skin, exocrine and endocrine glands, and epithelium of the respiratory, GI, and genitourinary tracts. The manifestation and chronological onset of clinical signs depend on the CDV strain involved.[5]

Initial clinical signs of CDV include ocular and nasal discharges, conjunctivitis, a nonproductive cough, slight depression, and loss of appetite. These signs mimic those of other CIRDC pathogens and may initially be overlooked. Secondary infections can lead to mucopurulent nasal and ocular discharges and bacterial bronchopneumonia, resulting in tachypnea or dyspnea and a productive cough. Gastrointestinal tract destruction by the virus can follow, leading to vomiting, diarrhea, electrolyte abnormalities, and dehydration. Without supportive care, sudden death from systemic collapse can occur.[5]

Depending on the CDV strain involved and the immunocompetence of the host, up to 30% of infected dogs develop neurologic signs. Dogs with mature or partial immunity can develop neurologic signs. Distemper-induced encephalomyelitis causes multifocal demyelination and can lead to signs such as myoclonus, seizures, tremors, ataxia, obtundation, and paresis/paralysis.[37,38] Neurologic disease typically occurs concurrently with other systemic signs, but can occur six to seven weeks after onset of acute signs or months later. Neurologic disease also can be the only clinical sign of CDV infection. Acute encephalomyelitis is related to direct viral injury to tissues, whereas chronic manifestations of neurologic disease are due to an inflammatory response related to a CDV-specific immune response.[39] Although neurologic signs can be acute or chronic, they are typically monophasic and progressive. Dogs that recover often have residual neurologic deficits such as persistent myoclonus. Old dog encephalitis, a rare and distinct form of chronic neurologic disease, is an active, progressive inflammatory encephalomyelitis process that develops in dogs after acute CDV infection.[5]

In addition to respiratory, GI, and neurologic signs, a variety of clinical signs are related to CDV. Ocular lesions of persistent CDV infection include uveitis, keratoconjunctivitis sicca, keratitis, and optic neuritis resulting in sudden blindness. Additional cutaneous lesions include pustular dermatitis and digital and nasal hyperkeratosis. Hyperkeratosis can be associated with varying levels of neurologic disease.[5] Enamel and dentin hypoplasia may be seen in young dogs following recovery from acute infection. In growing dogs, metaphyseal osteosclerosis can occur and hypertrophic osteodystrophy may be associated with CDV.[5,40] Because of its wide clinical manifestation spectrum, CDV can mimic a variety of infectious diseases, including other CIRDC pathogens and canine parvovirus (CPV), which are common in animal shelters.[6]

Physical exam findings in dogs with CDV will vary depending on the severity and stage of disease and, as noted previously, 25-75% of infections are likely subclinical. Most dogs present with serous or mucopurulent nasal and ocular discharges and varying degrees of dehydration and fever. A harsh cough may be elicited upon tracheal palpation, and thoracic auscultation may reveal referred upper airway sounds and increased bronchovesicular sounds. Crackles or dull lung sounds may be present in patients with pneumonia. For patients with concurrent gastrointestinal signs, hypersalivation may be noted and/or fecal staining of the perineum. Dogs with chronic signs may have nasal or digital hyperkeratosis. A fundic exam in recovered dogs may reveal healed chorioretinitis, indicated by characteristic hyperreflective circular (gold medallion) lesions. Dogs with neurologic disease may manifest with myoclonus. Myoclonus may be present without other neurologic signs.[1,5]

Hematologic laboratory abnormalities commonly recognized early in the disease course include mild anemia and lymphopenia. Lymphocyte count may be normal with chronic infection. If pneumonia is present, leukocytosis, characterized by a neutrophilia with possible toxic changes and a left shift, may be present if secondary bacterial infection is severe. Intracytoplasmic viral inclusions in peripheral blood or conjunctival epithelial cells can be seen early in the disease course. Serum biochemistry abnormalities are nonspecific and are related to electrolyte changes due to GI-related fluid loss. Hypoalbuminemia is common. No specific findings are seen on urinalysis. Cerebrospinal fluid analysis results may be normal in acute non-inflammatory demyelinating encephalomyelitis, but increases in protein and cell count can be present with chronic disease. Pulmonary abnormalities may be present on thoracic radiography, ranging from an interstitial pattern to an alveolar pattern with consolidation, indicating

bronchopneumonia. Magnetic resonance imaging can reveal hyperintense foci and loss of contrast in T2-weighted images of the brain, corresponding to demyelination.[5]

Differential diagnoses for CDV include: other CIRDC pathogens; infectious causes of gastroenteritis such as CPV and bacterial infections; non-infectious causes of gastroenteritis such as stress, abrupt diet change, dietary indiscretion, or endoparasitism; rabies; toxins such as lead; protozoal meningoencephalitis such as neosporosis or toxoplasmosis; and systemic fungal infections such as cryptococcosis.[1] In animals that have the full spectrum of clinical signs, diagnosis of CDV is less challenging, particularly with concurrent neurologic signs such as myoclonus. However, CDV diagnosis is more challenging when clinical signs occur in isolation, or overlap with signs of other CIRDC pathogens.[6,37]

In the shelter setting, clinical laboratory testing such as hematology, serum biochemistry, urinalysis, cerebrospinal fluid analysis, thoracic radiography, and magnetic resonance imaging, are not typically performed due to financial limitations. In lieu of bloodwork, suspect animals are typically tested with specific diagnostic assays. Various antemortem laboratory tests are available to help confirm the suspicion of CDV, but such tests have limited sensitivity and a negative result does not completely rule out CDV. In addition, false positive results are also possible related to recent MLV vaccination.[5]

Commercially available diagnostic assays for CDV include direct fluorescent antibody (DFA), serology, and PCR. Direct fluorescent antibody assays were developed prior to more reliable and sensitive diagnostic techniques and require presence of intact virus, increasing the odds of false negative results related to a shorter period of detection time.[2] However, a positive result is likely to indicate wild-type infection rather than vaccination.[1,2]

Serological tests for CDV include serum neutralization, indirect fluorescent antibody, and enzyme-linked immunosorbent assays (ELISA) to detect immunoglobulin M (IgM) and immunoglobulin G (IgG). Immunoglobulin M titers have been more accurate in detecting acute clinical cases compared with chronic, inflammatory cases. Immunoglobulin G can indicate either past or present infection or past vaccination against CDV.[5] Serum neutralization is considered the gold standard for measuring protection against infection, but titer results from indirect fluorescent antibody testing are comparable.[41] Neutralization titers of at least 1:16 to 1:20 correlate with protection after vaccination, and titers of 1:100 or more correlate with MDA protection in puppies.[1,5] Although the use of serology to diagnose CDV is complicated by the confounding effect of vaccination at intake in shelter dogs, it is an invaluable tool in a shelter outbreak scenario to help determine the immunologic status of dogs entering the shelter or those that are present at the time of an outbreak. Point-of-care ELISAs that provide semiquantitative measurements of CDV antibodies are commercially available, and can be used on-site to facilitate population management during a shelter outbreak.[42]

A commonly used diagnostic assay in shelters is PCR. Compared to DFA, PCR is more sensitive, because it detects viral nucleic acid rather than intact antigens.[2,5] Diagnostic testing for CDV can be performed alone or in combination with other CIRDC pathogens through polymicrobial PCR panels offered by various commercial veterinary diagnostic laboratories. The turnaround time of one to three days is helpful during CDV outbreaks. The assay can be performed on a variety of samples, but many shelters typically submit upper respiratory samples from nasal, oropharyngeal, and/or conjunctival epithelium due to ease of collection. Testing specimens from multiple anatomic sites improves the sensitivity of the assay. False negative results can occur occasionally due to transient or intermittent viral shedding. False positive

results can occur due to recent MLV vaccination against CDV; this does not occur with recombinant vaccines.[5] False positive results can occur within two days of MLV vaccination, but it is unclear how long after vaccination an animal remains positive.[43] However, assays are available that distinguish wild-type and vaccine strains of CDV.[44] In addition, quantitative PCR has been developed that differentiates low viral loads attributed to MLV vaccines from high viral loads attributed to natural infection.[45,46]

Postmortem testing is more reliable than antemortem testing, as multiple tissues can be tested through different assays, and histopathology is diagnostic for CDV. Gross pathologic findings include conjunctivitis; upper respiratory inflammation (rhinitis, tracheobronchitis); pulmonary congestion and consolidation; liquid intestinal contents; lymph node enlargement; and, in neonatal dogs, thymic atrophy. Gross lesions of the central nervous system lesions are typically absent, with occasional meningeal congestion and ventricular dilatation. Histopathologic findings of the CNS vary but include neuronal necrosis and white matter degeneration and demyelination.[1]

Diagnostic testing for CDV is indicated and should be pursued in the shelter setting if increased frequency or severity of CIRDC is noted, if clinically affected dogs are not responding to supportive care, and if neurologic and/or other signs of systemic disease develop. Postmortem testing should be performed on any deceased patients or representative antemortem testing should be performed on acutely affected dogs.

Treatment for CDV entails intensive supportive care. However, the decision to treat CDV is based on both the severity of disease within a patient and the resources available to the shelter. It is imperative that shelters proactively determine whether treatment of CDV is a viable option for their organization. Because of the highly transmissible nature of CDV, the most critical factor

in deciding whether to treat CDV is to determine if affected patients can be successfully treated without exposing other animals in the shelter.[15] Ideally, an isolation building or ward is present. In addition, a veterinarian, as well as trained medical and animal care staff, should be available to provide adequate veterinary care, monitoring, husbandry, and attention to behavioral well-being for affected animals. If a shelter cannot meet these criteria, it should consider transferring affected patients to a local veterinary clinic if financially feasible. Otherwise, euthanasia of affected patients may be the most prudent decision to protect the remaining shelter population.

In addition to a population-based treatment decision, an assessment of individual patient welfare should be made when deciding to treat CDV. Depending on the severity of disease, support includes nursing care, fluid therapy, and prevention and treatment of secondary bacterial infections through antibiotic use. Two antiviral drugs have been shown to have efficacy in vitro against CDV, but there is no specific antiviral medication available for treatment.[47] In the case of bronchopneumonia, culture and sensitivity testing should be performed. Due to limited resources, many shelters are unable to do so, often using instead broad-spectrum antibiotic therapy that is effective against *B. bronchiseptica* and *M. cynos*. Culture and sensitivity should be pursued in shelter settings in which pneumonia is wide-spread and dogs fail to respond to empirical treatment. If gastrointestinal signs are present, parenteral therapy, including broad-spectrum antibiotics, anti-emetics, and intravenous fluid replacement are needed. Treatment for neurologic signs is typically less successful than treatment for other systemic signs. If neurologic signs are present, glucocorticoid therapy for CNS edema may mitigate neurologic signs. Seizures should be treated with anticonvulsants. Myoclonus is typically untreatable and irreversible, but treatment with anticonvulsants may lessen the severity of muscle contractions.[5] With supportive care, the prognosis for dogs with signs limited to GI and/or respiratory disease is fair to good for

initial recovery. For dogs with severe neurologic signs, the prognosis is poor; however, some signs, such as mild myoclonus, may be compatible with a reasonable quality of life.[1] Both a humane medical health condition, as well as a humane behavioral health condition, should be maintained for any patient under treatment. Behavioral well-being should be upheld without violating biosecurity protocols. In addition, objective and subjective assessments of medical and behavioral well-being should be established to define humane endpoints of treatment and prevent ethical debate over treatment and euthanasia policies. Shelters that adopt out recovered animals should relay that neurologic signs can develop months after infection.

Although a specific antimicrobial drug is not available for CDV, antibiotics are used for secondary bacterial infections as part of a supportive care protocol. If bronchopneumonia is present, as noted previously, performing culture and susceptibility is ideal to guide antibiotic therapy. When that is not possible, empirical antibiotic therapy effective against *B. bronchiseptica* and *M. cynos,* which are common CIRDC pathogens in the shelter setting, is used. A parenteral broad-spectrum antibiotic combination, such as ampicillin and a fluoroquinolone, should be used. Although the antibiotic doxycycline is commonly used for shelter CIRDC, it is not the drug of choice for CDV-associated bronchopneumonia, because it is bacteriostatic and its intravenous formulation is costly and difficult to administer.[1]

The viral shedding of CDV typically resolves within one to two weeks of acute illness, but it can persist up to 16 weeks in recovered dogs.[5] Accordingly, shelters should document cessation of viral shedding through PCR if they plan to adopt out recovered dogs.[2] Because CDV shedding can be transient and intermittent, documentation of two negative PCR results can further substantiate cessation of shedding. At minimum, adopters of recovered or exposed dogs should be made aware of the disease risk to other dogs. Recovered dogs should be separated

from puppies, newly vaccinated dogs, and communal dog spaces such as pet stores, boarding facilities, and play yards.

The key to CDV prevention is vaccination. Canine distemper virus infection can be effectively prevented through immunization in adult dogs without MDA interference.[1] The prevalence of disease is low where community vaccination rates are high.[5] Conversely, in communities where vaccination rates are low and CDV is not well controlled in uncared-for dogs, prevalence of disease is higher and dogs entering shelters are less likely to have protective antibody titers against CDV. Data collection on CDV antibody titers for Florida shelter dogs reveal that up to 65-70% of dogs do not have protective titers against CDV on admission.[2,48] Because both modified live and recombinant CDV vaccines may start providing protection within hours of administration, properly timed vaccination is key to CDV prevention within the shelter setting.[2,49,50] Both vaccine types confer full immunity within three to five days.[49,50] Early post-vaccine immunity does not provide complete protection against infection and viral shedding, but it does prevent the development of severe neurologic disease and death.[2] Accordingly, delaying vaccination results in prolonged disease susceptibility, since infectious disease exposure immediately upon admission is a possibility in any shelter. Ideally, all dogs over four weeks of age should receive a parenteral MLV combination vaccination that includes CDV prior to entry and, if not possible, they should be vaccinated immediately upon admission to the shelter. Dogs presenting with signs of mild illness, as well as those that are pregnant or nursing, should be vaccinated. Puppies should be revaccinated every two weeks until maternal antibodies have theoretically waned at 18-20 weeks of age.[20] Because puppies are at higher risk for acquiring CDV due to incomplete immunocompetence and potential delays in vaccine response, revaccination, along with physical prevention from disease exposure, optimally in a

foster home outside of the shelter setting, is critical to maintaining healthy puppies. In the shelter setting, an intake room may facilitate vaccination on intake for all newly admitted dogs, as well as examination for signs of infectious disease. In a shelter where puppies are quickly transferred to foster and all adult dogs are vaccinated immediately on admission, the risk of CDV is significantly diminished.

Although both modified live and recombinant vaccines provide rapid onset of immunity against CDV and similar durations of immunity, the recombinant vaccine may provide earlier protection in puppies when MDA are present.[51] However, because a high percentage of dogs entering shelters do not have protective antibodies, it is likely that most puppies entering shelters do not have MDA. Therefore, MLV vaccination is the preferred choice for shelter puppies and adult dogs.[52] Modified live CDV vaccines are labile and should be used within one hour of reconstitution.[5,20]

Similar to other CIRDC pathogens, additional strategies to minimize disease exposure and support host health are essential to CDV prevention. The foundation of infectious disease prevention is maintaining a population density that is congruent with the shelter's capacity to provide adequate care for all animals in its custody. When a shelter operates beyond its appropriate capacity, crowding occurs, compromising the health and welfare of individual animals, as well as the shelter population.[14] The most apparent consequence of crowding is that it results in increased contact rates among animals and staff, allowing for increased opportunities for disease transmission.[2] An additional and common outcome of crowding is the inappropriate use of housing. For example, shelters may use crates as long-term primary enclosures in an attempt to create additional housing capacity. Based on guidelines for standards of care in animal shelters, this practice is unacceptable and severely compromises animal welfare.[53] In other cases,

a double compartment kennel designed to function as a single housing unit for one dog might be used as two single compartment kennels to create additional capacity. This also compromises animal welfare as it typically does not allow animals to rest and eat apart from where they eliminate.[35,54] Single compartment housing, whether crates or kennels, requires animals be removed from their housing units for cleaning and, therefore also increases infectious disease risk. Increased stress associated with crowding and/or the inappropriate use of housing negatively impacts an animal's immunocompetence, therefore contributing to infectious disease risk in the shelter setting.[10,11,35] Crowding also adversely impacts other aspects of sheltering. Ventilation and air quality are reduced relative to an increased population density. In addition, animal care duties such as cleaning and disinfection, vaccination on intake, disease recognition, and isolation of affected animals are compromised when animal capacity is increased without a proportionate increase in staffing capacity.[33]

A shelter's capacity for care is based on housing, holding, and staffing capacities. Housing capacity is based primarily on the number of appropriate housing units available, but also varies with the age of dogs within the shelter. For example, puppies have specific housing requirements, such as double compartment units, that help reduce disease exposure by avoiding the need to handle puppies frequently. Holding capacity is based on the physical space necessary for holding stray animals for legally required holding periods, as well as the optimal number of animals to have actively available for adoption. These are referred to as the required stray holding capacity and adoption driven capacity, respectively. Staffing capacity is based not only on the number of staff available, but also the daily care requirements of animals, the type of housing present, and the shelter's cleaning and disinfection process.[35] The National Animal Care and Control Association and the Humane Society of the United States recommend allocating 15

minutes per animal per day to ensure minimum care standards within shelters.[55] More time may be needed if each animal must be removed from its housing unit prior to cleaning and disinfection, or if many neonatal animals are present and require extensive care. This recommendation also does not take into account additional daily care tasks such as enrichment and disease management.

As noted previously, capacity also is related to LOS, in that increased average LOS necessitates increased shelter capacity. In addition, the longer an animal stays within the shelter, the greater its demand for sufficient space, interaction, and environmental enrichment due to stress-related confinement and the greater its risk for developing signs of clinical disease. Accordingly, increased LOS affects shelter capacity in a multifactorial fashion.[16] Length of stay for individual animals will vary depending on multiple factors, including an animal's age, medical condition, or if an animal requires a legal stray holding period; however, an average LOS of 14 days is generally recommended for animals available for adoption.[56]

Capacity for care, which is composed of various shelter factors, is maintained through proactive population management. Population management is a systematic, active, and intentional process through which a shelter's population and flow are directed. Ideally, a team of shelter personnel oversees population management. This may include an operations manager, veterinarian, and lead staff members involved in departments such as behavioral health, transfer coordination, and adoptions. Accordingly, all critical aspects of the sheltering system are addressed through a collaborative population management team, allowing the shelter to maintain its capacity for care, uphold animal welfare, and ensure optimal outcomes for all animals in a timely manner. Individually, each population management team member oversees their respective departments to ensure the different components of capacity for care are effectively

maintained.[53,57] For infectious disease management, prevention of crowding and effective medical oversight are two critical components of maintaining a healthy population. Accordingly, a veterinarian should create medical and infectious disease protocols for a shelter, and a veterinary technician should be present to help enforce such protocols. Shelters that do not have the financial resources to employ a veterinarian may instead work with a private veterinarian to create medical and infectious disease protocols.

Additional infectious disease prevention and management strategies include population-level disease surveillance, prompt disease recognition, effective population segregation, adequate cleaning and disinfection practices, and fomite control. Ongoing disease surveillance allows for timely detection of acute or progressive increases in disease rates within a shelter population, resulting in more prompt responses to potential disease outbreaks. Effective disease surveillance requires prompt disease recognition and reporting, a system to record data, and routine oversight and interpretation of data.[58] Disease tracking can be performed through computerized shelter software systems or through simpler method hand-written systems. Any system can be effective as long as it is consistent, accurate, regularly interpreted. Without ongoing disease surveillance, a disease such as CDV, which can resemble those of other CIRDC pathogens or gastrointestinal diseases such as CPV, is more likely to disseminate throughout a shelter undetected.[14,15]

Prompt disease recognition and reporting, one of the components of a disease surveillance system, is critical in disease prevention and management. Prompt action steps for clinical respiratory disease, even if mild, should be taken to limit disease spread. Disease recognition in shelter settings is primarily achieved by training staff to identify and report infectious disease concerns through daily health rounds. Conducting daily rounds empowers staff to monitor, report, and take action steps regarding the health status of each animal in the shelter.

Staff should be instructed to isolate clinically affected animals before reporting concerns to the medical team. Otherwise, leaving clinically affected animals in the general population results in disease transmission and increased rates of disease.[2,53]

For CDV, which can be transmitted up to 7.5 meters via aerosolization, effective population segregation includes utilizing separate air supplies for clinically affected dogs.[2,5] Ideally, isolation is within a separate building or ward with separate air flow. If this cannot be achieved due to space limitations within a shelter, a designated area with strict biosecurity practices, separated by at least 7.5 meters from the susceptible population may be acceptable.[15] Effective population segregation in terms of CDV prevention also includes instituting specific housing and handling protocols for puppies, as they are at higher risk of infectious disease due to lack of immunity and potential delays in vaccine response. Efforts should be made to relocate puppies from the shelter setting and into an environment, such as a foster home, where the risk of infectious disease is lower.

Environmental elimination of CDV is readily achieved through the use of most commonly used disinfectants in the shelter setting, because it is an enveloped virus that is quickly inactivated outside of its host within hours.[5] Commonly used disinfectant products in the shelter setting include accelerated hydrogen peroxide, potassium peroxymonosulfate, quaternary ammonium compounds, and sodium hypochlorite. All disinfectants must be stored and used appropriately for optimal efficacy. For example, sodium hypochlorite has no detergent action, and, as such, it cannot be used as the sole cleaning and disinfectant product in a sanitation protocol.[59] It must be applied to a cleaned surface to be an effective disinfectant.

Although CDV is readily inactivated outside of its host, fomite transmission is a concern in the shelter setting where susceptible dogs may be densely housed and frequently handled,

allowing disease transmission in the few minutes that virus particles survive outside of the host. Fomite control includes utilizing PPE when handling clinically affected animals, handling nonclinical animals before apparently affected animals, practicing proper hand hygiene, and regular cleaning and disinfection of communal spaces such as animal control vehicles and intake processing rooms. Because CDV can be transmitted through all body secretions, covered drainage systems and barriers between housing units are also important in preventing disease transmission.

Certain animal and environmental risk factors in shelters can lead to a CDV outbreak. Risk factors include inadequate vaccination; crowding beyond capacity for care due to inadequate population management; inappropriate use of housing; lack of segregation between affected and nonclinical animals; delayed response to respiratory disease; and transferring animals in from source shelters in endemic communities.[2,14] The negative consequences of a CDV outbreak are significant and include compromised animal welfare, diminished staff morale, negative publicity and loss of community trust, liability for disease transmission to community pets, and financial loss. Although available resources largely determining how a shelter will respond to an outbreak, any shelter can implement systematic management measures to mitigate these concerns without requiring drastic measures such as depopulation.

Many shelters will temporarily close during the initial stages of an outbreak to limit disease spread and organize and coordinate management decisions. This allows also for animal movement within the shelter to be suspended until further outbreak response steps can be implemented. The first step thereafter is to promptly confirm diagnosis of a suspected pathogen.[15,14] As noted previously, multiple acutely affected dogs should be tested. Polymerase chain reaction is the preferred diagnostic method because of its rapid turnaround time and its

high degree of sensitivity. Even in the face of recent MLV vaccination, multiple dogs with clinical signs consistent with CDV and positive test results substantiate CDV as the causative agent. A definitive diagnosis will direct treatment protocols, dictate quarantine periods, and determine the necessary decontamination process.

Concurrent with diagnostic testing, all animals involved in the outbreak should be grouped into risk categories. Categories include animals that are clinically affected, nonclinical animals that have been exposed and are at high-risk of developing infection, nonclinical animals that have been exposed but are at low-risk of developing infection, and animals that have not been exposed. The first step is thorough physical examination of all animals by a veterinarian, ensuring that all clinically affected animals are isolated, as this is the most critical component in limiting disease transmission. As previously noted, isolation and strict biosecurity measures when handling affected animals should be implemented. Exposed animals could be quarantined for the duration of the incubation period of CDV or risk assessed to determine meaningful risk. Because the prolonged incubation period of CDV makes quarantine impractical and raises welfare concerns for shelters, risk assessment based on the degree of exposure and level of susceptibility should be performed. Risk assessment, therefore, directs population management decisions during an outbreak and includes both environmental exposure and individual animal exposure.[15]

As assessment of environmental exposure allows the shelter to gauge how great the infectious dose may be within the environment, as well as how widespread the disease may be. Factors to consider when assessing environmental exposure include the durability of the pathogen, the possible routes of transmission, the type of housing present, the degree of fomite control, and the cleaning and disinfection processes in place at the shelter.[15] Even though CDV

cannot survive outside of its host for long, it can be readily transmitted via aerosolization and through fomites in a high-density setting. In addition, the risk of exposure to large amounts of virus may be increased the longer it takes an outbreak to be recognized, as most cases of CDV are assumed to be other CIRDC pathogens until diagnostically confirmed.[60] Accordingly, in many shelter outbreaks, the environmental exposure of CDV is great and detailed individual risk assessment is required.

Factors to consider for individual risk assessment include age, vaccination status, medical history, and the degree to which an animal is exposed. Puppies are always at risk of CDV due to incomplete immunity and the delay of vaccine response related to interference by MDA. Conversely, adult dogs that have been vaccinated at least one week prior to exposure are likely to be protected against CDV. Proximity to infected animals also contributes to individual risk. Direct or near-direct exposure to an infected animal confers greater risk and, in CDV's case, animals within 7.5 meters of infected animals are considered at greater risk.[15]

Regardless of how much information is available to thoughtfully risk assess animals, some aspects of risk assessment may be subjective and therefore have limitations. For example, effective vaccination requires proper vaccine storage, handling, and administration. If any of these steps are inadequate, vaccine failure is possible, inadvertently rendering an animal unprotected. Similarly, owner-surrendered animals that do not have veterinary records verifying vaccination status should not be assumed to be protected against disease when assessing risk. Consequently, using vaccination status for risk assessment has its limitations. In addition, an individual animal's likelihood of exposure to a highly transmittable respiratory pathogen may be difficult to confirm in a shelter setting where animals may be relocated throughout the facility multiple times. Accordingly, it is impossible to guarantee complete absence of risk for any

animal. Nonetheless, individual risk assessment is an important step of outbreak management, and although not all animals can be risk assessed with confidence, other animals may be more easily assessed. For example, an apparently healthy adult dog with veterinary records verifying vaccination prior to shelter admission should be considered low-risk.[15]

Serology can be used to facilitate individual risk assessment and can be particularly helpful to guide population management decisions in a CDV outbreak. Because the prolonged incubation period of CDV makes quarantine impractical, serology can facilitate the movement of certain populations through the sheltering system and mitigate welfare and capacity concerns associated with prolonged quarantines. Although veterinary diagnostic laboratories can perform serology using serum neutralization or indirect fluorescent antibody testing, point-of-care ELISAs that provide semiquantitative measurements of CDV antibody titers within 20 minutes typically are used for risk assessment in a shelter outbreak. The only currently available point-of-care assay in the United States is a semiquantitative ELISA that measures IgG in serum or plasma.[a] [b] belowIn one shelter study, investigators reported that the overall diagnostic accuracy of this point-of-care ELISA was greater than that of indirect fluorescent antibody testing.[61] Because it is a well-type test, a technician experienced with running similar assays should perform the test to ensure accuracy.[62] Although this point-of-care ELISA cannot differentiate CDV antibody titers induced by active immune response, previous exposure, MDA, or prior vaccination, it remains a useful tool for individual risk assessment in a shelter outbreak when other factors, such as host age, vaccination history, and clinical condition are taken into account.

Although there are costs involved with serological testing, this should be balanced with the daily animal care costs and welfare concerns involved with prolonged quarantine. In some

instances, shelters may be able to offset cost of testing by fundraising at a later point or applying for a grant from a nonprofit, national animal welfare organization.

Typically, serology is only used on exposed animals that are nonclinical, because serologic status of such animals may correlate with protection against CDV.[15] Positive titers in a nonclinical animal without a recent history of CIRDC correlates well with protection, indicating the animal is low-risk for disease and should be moved through the sheltering system instead of quarantined. Negative titers in a nonclinical animal indicate it is potentially at risk of acquiring disease and is, therefore, a candidate for quarantine. Interpretation of antibody titers in nonclinical puppies is less definitive, as positive titers may reflect either an active immune response or waning MDA. Differentiation cannot be made regarding the source of titers. Therefore, puppies with CDV-positive antibodies should still be considered to be at risk of acquiring disease and should be moved out of the shelter quickly into an environment that poses less risk of infectious disease.

Because point-of-care ELISAs do not differentiate the origin of antibody titers, they should not be used to risk assess clinically affected animals. Positive titers in a clinically affected animal may indicate active immune response to CDV infection rather than protection from CDV. Accordingly, an antigen test is performed on clinical animals. An additional limitation of the point-of-care ELISA is specifically related to CDV's prolonged incubation period. Due to the possibility of a six-week incubation period, it is feasible that titers may rise faster than clinical signs develop in response to infection, such that a positive CDV antibody titer in a nonclinical animal may be related to both immunity *and* infection.[2] This may make nonclinical, CDV antibody titer-positive dogs, who are considered low-risk for acquiring disease, more at risk than recognized. This limitation of serological testing reflects the importance of physical examination

of all animals associated with an outbreak. If clinical signs go undetected in an infected animal during risk assessment and it is antibody titer tested it may be incorrectly identified as being low-risk.[62]

As animals are categorized into risk levels and moved accordingly through the sheltering system, decontamination should occur to create a sanitary environment for low-risk animals and any new animals that are admitted. Although CDV is not a hardy virus in the environment, decontamination of the shelter during an outbreak allows for groups of animals to be relocated based on risk levels. Infected animals should remain in isolation until clinically resolved and cessation of viral shedding has been documented, while low-risk animals should be housed in areas that allow for adoption to occur so shelter operations can resume. Animals that are high-risk for acquiring CDV should be quarantined off-site in a highly sanitary environment that poses minimal risk of infectious disease.

Decontamination also ensures that the shelter is prepared to admit new animals without putting them at risk of being exposed to CDV. This involves the creation of a clean break between the exposed/at-risk population and the newly admitted population. Ideally, this area should be located in a separate building. However, at minimum, it can be located 7.5 meters away from exposed dogs. Staff should be designated to handle animals in this area to prevent cross-contamination. In addition, all newly admitted dogs should be vaccinated prior to or immediately upon admission to the shelter.[15]

Throughout the management of a CDV outbreak, positive cases, diagnostic results, as well as temporal and spatial patterns of disease spread should be documented. This can help determine the origin of the outbreak, how the disease spread, and how to prevent future outbreaks. In addition, proactive communication with adopters, transfer partners, volunteers, and

local veterinary practitioners can help limit the spread of disease and help maintain a positive public image for the shelter.

Clinical Report

In May 2015, the author received an email from an animal shelter experiencing increased prevalence and severity of CIRDC. The shelter was a privately operated, open admission facility with managed intake in the western United States. In the previous year, the shelter admitted 1,601 dogs and 1,364 cats. On average, the daily dog population consisted of 52 animals with an average length of stay of 17 days to all outcomes. The annual live release rate as a percentage of intake for dogs was 96%, with adoptions constituting the majority of live releases (83%). Admission consisted of owner-surrendered animals, animals confiscated due to legal concerns, dogs transferred in from out-of-state municipal shelters through a national dog rescue network (transfers), and stray animals from two local municipalities. The mandated legal hold period for strays was five days. Intake by source consisted of: confiscations (19%), dogs previously adopted but returned (15%), owner surrenders (10%) and strays (5%). Transferred dogs were the majority of the shelter's annual dog intake (51%) as of 2014. Between 2013 and 2014, there was a 344% increase in the number of dogs transferred from out of state. Dogs were classified at intake according to age, with puppies (defined as dog younger than five months of age) accounting for 16% and adults (defined as five months of age or older) accounting for 84% of dog intake. The majority of transferred dogs were adults (80%).

There were 47 adult dogs on-site at the shelter and two puppies in foster care at the time of initial presentation of this case. Of the 47 dogs on-site, 12 were owner surrenders and 14 were strays. The remaining 21 dogs, as well as the two puppies in foster care, were transfers.

Summary tables of case information, including the signalment, medical history, diagnostic results, and risk assessment of each dog involved in this case, are represented in Tables 1, 2, 3, 4, and 5. These tables include one dog already deceased at initial presentation of this case, as well as 13 additional, off-site dogs subsequently determined to be exposed. Tables are organized by the on- or off-site location of animals.

The shelter, originally built in 1975, consisted of six indoor rooms for primary dog housing (Rooms A-F) and two outdoor areas where residents were routinely held during daily cleaning procedures (Figure 1). Five of the rooms served as adoption wards, while one was used as a holding ward for stray dogs. One adoption room (Room D) was inconsistently used for isolation when necessary.

In all instances adult dogs were individually housed. Room F contained seven dog crates (74 x 79 x 122 centimeters each) and was used for housing small dogs for adoption. Rooms A-E contained a total of 64 single compartment, chain-link kennel runs (1.2 x 2.1 meters each), which were used to house dogs of a variety of sizes. Other areas of the shelter through which dogs trafficked included: the lobby, surgical suite, and chain-link pen with a concrete surface that served as an outdoor socialization space.

Rooms A and B each consisted of two single rows of kennels, which faced each other and were separated by an aisle 1.5 meters wide. The rows in Room A consisted of seven and eight kennels, respectively, which were each separated by cinderblock walls of 1.5 meters height. Room B was identically designed except both rows consisted of seven kennels each. Each kennel had a full height chain-link front gate. However, many of the gates in these rooms were in poor working order. As a result, only large dogs were housed in these rooms because of the escape risk for small dogs posed by the defective gates. A single, uncovered collection trough spanned

Table 1. Summary of Signalment, Medical History, Diagnostic Results, and Individual Risk Assessment for Deceased Dog

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostics	Risk Category
CAS	2y	3/30/15	Owner surrender	None	Deceased (5/5/15: euthanized)	Progressive CIRDC, anorexia	Necropsy 5/8/15: positive	N/A

Table 2. Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs in Adopted Homes Reported to Have CIRDC

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
MOL	4y	2/6/15	Owner surrender	3/17/15	Adopted	Recurrent CIRDC, myoclonus, focal seizures (jaw snapping)	PCR + AB +	High/Infected
SEL	6m	3/26/15$^{\phi}$, 4/11/15	Out of state (2)	3/31/15*, 4/14/15**	Adopted	Recurrent CIRDC	PCR +	High/Infected
BOB	1.5y	4/2/15	Out of state (6)	3/19/15	Adopted	CIRDC	PCR – AB +	High
MIS	3y	4/22/15	Regional animal control	4/23/15	Adopted	CIRDC	PCR – AB +	High
JEF	8m	3/6/15*, 4/11/15	Out of state (2)	3/10/15*, 5/28/15**	Adopted	Recurrent CIRDC, vomiting, lethargy, focal seizures (jaw snapping)	PCR +	High/Infected

Φ Intake to source shelter

* Vaccination performed at source shelter

** Vaccination performed by local practitioner

Table 3. Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs On-Site

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
BOS	2y	3/17/15	Regional animal control	4/28/15, 5/12/15	Room D	Recurrent CIRDC, anorexia, diarrhea (CPV antigen 4/30/15: negative)	PCR – AB +	High
COO	2y	4/20/15	Owner surrender	4/21/15, 5/12/15	Room D	Persistent CIRDC, anorexia	PCR – AB +	High
DER	10m	4/20/15	Owner surrender	4/23/15, 5/12/15	Room D	Persistent CIRDC, diarrhea (CPV antigen 4/24/15: negative)	PCR – AB +	High
JOH	3y	4/27/15	Local animal control	4/28/15, 5/12/15	Room D	Persistent CIRDC, anorexia	PCR – AB +	High
MSB	4y	4/29/15	Regional animal control	5/8/15, 5/12/15	Room D	CIRDC	PCR – AB +	High
OLY	10m	4/19/15	Owner surrender	4/21/15, 5/12/15	Room C	CIRDC, anorexia	PCR – AB +	High
ROR	6m	5/2/15	Local animal control	5/8/15, 5/12/15	Room C	CIRDC	PCR – AB +	High
ELV	6y	4/11/15	Out of state (1)	4/3/15*, 7/2/15	Room D	Persistent CIRDC, anorexia, weight loss	PCR + AB +	High
GUS	2y	4/30/15	Out of state (2)	4/24/15*	Room D	Progressive & recurrent CIRDC, anorexia, diarrhea (CPV antigen 5/12/15: negative), recumbent	PCR + AB +	High

*Vaccination performed at source shelter

Table 3 (cont.). Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs On-Site

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
JAK	11y	3/31/15	Owner surrender	4/3/15, 7/3/15	Room D	Progressive & recurrent CIRDC, anorexia	PCR + AB +	High
ABB	3y	4/30/15	Out of state (2)	3/30/15*, 5/12/15	Room D	CIRDC, lethargy	PCR – AB +	High
ARR	6m	4/24/15	Local animal control	4/28/15, 5/12/15	Room D	CIRDC, anorexia	PCR – AB +	High
BET	8m	4/30/15	Out of state (2)	4/18/15*, 5/8/15	Room D	CIRDC	PCR – AB +	High
LOL	3y	4/30/15	Out of state (5)	4/18/15*, 5/8/15	Room D	CIRDC, anorexia	PCR – AB +	High
WMA	8m	4/30/15	Out of state (2)	4/18/15*, 5/8/15	Room D	CIRDC	PCR – AB +	High
ADR	2y	3/28/15	Local animal control	4/23/15, 5/15/15	Room C	CIRDC, anorexia	PCR – AB +	High
BRO	1.5y	4/14/15	Owner surrender	5/8/15, 5/22/15	Room C	CIRDC, anorexia	PCR – AB +	High
MAM	2y	4/30/15	Out of state (4)	3/7/15*, 5/8/15	Room C	Remained nonclinical	PCR – AB +	Low
MAN	2y	4/30/15	Out of state (2)	4/13/15*, 5/8/15	Room C	Remained nonclinical	PCR – AB +	Low
MIA	3y	5/5/15	Local animal control	5/5/15, 5/19/15	Room C	CIRDC	PCR – AB –	High
RAB	3y	4/30/15	Out of state (2)	4/10/15*, 5/8/15	Room C	Remained nonclinical	PCR – AB +	Low
ROC	2y	4/30/15	Out of state (2)	4/24/15*, 5/15/15	Room C	Remained nonclinical	PCR – AB +	Low

* Vaccination performed at source shelter

Table 3 (cont.). Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs On-Site

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
SCO	5y	4/30/15	Out of state (2)	4/24/15*, 5/15/15	Room C	Remained nonclinical	PCR – AB +	Low
TRA	2y	4/30/15	Out of state (1)	4/2/15*, 5/8/15	Room C	CIRDC, lethargy	PCR – AB +	High
CAH	5y	4/11/15	Out of state (7)	3/21/15*, 5/8/15	Indoor Room A	Remained nonclinical	PCR – AB +	Low
GRA	3y	3/6/15	Out of state (2)	10/22/14*, 5/8/15	Indoor Room A	Remained nonclinical	PCR – AB +	Low
HER	8y	3/25/15	Local animal control	4/23/15, 5/8/15	Indoor Room A	CIRDC, anorexia	PCR – AB +	High
KHL	3y	5/7/15	Owner surrender	5/8/15, 5/22/15	Indoor Room A	Remained nonclinical	PCR – AB +	Low/ Moderate
KOB	3y	4/11/15	Out of state (1)	3/12/15*, 5/7/15	Indoor Room A	CIRDC	PCR – AB +	High
MAI	4y	5/9/15	Regional animal control	5/9/15, 6/10/15	Indoor Room A	CIRDC	PCR + AB +	High
MUR	9m	5/13/15	Owner surrender	5/13/15, 5/27/15	Indoor Room A	Remained nonclinical	PCR – AB +	Low
PEA	2y	7/23/14	Local animal control	8/14/14, 5/8/15	Indoor Room A	Remained nonclinical	PCR – AB +	Low
ROL	9y	5/12/15	Owner surrender	5/12/15, 5/26/15	Indoor Room A	Remained nonclinical	PCR – AB +	Low
AND	5y	4/11/15	Out of state (4)	5/7/15, 5/21/15	Room F	CIRDC	PCR – AB +	High
CAR	6m	4/11/15	Out of state (2)	3/2/15*, 5/15/15	Room F	Remained nonclinical	PCR – AB +	Low
FIN	10m	5/4/15	Owner surrender	5/4/15, 5/15/15	Room F	Remained nonclinical	PCR – AB +	Low
GRS	5y	4/2/15	Out of state (6)	3/19/15*, 5/15/15	Room F	CIRDC	PCR – AB +	High

* Vaccination performed at source shelter

Table 3 (cont.). Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs On-Site

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
KYL	5y	4/3/15	Owner surrender	10/10/14[∞], 6/24/15	Room F	Recurrent CIRDC, vomiting (CPV antigen 4/30/15: negative)	PCR + AB +	High
OZZ	5y	5/12/15	Owner surrender	5/12/15, 5/26/15	Room F	Remained nonclinical	PCR – AB +	Low
PET	8m	4/30/15	Out of state (4)	2/17/15*, 5/1/15	Room F	Remained nonclinical	PCR – AB +	Low
CHI	10m	6/6/14	Out of state (3)	5/19/14*, 4/23/15	Staff Office	Remained nonclinical	PCR – AB +	Low
EMM	10y	4/12/15	Owner surrender	6/30/14[∞], 5/15/15	Staff Breakroom	Remained nonclinical	PCR – AB +	Low
LUK	10m	4/11/15	Local animal control	4/14/15, 5/15/15	Indoor Room F	Remained nonclinical	PCR – AB +	Low
MIK	1y	5/14/15	Local animal control	5/14/15, 5/29/15	Indoor Room F	Remained nonclinical	PCR – AB +	Low
MIY	3y	5/11/15	Local animal control	5/12/15, 5/26/15	Indoor Room F	Remained nonclinical	PCR – AB +	Low/ Moderate

[∞] Vaccination reported by owner; documentation not provided

*Vaccination performed at source shelter

Table 4. Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs in Foster

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
IRI	3m	3/6/15	Out of state (9)	2/28/15*, 5/5/15	Staff 3	Progressive & recurrent CIRDC, anorexia	PCR + AB +	High
ROS	3m	3/6/15	Out of state (9)	2/28/15*, 5/5/15	Staff 3	Progressive & recurrent CIRDC, anorexia	PCR + AB +	High

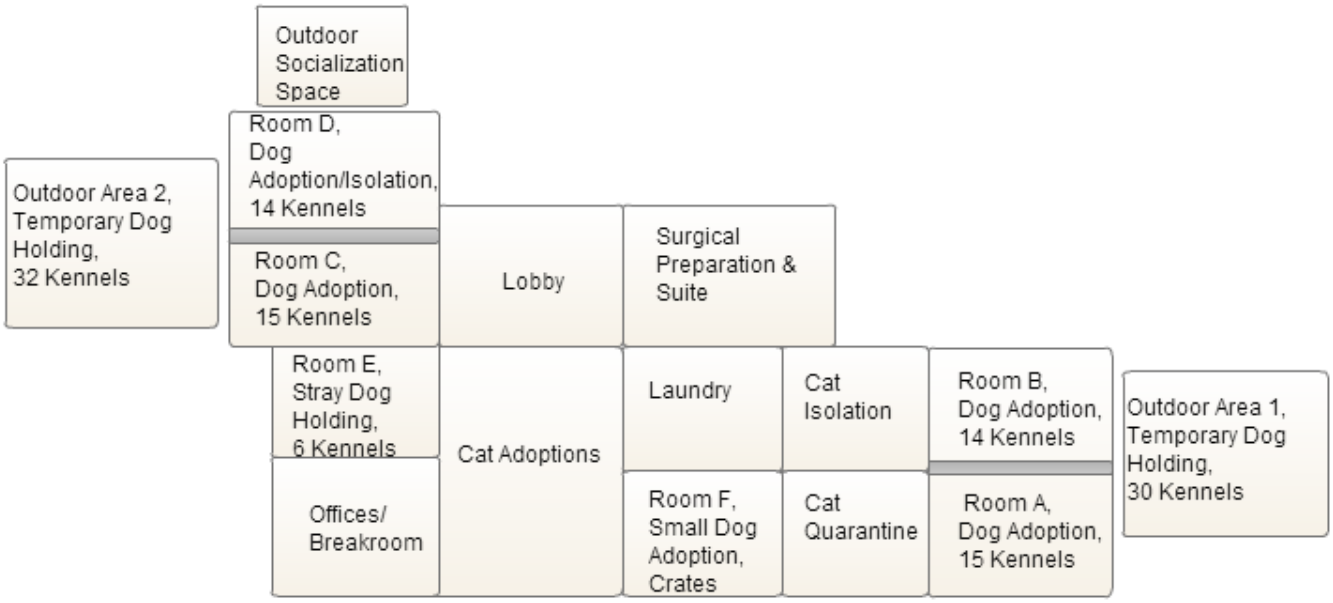
*Vaccination performed at source shelter

Table 5. Summary of Signalments, Medical Histories, Diagnostic Results, and Individual Risk Assessments for Dogs Owned by Staff Members

Animal I.D.	Age at Intake	DAPP Vacc. Date(s)[∞]	Initial Location	Clinical Signs (past or current)	CDV Diagnostic Results	Risk Category
EIG	9y	03/19/15	Staff 1	Remained nonclinical	PCR – AB +	Low
LLI	3y	09/11/14	Staff 1	Remained nonclinical	PCR – AB +	Low
REK	1.5y	11/3/14	Staff 2	Remained nonclinical	PCR – AB +	Low
SRE	3y	12/8/14, 03/1/15	Staff 3	Remained nonclinical	PCR – AB –	High
REP	10y	03/1/15	Staff 3	CIRDC	PCR – AB +	Low, then High
EIH	10y	03/1/15	Staff 3	Remained nonclinical	PCR – AB +	Low
NEL	5y	03/1/15	Staff 3	Remained nonclinical	PCR – AB +	Low
EVO	3y	06/30/14, 03/1/15	Staff 3	Remained nonclinical	PCR – AB +	Low

[∞] Vaccination reported by owner; documentation not provided

Figure 1. Schematic of shelter rooms, including original dog housing areas at initial presentation of the case.



the back of each row of kennels, depositing in a drain within the central-most kennel. Rooms A and B shared the same ventilation system.

Outdoor Area 1 was utilized for temporary holding of dogs from Rooms A and B during daily cleaning. This area consisted of a large concrete pad containing 30 chain-link kennels (1.2 x 2.1 meters each) separated into five rows of six kennels each. Two of the rows abutted each other, with the remaining arranged in single rows. Rows were separated by aisles 1.5 meters wide. Solid barriers were not present between these kennels, allowing direct contact between dogs. There were no drains present in this area.

Rooms C and D were nearly identical in design to Rooms A and B with the exception of the drainage system. There were no drainage troughs within the kennels, instead there was a row of four floor drains located centrally within each room. Rooms C and D shared the same ventilation system. As noted previously, both rooms served as adoption areas. However, Room D was utilized as an isolation area for dogs with signs of CIRDC when necessary. Outdoor Area 2, which was nearly identical in design to Outdoor Area 1, was utilized for temporary holding of dogs from Rooms C and D during daily cleaning.

Room E held stray dogs admitted by animal control and consisted of a single row of five kennels separated by cinderblock walls of 1.5 meters height. In addition, one stand-alone kennel was present in the room. The kennels did not have individual drains. Instead, one floor drain was centrally located within the room. This room had its own ventilation system. Room F held small dogs in crates, which were occasionally stacked on top of each other. This room also had its own ventilation system.

Full-time shelter staff included eight animal care team members who were responsible for daily animal care (divided daily into two to three dog care team members and two cat care team members), one licensed veterinary technician, five administrative personnel, and an executive director. One part-time veterinarian, who primarily served as the spay-neuter surgeon, was also on staff. Shelter staff used a web-based software program for data management.[b] Use of the software was limited to intake and disposition data. Medical recordkeeping consisted of paper charts.

The author served as a shelter medicine consultant for this shelter starting in May 2015. During the case, the author made multiple site visits, directed population risk assessment and management, and provided frequent and regular follow-up phone calls and emails until resolution of the case in October 2015. Decisions regarding individual patient medical and behavioral health management were outside of the author's control, although recommendations to ensure reasonable and humane care of individual animals were provided by the author.

Initial consultation revealed a history of a series of severe CIRDC cases, as well as increased prevalence of CIRDC within the shelter. Multiple dogs within the shelter were exhibiting signs of respiratory disease and some were experiencing gastrointestinal signs as well. One dog (CAS) had recently been euthanized by the shelter veterinarian and another recently adopted dog (MOL) was suffering from recurrent CIRDC, despite supportive care treatment. To obtain a diagnosis, the author directed the shelter director to submit the deceased patient for necropsy to an outside university-based veterinary diagnostic laboratory[c], and requested the recently adopted dog be tested for CDV by the shelter veterinarian or a private practitioner.

Medical record review and discussion with the shelter veterinarian confirmed an increased prevalence and severity of CIRDC within the shelter. Records indicated that nearly

half of dogs had signs of CIRDC and five dogs were experiencing recurring or non-resolving respiratory disease. Four cases of vomiting and/or diarrhea were documented as well. Medical records indicated that dogs with gastroenteritis had been tested using an in-house fecal CPV antigen test[d] and all were negative.

Additional review and discussion yielded information about the two systemically affected dogs, one of whom had been recently euthanized (CAS) and the other recently adopted (MOL). The deceased dog was an emaciated two-year-old, intact female pit bull type dog that had been surrendered to the shelter on March 30, 2015. The shelter did not vaccinate the dog on intake. The owner reported the dog was current on vaccines against distemper/adenovirus-2/parainfluenza-2/parvovirus (DAPP) and rabies, but did not provide documentation of vaccination. The dog developed signs of CIRDC within the shelter on April 14, 2015, including pyrexia, coughing, sneezing, ocular and nasal discharges. Despite administration of antibiotics and supportive care provided by the shelter veterinarian, the patient's signs progressed to anorexia, tachypnea, and lethargy, and she was euthanized on May 5, 2015. The recently adopted patient was an apparently healthy four-year-old, intact female mixed breed dog that had been surrendered to the shelter on February 6, 2015. The shelter did not vaccinate the dog on intake. The owner stated that the dog was current on its DAPP and rabies vaccines, but did not provide documentation of vaccination. The dog developed signs of CIRDC on February 18, 2015, including pyrexia, coughing, and sneezing. The dog was empirically treated for CIRDC for one month, appeared to have fully recovered, and was vaccinated with an MLV DAPP vaccine and spayed on March 17, 2015. The dog remained in the shelter until it was adopted on April 11, 2015. Respiratory signs of CIRDC recurred and the dog also developed myoclonus while under treatment by a local practitioner.

Based on available information, the problem list for the shelter population included increased prevalence and severity of CIRDC, multiple cases of recurrent respiratory signs, and the lack of vaccination on intake. These population level problems, taken in context of the development of neurologic disease in one patient, made CDV the most urgent differential to rule in.

The problem list for the two systemically affected patients included pyrexia, coughing, sneezing, ocular and nasal discharges, tachypnea, anorexia, lethargy, and emaciation. Differential categories for pyrexia, coughing, sneezing, and ocular and nasal discharges included a variety of infectious, inflammatory, immune-mediated, or neoplastic processes. Tachypnea differentials included respiratory disease, cardiac disease, acid-based imbalances, pain, or pyrexia. Differentials for anorexia and lethargy included systemic disease such as inflammation, infection, neoplasia, endocrine disease, or metabolic disease. The deceased dog had presented to the shelter already emaciated, therefore other differential diagnoses were considered as the dog may have been harboring a systemic disease, which had contributed to its emaciation when admitted to the shelter. Differentials for emaciation were similar to anorexia and weakness, but included specific gastrointestinal disease related to the inability to use or retain nutrients, as well as starvation or a primary myopathy. The problem list for the dog recently adopted included myoclonus. Myoclonus differentials were categorized into infectious, inflammatory, toxic, electrolyte, metabolic, neoplastic, degenerative, traumatic, or vascular processes affecting the central nervous system.

The problem list for the individual shelter dogs affected by CIRDC entailed similar respiratory signs as the deceased and adopted dogs but included diarrhea and vomiting. Differential categories for the gastrointestinal signs include inflammatory, infectious, toxic,

metabolic, neoplastic, or immune-mediated processes affecting the gastrointestinal system directly or non-gastrointestinal organs. Mild diarrhea is not uncommon in the shelter setting where abrupt diet changes, stress, or parasitic disease can disrupt normal gastrointestinal function. Accordingly, common causes of mild diarrhea in shelter dogs include gastroenteritis and/or endoparasitism. Infectious diseases, however, are also common causes of diarrhea in shelter animals, particularly when vaccination and medical histories are unknown. Canine parvovirus can be ubiquitous in some shelters and communities and is always a differential for shelter diarrhea. Differentials for vomiting are similar to those of diarrhea, but can be related more frequently to systemic disease. Canine parvovirus can also result in vomiting.

Regarding the temporal manifestation of clinical signs in affected dogs, respiratory signs were followed by gastrointestinal and systemic signs. Because environmental and host risk factors associated with the shelter setting can contribute to the presence and dissemination of infectious disease, an infectious etiology was considered the most likely cause for the combination of clinical signs noted in multiple dogs. Infectious etiologies included viral, bacterial, fungal, and protozoal pathogens. Viral and bacterial causes of CIRDC are more common within the shelter setting compared with other infectious causes.[6] Potential viral causes include CDV, CPiV, CAV-2, CIV (H3N8 and H3N2), canine herpesvirus-1, canine reovirus, CRCoV, and CnPnV.[4] Bacterial pathogens may include *B. bronchiseptica, M. cynos,* and *Streptococcus equi* subspecies *zooepidemicus*.[4] Coinfections with both viral and bacterial pathogens are also recognized.[4,11,12]

The development of a nearly pathognomonic neurologic sign, myoclonus, preceded by recurrent respiratory signs in an individual patient established CDV as the primary differential.[37] Other infectious diseases that can cause neurological signs, such as neosporosis, toxoplasmosis,

or cryptococcosis, could not be completely ruled out; however, CDV was the more likely causative agent in this shelter setting. Lead poisoning, another differential for myoclonus, was also considered, but deemed unlikely, as lead poisoning does not typically result in respiratory signs followed by neurologic signs.[63] Gastrointestinal signs concurrent with respiratory signs in some shelter dogs also supported CDV as the primary differential.

Following the initial consultation, the necropsy report for the deceased dog confirmed bronchointerstitial pneumonia as the primary finding with CDV as its causative pathogen. In addition, the recently adopted dog was diagnosed with CDV through a DFA assay sent by a private practitioner to an outside university-based veterinary diagnostic laboratory[c]. This dog was medically stable but continued to display intermittent, mild myoclonus.

With the confirmation of CDV, information about risk factors contributing to infectious disease in the shelter was obtained with the immediate goal of preventing further disease transmission in the shelter. Review of medical records, biosecurity protocols and population statistics, as well as discussions with shelter staff were used to create a necessary minimum database. Both individual host and shelter risk factors were assessed. Individual risk factors included host immune status and medical status. Shelter risk factors included deficiencies in biosecurity, lack of specific protocols for transferred dogs, inappropriate use of housing, shelter capacity, and a recent history of increased severity and prevalence of CIRDC.

Neither of the dogs diagnosed with CDV received an MLV DAPP vaccination on admission to the shelter. Lack of vaccination was deemed a causative risk factor for both hosts and the shelter population. For the deceased patient, who was emaciated on admission, the likelihood of a debilitated immune system was an additional host risk factor for CDV.[64]

Absence of vaccination on intake also revealed multiple shelter biosecurity risk factors. An intake room was not designated and intake processing protocols were not present, resulting in cursory physical examinations and inconsistent vaccination of newly admitted dogs. Intake vaccination was performed irregularly, based on the dog's age, source of intake, and medical history. Stray dogs typically were vaccinated at the time of sterilization. Owner-surrendered dogs were not vaccinated if the owner relayed a history of vaccination, but documentation was not required. Transferred dogs were not vaccinated if they arrived with a recent vaccine history from the source shelter. Specific protocols for management of puppies were not defined, including vaccination and housing; however, foster care placement was typically sought for puppies less than two months of age.

On-site observation revealed that the shelter's cleaning and disinfection process also contributed to disease transmission. The daily morning cleaning and disinfection process for the dog kennels was performed by two to three animal care team members. Team members wore dedicated boots and aprons during morning cleaning and disinfection but did not use hand protection such as gloves. Dogs were removed from their kennels and placed into the individual outdoor holding kennels while indoor kennels were cleaned and disinfected. Indoor kennels were rinsed with water, solid and liquid waste material were hosed into drains, a quaternary ammonium detergent[e] and a sodium hypochlorite disinfectant[f] were combined into one container and applied onto kennel surfaces for 10 minutes, and kennels were rinsed and squeegeed. The shelter staff were unaware that sodium hypochlorite must be applied to clean surfaces, rendering their one-step cleaning and disinfection process ineffective. After this task was completed, dogs were returned to their indoor kennels and all used outdoor kennels were cleaned and disinfected similarly.

The lack of a consistently designated isolation ward, as well as a lack of a formal monitoring system for infectious disease concerns, resulted in inconsistent identification and segregation of clinical dogs. Clinical dogs were housed with nonclinical dogs within Room D or were not removed from the general population at all. In addition, Room D shared a ventilation system with Room C, which could theoretically increase disease transmission for a respirable pathogen. Before the author was involved in the case, the shelter had started segregating clinical dogs into Room D; however, because Room D was typically used as an adoption area, many dogs were moved throughout the facility to create capacity within Room D for isolation, resulting in increased disease transmission and exposure. Furthermore, due to the number of clinically affected dogs, Room C also was being used as isolation overflow. Accordingly, half of Room C consisted of clinically affected dogs and the other half consisted on nonclinical dogs. Additionally, a protocol for animal handling with regard to infectious disease transmission was not present, resulting in animal care team members contributing to fomite transmission by handling clinical and nonclincal dogs throughout the day.

Several key findings involved the intake, handling, and housing of transferred dogs. Historically, the shelter admitted dogs transferred from local or regional areas, which were considered low-risk for CDV and other infectious diseases. However, in the preceding two months, the shelter had participated in an increasing number of out-of-state transports, ultimately receiving six different groups of dogs, originating from a total of nine different facilities. An air-based national dog rescue network was utilized in which 16 to 46 dogs from three to four different, out-of-state source municipal facilities were transported together at one time.

Biosecurity protocols for the management of these transferred dogs were lacking, resulting in the potential for increased disease exposure to the general shelter population. A

designated housing area for transferred dogs was not available; therefore, these dogs were mixed into the general population on admission, wherever a kennel or crate was available. Transferred dogs were not routinely vaccinated on intake. However, the shelter did require that dogs at source shelters receive two MLV DAPP vaccines two weeks apart before being transported. Unfortunately, this selection process resulted in dogs remaining in high-risk source shelters for at least two weeks before they could be transported, resulting in increased disease exposure at the source shelter. Further, a review of transported dogs' medical records revealed that some dogs were not vaccinated on intake at their source shelter.

Records also indicated that many transferred dogs were either displaying signs of CIRDC at the time of admission, or shortly after arrival. Inquiries to nearby facilities that also had received dogs through the same air transports revealed that at least two additional shelters had received sick dogs and were seeing an increase in CIRDC prevalence. Canine distemper virus was eventually diagnosed at both of those shelters. Accordingly, the source communities and shelters were considered high-risk for infectious diseases.

Inspection of the housing in the facility revealed obvious limitations in functionality that contributed to increased infectious disease transmission. The shelter consisted of single compartment kennels, which required frequent handling and movement of dogs. Kennels faced each other, allowing for respirable infectious pathogens to be transmitted between dogs. Many outdoor kennels lacked side-to-side barriers, allowing for direct contact between dogs. The presence of an open trough drain running through multiple kennels resulted in cross-contamination. Of particular importance to disease transmission, as well as animal welfare, was the use of crates, often stacked on top of each other, within Room F, which was used to house small dogs. This resulted in a dense population that required frequent handling of dogs during

cleaning and disinfection and feeding. Increased chances for disease transmission occurred every time a dog was handled or moved.

Capacity calculations were used to objectively confirm that the shelter was operating beyond its capacity to adequately care for all its animals, based on housing, holding, and staffing capacities. Regarding housing capacity, the shelter had 64 single-compartment kennels and seven crates as housing for the 47 dogs on-site during initial presentation of the case. Accordingly, there were enough kennels to house all dogs, precluding the need for crates. However, because many kennels had defective front gates within Rooms A and B, small dogs could not be safely housed in them. In addition, because all of the kennels in Rooms C and D were occupied for isolation, there was a lack of appropriate housing for small dogs in the shelter. Accordingly, there was a disparate number of functional kennels related to the size of dogs on-site, so crates were used for housing small dogs. As noted previously, using crates as primary enclosures is an unacceptable practice and often indicates that a shelter is attempting to create additional capacity when it is not available.[53]

Regarding daily holding capacity of dogs, calculations of adoption driven capacity (based on a target LOS of 10 days) and required stray holding capacity (based on a five-day required stray hold period) revealed that the appropriate average number of dogs to have on-site daily was 36. This indicated that the shelter had too many dogs on-site, despite the number of housing units present. Furthermore, the shelter's average LOS of 17 days for dogs was slightly prolonged, particularly for a shelter that did not admit many dogs requiring a stray hold period, and reflected that operating beyond an appropriate daily capacity resulted in an increased average LOS.[56]

Regarding staffing capacity, 11.75 hours of daily cleaning and feeding were required for the number of dogs on-site based on the National Animal Care and Control Association's and the

Humane Society of the United States' staffing recommendations to ensure minimum care standards within shelters.[55] This equaled four to six hours of daily cleaning and feeding for the two to three animal care team members assigned to complete these duties. While four to six hours constituted the majority of an animal care team member's workday, it did not allow for other duties that were required of animal care team members such as providing behavioral enrichment to animals, medicating animals, admitting new animals, and helping with adoptions. This indicated that the shelter was operating beyond its staffing capacity. Furthermore, the shelter had purposefully increased the number of transferred dogs by 344% over the past two years, but had not concurrently established additional staffing or appropriate housing capacity for this significant increase in intake.

On-site observation also revealed critical deficiencies in disease surveillance and population health management. The shelter reported increased severity and prevalence of CIRDC and, at initial presentation of the case, 23 dogs were exhibiting signs of CIRDC within the shelter. However, there had been a delay in the recognition and management of the respiratory outbreak, because a formal disease surveillance system was not in place. Daily rounds were not conducted and handwritten medical records did not facilitate disease tracking.

The various risk factors for infectious disease present in the shelter reflected a systemic inadequacy in population management. Although various shelter personnel managed different aspects of the sheltering system, a formal population management team did not exist to ensure that capacity for care and medical and behavioral well-being were maintained. In addition, even though a full-time veterinary technician and a part-time veterinarian were present, medical oversight was lacking, resulting in significant deficiencies in infectious disease prevention.

The problem list for the shelter is summarized in Table 6. Based on the considerable risk factors present throughout the shelter, widespread disease exposure was assumed. Shelter risk factors were prioritized and the following actions steps were implemented for immediate infectious disease control:

1. Confirmation of CDV within the shelter through diagnostic testing.
2. Continued segregation of all clinical dogs with signs of CIRDC, even if mildly affected, into Room D, with overflow CIRDC dogs housed on one side of Room C and nonclinical dogs on the other side of Room C.
3. Temporary suspension of adoptions, as well as admission of any dog the shelter was not contractually obligated to admit, until the extent of CDV was well defined.
4. Creation of a clean break to limit disease exposure for stray dogs the shelter was required to admit. Four kennels within Room A were curtained off and demarcated for newly admitted dogs. This area was over 7.5 meters away from all other dogs. Each new admit was administered an MLV DAPP vaccine by a cat care team member before entering its kennel.
5. Modified live virus DAPP vaccination on every dog over four weeks of age admitted to the shelter, as well as any dog in the shelter that had not been vaccinated in the past two weeks.
6. Institution of strict fomite control protocols to prevent cross-contamination, including the use of PPE throughout the shelter and the designation of one to two dedicated animal care team members as the only staff handling CDV suspect dogs.
7. Separation of the quaternary ammonium detergent and the sodium hypochlorite disinfectant into a two-step process for more effective cleaning and disinfection.

Table 6. Shelter problem list.

Risk Factor Category	Specific Concerns
Biosecurity	Lack of protocols for: intake, vaccination, cleaning/disinfection, disease surveillance/daily rounds, puppy management
	Inconsistent vaccination on intake
	Lack of intake room
	Ineffective cleaning and disinfection process
	Lack of a consistent isolation ward with separate ventilation system
	Unrecognized fomite transmission by staff
Lack of protocols for transferred dogs	Lack of separate housing area
	Inconsistent vaccination on intake
	Admission of clinical dogs
	Dogs awaiting two vaccines at source shelter
	Source shelters not vaccinating on intake
	Two additional shelters reported CDV
Housing	Single-compartment housing resulting in frequent movement of dogs daily
	Inappropriate use of crates as dog housing
	Lack of barriers between some kennels
	Open trough drain running through some kennels
Shelter Capacity	Inadequate housing unit numbers for small dogs due to kennels in disrepair
	Daily dog population beyond adoption driven capacity and required stray holding capacity
	Increased average LOS for dogs
	Inadequate staff numbers
	Lack of population management team
Delayed recognition and management of outbreak	Lack of disease tracking/daily rounds
	Increased severity and prevalence of CIRDC

8. Communication with adopters, source shelters, and local practitioners to alert them to the potential of CDV and to assess how widespread CDV was in the community.

For confirmation of CDV, the shelter submitted respiratory samples (oropharyngeal, nasal, and conjunctival) from nine shelter dogs with clinical signs consistent with CDV for PCR testing to an outside university-based veterinary diagnostic laboratory[g]. The only pathogen tested for was CDV. It was emphasized that the shelter should assume CDV was present in the shelter and to implement appropriate infectious disease prevention measures, as outlined above, while PCR tests pended.

This initial round of PCR testing confirmed CDV within the shelter with three of the nine dogs sampled PCR-positive for CDV (Table 7). Of these three dogs, only two were considered true wild-type infection based on viral load. Based on these results, the CDV PCR-positive dogs, regardless of viral load, were immediately isolated from other clinical dogs. All nonclinical dogs without a recent history of CIRDC were kept in their current location until further risk assessment through additional diagnostic testing was performed. Surgery and outdoor socialization were suspended, as well. Housing designations at this point in the case are represented in Figure 2.

With the confirmation of CDV within the shelter, the author made an immediate site visit to help with mitigation of disease transmission, risk assessment, and population management. The goal was to prevent further transmission of CDV within the shelter while facilitating the movement of dogs through the sheltering system. Together, the author, the shelter veterinarian, and veterinary technician performed a physical examination on each dog in the shelter to ensure that all clinical dogs were identified.

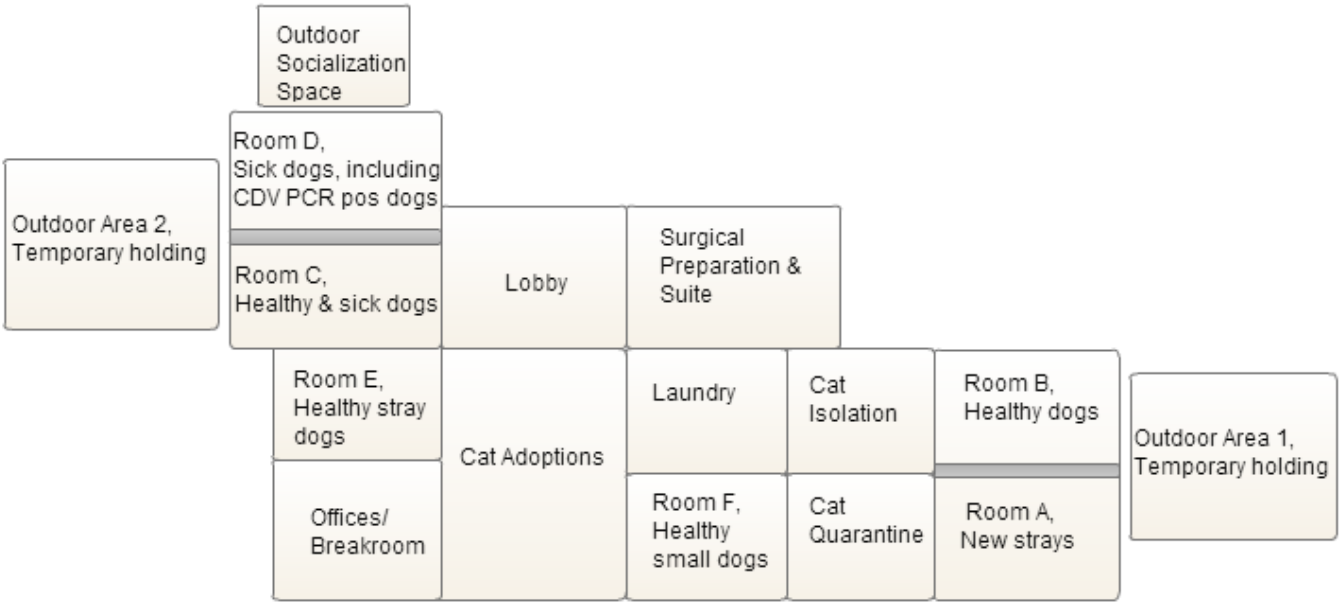
Table 7. Qualitative and Quantitative Results* of CDV Real-Time PCR for 9 Clinical Shelter Dogs – 5/12/15 (Outside Laboratory[g])

Animal I.D.	CDV PCR	Cycle Threshold Value
ELV	POSITIVE	32.8
COO	NEGATIVE	
JAK	POSITIVE	36.3
ROR	NEGATIVE	
GUS	POSITIVE	33.6
JOH	NEGATIVE	
BOS	NEGATIVE	
MSB	NEGATIVE	
DER	NEGATIVE	

*Explanation from laboratory:
Real-Time PCR provides a relative value (cycle threshold (CT)), which indicates the amount of target nucleic acid in the sample. CT is inversely proportional to the amount of target present in the sample (lower CT value indicates more nucleic acid). Values < 36 are positive. Values from 37-40 indicate minimal amounts of target nucleic acid, which could represent early or late infection, residual vaccine, or environmental contamination.

Color Key: Red = Positive with high viral load; Yellow = Positive with low viral load

Figure 2. Schematic of updated dog housing areas – May 13, 2015.



Risk assessment for individual dogs was subsequently performed. Initially, the author used each dog's age, intake date, source of intake, clinical history, vaccination history, and proximity to CDV PCR positive dogs to categorize risk. However, disease exposure was widespread and many dogs lacked proof of vaccination prior to shelter admission or proper vaccination on intake at a source shelter could not be verified. Consequently, the majority of dogs were considered moderate to high-risk.

Due to these confounding issues, PCR and serology were indicated to better define risk categories. If a dog was clinical for CIRDC or had experienced signs within the past six weeks, it was PCR tested and considered high-risk for CDV. If a dog was nonclinical and had not had recent CIRDC signs, it was considered low-, moderate-, or high-risk for CDV, depending on its age and antibody titer results. A flowchart for individual dog risk assessment is illustrated in Figure 3.

All dogs with current or recent signs of CIRDC were PCR tested to assess whether they were shedding CDV (Table 8). These dogs were considered highest risk for CDV. All high-risk dogs on-site were tested; however, high-risk dogs off-site (recently adopted and reported to be clinical, within a foster home, or owned by a staff member) were tested if their caretaker was able to bring them in for collection sampling. A total of 27 dogs were PCR tested. Seven clinical dogs tested PCR-positive for CDV. Four of the positive dogs were on-site. They were housed within Room D and treated with supportive care, overseen by the shelter veterinarian. Of the three off-site CDV PCR-positive dogs, one was the recently adopted dog that had tested CDV-positive through a DFA assay. This patient remained in its adoptive home and had clinically improved except for occasional jaw-snapping focal seizures but was eventually lost to follow up. The other two positive dogs were in foster care at a shelter staff member's home and were

Figure 3. Flowchart for individual dog risk assessment for CDV.

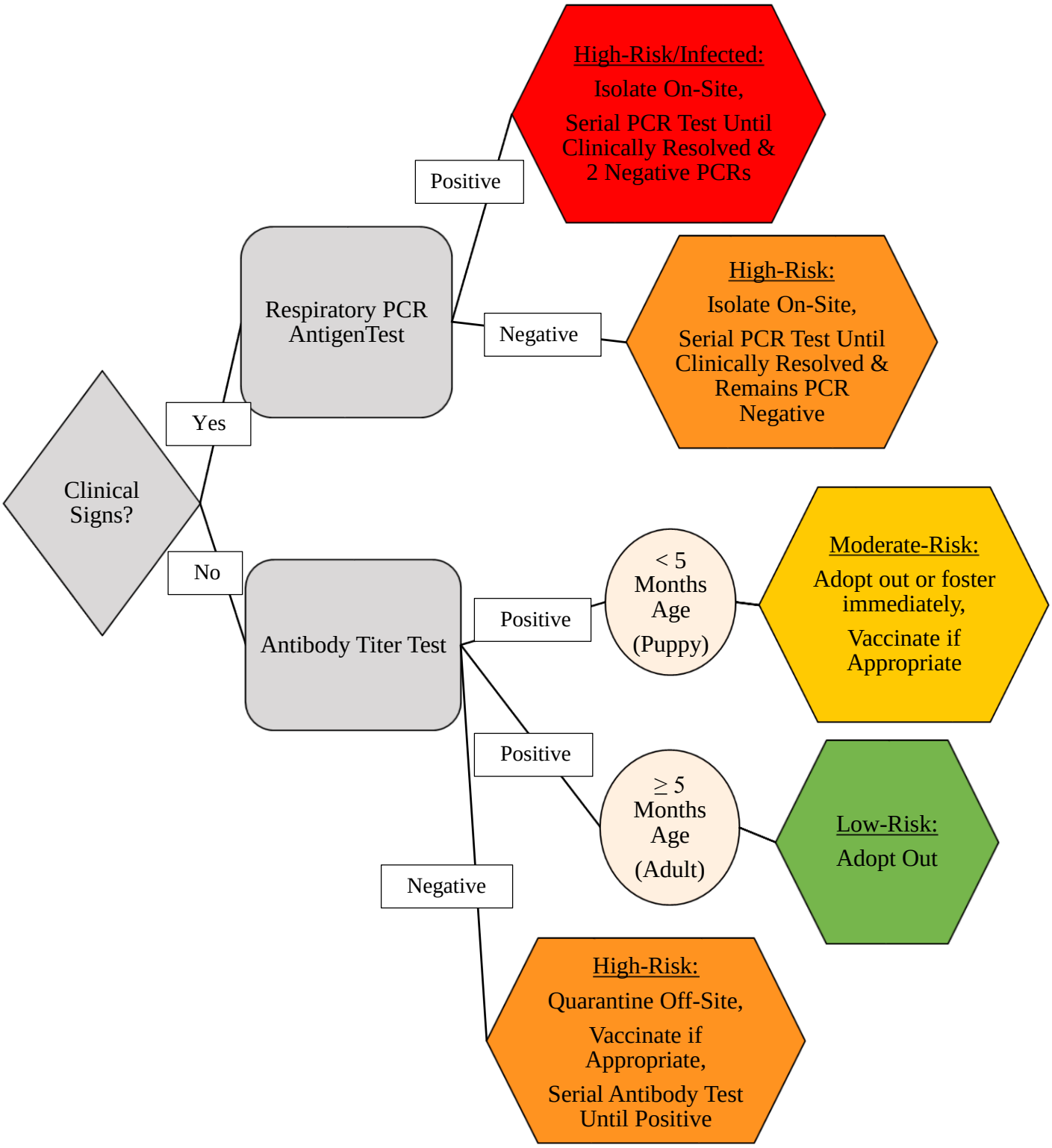


Table 8. Qualitative and Quantitative* Results of CDV Real-Time PCR for All Clinical Dogs – 5/19/15 (Outside Laboratory[8])

Animal I.D.	CDV PCR	Cycle Threshold Value
MOL	POSITIVE	34.7
ABB	NEGATIVE	
ARR	NEGATIVE	
BET	NEGATIVE	
BOS	NEGATIVE	
COO	NEGATIVE	
DER	NEGATIVE	
ELV	POSITIVE	36.4
GUS	POSITIVE	24.7
JAK	POSITIVE	36.4
JOH	NEGATIVE	
LOL	NEGATIVE	
MSB	NEGATIVE	
WMA	NEGATIVE	
ADR	NEGATIVE	
BRO	NEGATIVE	
MIA	NEGATIVE	
OLY	NEGATIVE	
ROR	NEGATIVE	
TRA	NEGATIVE	
HER	NEGATIVE	
KOB	NEGATIVE	

Table 8 (cont.). Qualitative and Quantitative Results* of CDV Real-Time PCR for all Clinical Dogs – 5/19/15 (Outside Laboratory[g])

AND	NEGATIVE	
GRS	NEGATIVE	
KYL	POSITIVE	32.4
IRI	POSITIVE	33.7
ROS	POSITIVE	36.3

* Explanation from laboratory:
Real-Time PCR provides a relative value (cycle threshold (CT)), which indicates the amount of target nucleic acid in the sample. CT is inversely proportional to the amount of target present in the sample (lower CT value indicates more nucleic acid). Values < 36 are positive. Values from 37-40 indicate minimal amounts of target nucleic acid, which could represent early or late infection, residual vaccine, or environmental contamination.

Color Key: Red = Positive with high viral load; Yellow = Positive with low viral load

clinically improved except for occasional coughing. Table 9 summarizes the signalment, medical history, initial diagnostic results, and outcomes of all dogs that tested positive for CDV over the entire course of the case.

Primary medical case management of CDV PCR-positive shelter dogs was performed by the shelter veterinarian; however, the author ensured that treatment practices were humane and reasonable. A system for patient monitoring was implemented to ensure that acute, critical changes in an animal's medical condition were promptly recognized. An emphasis was also placed on maintaining behavioral well-being for dogs requiring prolonged treatment and/or isolation. Although the shelter was committed to trying to save the lives of clinically affected, CDV PCR-positive dogs, the author ensured that a clear policy, which specified humane endpoints of treatment, was in place. The shelter leadership, veterinarian, and author established specific criteria for euthanasia decisions based on objective Accassessments of trends in weight loss, body condition score, the inability to eat, and the inability to move. Subjective assessments of pain, discomfort, and the lack of a desire to eat were incorporated, as well. In addition, a decision was made that treatment of affected patients at a private veterinary practice was not financially sound and therefore would not be pursued. However, shelter leadership agreed that they would finance post-adoption medical care if a recovered dog developed delayed neurological signs. In addition, the author highlighted that in choosing to treat clinically affected dogs, the shelter would have to accept the risk this posed on the remaining population particularly since a designated isolation space was not present. Accordingly, biosecurity practices in the shelter would have to be enhanced and staff would have to be compliant with such changes.

Table 9. Summary of CDV PCR-Positive Dogs.

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Location* During Outbreak	Clinical Signs	Outcome Type & Date	CDV Diagnostics	Shedding Period
CAS	2y	3/30/15	Owner surrender	None	Deceased	Progressive CIRDC, anorexia	Euthanized: 5/5/15	Necropsy 5/8/15: positive	N/A
MOL	4y	2/5/15	Owner surrender	3/17/15	Adopted	Recurrent CIRDC, myoclonus, focal seizures (jaw snapping)	Adopted: 4/11/15	DFA 5/10/15: positive[c] PCR 5/19/16: positive	At least 34 days, lost to follow-up
ELV	6y	4/11/15	Out of state (1)	4/3/15, 7/2/15	Room C → Room D → Room B	Progressive CIRDC, anorexia, weight loss	Adopted: 7/2/15	PCR 5/12/15: positive	At least 37 days
GUS	2y	4/30/15	Out of state (2)	4/24/15	Room C → Room D → Room B → Deceased	Progressive CIRDC, anorexia, diarrhea (CPV antigen 5/12/15: negative), recumbent	Euthanized: 5/24/15	PCR 5/12/15: positive	At least 12 days
JAK	11y	3/31/15	Owner surrender	4/3/15, 7/3/15	Room D → Room D	Recurrent CIRDC, anorexia	Adopted: 7/3/15	PCR 5/12/15: positive	At least 34 days
KYL	5y	4/3/15	Returned after adoption; originally owner surrender	10/10/14, 6/24/15	Room F → Room B	Recurrent CIRDC, vomiting (CPV antigen 4/30/15: negative)	Foster at non-staff member home: 6/24/15-9/15/15 Adopted: 9/20/15	DFA 4/28/15: negative[c] PCR 5/19/15: positive	At least 105 days, lost to follow-up

Table 9 (cont.). Summary of CDV PCR-Positive Dogs.

Animal I.D.	Age at Intake	Intake Date	Source of Intake	DAPP Vacc. Date(s)	Location* During Outbreak	Clinical Signs	Outcome Type & Date	CDV Diagnostics	Shedding Period
IRI	3m	3/6/15	Out of state (9)	2/28/15*, 5/5/15	Foster at Staff 3 → Room B	Progressive & recurrent CIRDC, anorexia	Foster to Adopt: 6/19/15	PCR 5/19/15: positive	At least 57 days
ROS	3m	3/6/15	Out of state (9)	2/28/15*, 5/5/15	Outside Vet Clinic → Foster at Staff 3 → Room B	Progressive & recurrent CIRDC, anorexia	Foster to Adopt: 6/19/15	PCR 5/19/15: positive	At least 14 days
SEL	6m	3/26/15 ***, 4/11/15	Out of state (2)	3/31/15, 4/14/15 ****	Adopted	Recurrent CIRDC	Adopted: 4/12/15	PCR 5/27/15: positive	At least 75 days
JEF	8m	3/6/15 ***, 4/11/15	Out of state (2)	3/10/15 **, 5/28/15	Adopted	Recurrent CIRDC, lethargy, focal seizures (jaw snapping)	Adopted: 4/13/15	DFA 5/24/15: positive[c] PCR 5/27/15: positive	At least 131 days, lost to follow up
MAI	4y	5/9/15	Regional animal control	5/9/15, 6/10/15	Indoor Room A → Room B	Mild CIRDC	Adopted: 6/20/15	PCR 5/27/15: positive	At least 6 days

* Vaccination performed at source shelter

*Room locations include movements based on risk assessment and housing designations

**Vaccinations reportedly performed outside of shelter but not documented

***Intake to source shelter

****Vaccinated at outside clinic and documented

One CDV PCR-positive dog (GUS) was euthanized after he became progressively affected with severe respiratory signs, pyrexia, and persistent anorexia, despite medical treatment. Although the author requested this patient be submitted for necropsy, the shelter did not follow through on this recommendation.

Dogs that were clinically affected with CIRDC but CDV PCR-negative were segregated from other dogs and were considered high-risk for CDV based on the intermittent shedding of CDV. These dogs were under supportive care treatment overseen by the shelter veterinarian.

All dogs were serologically tested for CDV, because exposure to CDV was considered widespread (Table 10). This included both clinically affected and nonclinical dogs. It included all shelter dogs, as well as dogs off-site in a foster, adoptive, or staff member's home when possible. The serum samples for serology were sent to the author's laboratory technician for testing using a point-of-care semiquantitative ELISA[a]. Sixty-one dogs, all considered adults, were serologically tested for CDV. All but two dogs were CDV antibody titer-positive. Nonclinical dogs that were CDV antibody titer-positive were considered low-risk and made available for adoption with a medical disclosure. Clinical dogs that were CDV antibody titer-positive were still considered high-risk and remained isolated on-site.

Both of the CDV antibody titer-negative dogs were nonclinical for disease. One dog was on-site (MIA) and had a recent history of CIRDC but was CDV PCR-negative. The other was a staff member-owned dog (SRE). Both were considered high-risk for acquiring CDV. The on-site dog (MIA) was immediately administered an MLV DAPP vaccine, as it had not received a vaccination within the past two weeks, and was promptly relocated to a foster home for quarantine to reduce its risk of exposure to CDV and to better maintain its behavioral well-being

Table 10. Semiquantitative Results of CDV Antibody Titer Test for all Exposed Dogs – 5/19/2015 (Outside Technician)

Animal I.D.	CDV Titer Result*
BOS	Positive, 4-5
COO	Positive, 4
DER	Positive, 6
JOH	Positive, >6
MSB	Positive, 6
OLY	Positive, 5-6
ROR	Positive, >6
ELV	Positive, >6
GUS	Positive, 5
JAK	Positive, >6
ABB	Positive, 4-5
ARR	Positive, 6
BET	Positive, 5
LOL	Positive, >6
WMA	Positive, 4-5
ADR	Positive, 5
BRO	Positive, >6
MAM	Positive, 6
MAN	Positive, 6
MIA	Negative, 1
RAB	Positive, >6
ROC	Positive, >6
SCO	Positive, 5
TRA	Positive, >6
CAH	Positive, >6
DEE	Positive, 6
DUK	Positive, 6
GRA	Positive, 6
HER	Positive, 6
KHL	Positive, 5
MOB	Positive, 6
MAI	Positive, >6
MUR	Positive, 6
PEA	Positive, 4
ROL	Positive, >6
AND	Positive, 6
CAR	Positive, >6
FIN	Positive, >6
GRS	Positive, 6

Table 10 (cont.). Semiquantitative Results of CDV Antibody Titer Test for all Exposed Dogs – 5/19/2015 (Outside Technician)

KYL	Positive, 6
OZZ	Positive, 6
PET	Positive, >6
CHI	Positive, 5
EMM	Positive, 4-5
LUK	Positive, 5
MIK	Positive, 4-5
MIY	Positive, 3
BEL	Positive, 6
EIG	Positive, 5-6
LLI	Positive, 5-6
REK	Positive, >6
IRI	Positive, 6
ROS	Positive, >6
SRE	Negative, 1
REP	Positive, >6
EIH	Positive, 3
NEL	Positive,>6
EVO	Positive, 6
BOB	Positive, 6
MOL	Positive, 6

* A score of 3 or above is considered a positive result. A score of 2 is considered an inconclusive result. A score of 1 or less is considered a negative result.

Color Key: Pink = Interpreted as negative result

if long-term confinement was required. The staff member's dog (SRE) was more difficult to quarantine because it was living with two foster dogs (IRI and ROS), both of which were CDV PCR-positive. The author advised that the dog (SRE) receive an MLV DAPP vaccination as soon as possible by a private practitioner. To aid in quarantine of the dog at its own home, the staff member returned both of her foster dogs (IRI and ROS) back to the shelter. Both CDV antibody titer-negative dogs were monitored for the development of clinical signs while being titer tested weekly until a rise in titer levels was documented. Both dogs' CDV antibody titers had risen to adequate levels within two weeks of being re-vaccinated (Table 11). Neither dog developed clinical signs of disease during this period. Accordingly, both dogs were cleared from quarantine within two weeks.

In addition to PCR and antibody titer testing for risk assessment, comprehensive infectious disease testing was performed on some dogs to determine if other respiratory pathogens were present in the population (Table 12). A combination of 11 nonclinical and clinical dogs were PCR tested for additional respiratory pathogens. Three mucosal swabs (conjunctival, oropharyngeal, and nasal) were collected from each dog and sent to a different outside independent national veterinary diagnostic laboratory[h]. This laboratory offered a comprehensive respiratory PCR panel that tested for the following pathogens: CDV, *B. bronchiseptica*, CAV-2, canine herpesvirus-1, CPiV, CIV (H3N8 and H3N2), CRCoV, CnPnV, *M. cynos*, and *Streptococcus equi* subspecies *zooepidemicus*. If a dog was CDV-positive on this panel, then quantification of viral load, as well as interpretation of the quantification, were provided by the laboratory. Three dogs already confirmed to be CDV PCR-positive by the outside university-based veterinary diagnostic laboratory[g] were tested through this panel and all three were CDV-positive. Results of viral loads, although calculated differently at the two

Table 11. Semiquantitative Results of CDV Antibody Titer Test for 2 Dogs Initially Titer Negative (Outside Technician)

Animal I.D.	5/19/15	5/26/15	6/3/15
MIA	Negative, 1	Negative, 1	Positive, 4
SRE	Negative, 1	Negative, 1	Positive, 5

* A score of 3 or above is considered a positive result. A score of 2 is considered an inconclusive result. A score of 1 or less is considered a negative result.

Color Key: Pink = Interpreted as negative result

Table 12. Positive Qualitative and Quantitative Results* of Comprehensive Respiratory PCR for 11 Dogs – 5/19/15 (Outside Laboratory[h])

Animal I.D.	Clinical Presentation	PCR-Positive
ELV	CIRDC	CDV + CDV quantification = 11,000/swab CDV interpretation = vaccine interference if recently vaccinated *Mycoplasma cynos* +
GUS	CIRDC	CDV + CDV quantification = 12,447,000/swab CDV interpretation = wild-type infection *Mycoplasma cynos* +
JAK	CIRDC	CDV + CDV quantification = 6,000/swab CDV interpretation = vaccine interference if recently vaccinated *Bordetella bronchiseptica* + *Mycoplasma cynos* +
ABB	CIRDC	*Mycoplasma cynos* +
ARR	CIRDC	*Bordetella bronchiseptica* + *Mycoplasma cynos* +
RAB	Nonclinical	*Mycoplasma cynos* +

Table 12 (cont.). Positive Qualitative and Quantitative Results* of Comprehensive Respiratory PCR for 11 Dogs – 5/19/15 (Outside Laboratory[h])

Animal I.D.	Clinical Presentation	PCR-Positive
DEE	Nonclinical	None
MAI	Nonclinical	*Mycoplasma cynos* +
ROL	Nonclinical	None
CAR	Nonclinical	*Mycoplasma cynos* +
MIK	Nonclinical	None

* Explanation from laboratory:
Three ranges of CDV Quantity: 1) CDV Vaccine Strain: Below 105 Thousand (105,000) CDV RNA particles per swab(s). 2) Indeterminate: Between 105 Thousand (105,000) and 1,000 Thousand (1 Million) CDV RNA particles per swab(s). 3) CDV Wildtype Infection: Above 1,000 Thousand (1 Million) CDV RNA particles per swab(s). A positive canine respiratory panel PCR result indicates the detected organism(s) is likely contributing to the clinical signs. Additional causes should be assessed separately. Vaccination with a modified live vaccine may result in positive results for up to a few weeks post-vaccination. A negative canine respiratory panel PCR result indicates that the organism was not detected in this sample and suggests the absence of an infectious cause, by these organisms, for the clinical signs. PCR may not detect 100% of the isolates or levels of the organisms may be too low to be detected.

Color Key: Red = Positive with high viral load; Yellow = Positive with low viral load

laboratories, were similar to each other in terms of interpretation of vaccine interference versus wild-type infection. Additional respiratory pathogens discovered through the comprehensive PCR panel included: eight of 11 dogs positive for *M. cynos* and two of 11 dogs positive for *B. bronchiseptica*.

Dog housing was rearranged to reflect updated knowledge of individual risk, and to accommodate the relocation of small dogs out of crates and into kennels. All dogs were moved out of their kennels into outdoor kennels, all indoor kennels were cleaned and disinfected with the newly implemented a two-step sanitation process, and dogs were moved into newly designated housing areas within the facility. Housing designations were updated such that Rooms A and B now served as isolation, housing all clinical dogs. Clinical dogs that were CDV PCR-negative were in Room A and clinical CDV PCR-positive dogs were in Room B. Rooms C and D now functioned solely as adoptions, housing all nonclinical CDV antibody titer-positive dogs. All newly admitted stray dogs were housed in Room E. Nonclinical CDV antibody titer-negative dogs had special housing arrangements made off-site, as noted previously. Updated room designations are shown in Figure 4.

To aid in future population management decisions, a diagnostic protocol for clinical dogs and newly admitted stray dogs was created. The protocol was based on the relatively long incubation and shedding periods of CDV. The protocol consisted of:

1. Clinical CDV PCR-positive dogs were PCR tested weekly to monitor their viral load. When clinically resolved and PCR-negative for two consecutive weeks, these dogs were cleared for adoption (Table 13).

Figure 4. Schematic of updated dog housing areas – May 20, 2015.

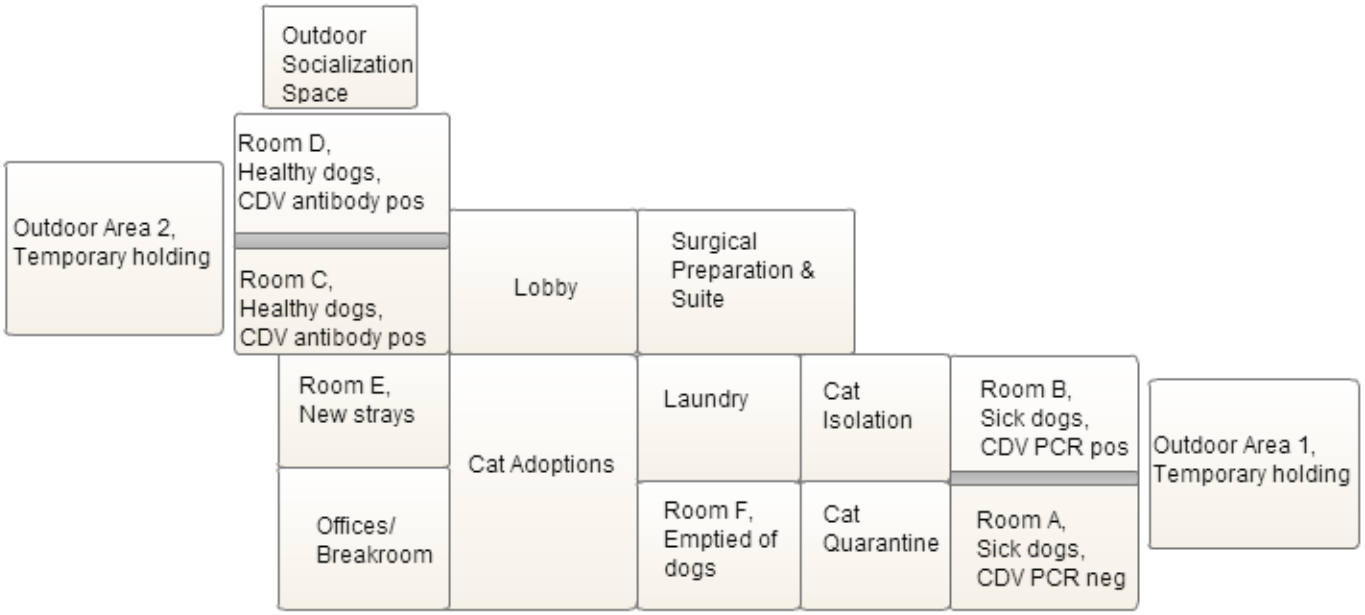


Table 13. Serial Qualitative and Quantitative* Results of CDV Real-Time PCR for CDV PCR-Positive Dogs (Outside Laboratory[g])

Animal I.D.	5/19/15	5/27/15	6/1/15	6/8/15	6/15/15	6/22/15	6/29/15	7/6/15	7/14/15	7/20/15	7/22/15	7/27/15	8/3/15	8/10/15	8/17/15	8/25/15	9/1/15	9/14/15	9/21/15	10/5/15
MOL	+ 34.7					+ 32.1														
ELV	+ 36.4	+ 35.4	+ 37.9		+ 38.1	-	-													
GUS	+ 24.7																			
JAK	+ 36.4	+ 36.5	-		+ 38.4	-	-													
KYL	+ 32.4	+ 34.1	+ 35.6		+ 30.8	+ 35.8	+ 34.3	+ 36.9	+ 38.4	-	+ 37.2	+ 36.9	+ 38.2	+ 36.1	+ 39.3	+ 37.5	-	-		
IRI	+ 33.7	+ 35.4	+ 37.9		+ 36	+ 37.2	+ 37.8	-	+ 38.2	-	-									
ROS	+ 36.3	-	+ 38.8		+ 39.8	-	-													
SEL		+ 36.5	+ 32.7	+ 33.7	+ 36.1	+ 34.3	+ 38.1	+ 35.4	+ 36.4	+ 32.9		-	+ 33.6	+ 39.3	-		-		-	
JEF		+ 29.2				+ 31.8	+ 31.1	+ 31.8	+ 27.8	-		+ 38.5	+ 34		+ 39.1	+ 34.9			+ 35.4	+ 31
MAI **		+ 37.8	-		-															

Table 13 (cont.). Serial Qualitative and Quantitative Results* of CDV Real-Time PCR for CDV PCR-Positive Dogs (Outside Laboratory[g])

* Explanation from laboratory:
Real-Time PCR provides a relative value (cycle threshold (CT)), which indicates the amount of target nucleic acid in the sample. CT is inversely proportional to the amount of target present in the sample (lower CT value indicates more nucleic acid). Values < 36 are positive. Values from 37-40 indicate minimal amounts of target nucleic acid, which could represent early or late infection, residual vaccine, or environmental contamination.

**This patient was CDV PCR-negative on 5/19/15 on the comprehensive panel performed at a different, outside laboratory.

Color Key: Red = Positive with high viral load; Yellow = Positive with low viral load

Note regarding presentation of results: If a qualitative result was positive, the quantitative result is listed below it.

2. Clinical CDV PCR-negative dogs were PCR tested weekly until clinically resolved. When clinically resolved and if their PCR status remained negative, these dogs were cleared for adoption.
3. Dogs that developed clinical signs were immediately PCR tested and then followed weekly as directed above based on their PCR status.
4. Newly admitted, nonclinical stray dogs were CDV antibody titer tested. If antibody-positive, they were housed and adopted out of Room E after their legal hold period was completed. If antibody titer-negative, they were sent to foster for quarantine. Animal control officers were directed to take sick stray dogs to a local private practitioner for care instead of bringing them on-site.

Despite the implemented diagnostic and population management protocols, additional dogs developed clinical signs. One dog developed signs in the shelter, two owners reported clinical signs in their recently adopted dogs, and one dog owned by a staff member developed signs. These dogs were all PCR tested for CDV (Table 14). The shelter dog (MAI) was an apparently healthy adult admitted on May 9, 2015 before admissions were temporarily stopped. The dog received an MLV DAPP vaccination on intake, but was not housed within a clean break area. The dog was nonclinical, considered low-risk for CDV, and was therefore not PCR tested during the initial rounds of testing on May 12 or 19. Antibody titer testing revealed a strong positive result for CDV. It was also one of the nonclinical dogs tested on May 19 through the more comprehensive respiratory disease panel. It was PCR-positive for *M. cynos* but negative for CDV. The dog developed signs of CIRDC on May 21 and tested weak PCR-positive for CDV on May 27. Extreme caution was used in interpreting these results because of the extent of CDV in the shelter and the clinical signs of the dog. Although the dog's antibody titer result suggested

Table 14. Qualitative and Quantitative* Results of CDV Real-Time PCR for Newly Affected Dogs – 5/27/15 (Outside Laboratory[g])

Animal I.D.	CDV PCR	Cycle Threshold Value
MAI	POSITIVE	37.8
SEL	POSITIVE	36.5
JEF	POSITIVE	29.2
REP	NEGATIVE	

* Explanation from laboratory:
Real-Time PCR provides a relative value (cycle threshold (CT)), which indicates the amount of target nucleic acid in the sample. CT is inversely proportional to the amount of target present in the sample (lower CT value indicates more nucleic acid). Values < 36 are positive. Values from 37-40 indicate minimal amounts of target nucleic acid, which could represent early or late infection, residual vaccine, or environmental contamination.

Color Key: Red = Positive with high viral load; Yellow = Positive with low viral load

protection, the low viral load on PCR testing indicated possible vaccine interference, and clinical disease due to *M. cynos* could not be ruled out, the dog was still considered high-risk for CDV. The dog resolved clinically and was negative on two subsequent CDV PCR tests.

The two recently adopted dogs (SEL and JEF) reported to be clinical had both been transferred from the same source shelter on an air transport on April 11, 2015. One dog (SEL) was six months old when transferred. A review of the medical records from the source shelter revealed she had entered the source shelter on March 26, received a DAPP vaccine on March 31, developed CIRDC signs on April 3, but was cleared for transport by April 10. She was apparently healthy on arrival and adopted the next day, but post-adoption medical records from a private practitioner revealed she exhibited CIRDC signs on April 29. She manifested CIRDC signs again on May 22, and a PCR test for CDV performed on May 27 revealed a weak positive result. Although she resolved clinically within a short period after initial CDV diagnosis, subsequent CDV PCR testing revealed she remained positive for nearly 11 weeks. She was under the care of a private practitioner and stayed in her adoptive home during this time with instructions to avoid communal dog spaces such as parks and daycares.

The other dog (JEF) was eight months old when transferred. Similar to the other transferred dog, medical records from the source shelter revealed this dog had entered the source shelter, was vaccinated four days later, developed CIRDC 10 days later, but was declared healthy for transport by April 11. He was apparently healthy on arrival and adopted within two days. Post-adoption, private practice medical records revealed recurrent CIRDC, vomiting, the development of jaw-snapping focal seizures, and diagnosis of CDV through a DFA assay performed at an outside university-based veterinary diagnostic laboratory[c] on May 24. When PCR tested by the shelter on May 27, the dog was CDV-positive, as well. The dog improved

clinically, but maintained intermittent, mild jaw snapping. Subsequent CDV PCR testing revealed he remained positive for nearly 19 weeks. The dog was eventually lost to follow-up.

An owned dog (REP) within the home of the staff member, who was fostering two CDV PCR- positive dogs (IRI and ROS), also developed CIRDC signs. Because this dog had been reported to be nonclinical during the initial rounds of diagnostic testing, it was categorized as low-risk and only antibody titer tested. It had been positive for CDV antibody titers. When subsequently PCR tested for CDV on May 27, it was negative. The dog resolved clinically within one week and remained negative for two additional PCR tests.

With the diagnosis of additional cases, there was concern that individual risk assessments were incorrectly assigned and that nonclinical dogs initially categorized as low-risk based on CDV antibody-positive titer tests could pose a greater risk than recognized. As noted previously, based on the long incubation period for CDV, a positive titer may be related to both immunity *and* infection, thereby confounding positive antibody titer results.[2] There was also concern that off-site dogs who were not physically examined by the author could have been incorrectly risk assessed. Subsequently, adoptions were closed again until further diagnostic testing and reevaluation of individual risk could be completed. All nonclinical dogs initially categorized as low-risk were PCR tested for CDV. No additional dogs tested PCR-positive (Table 15). Adoptions was reopened and all nonclinical, low-risk, antibody-positive, PCR- negative dogs were moved through the sheltering system.

With confirmation of appropriate risk categorizations and no development of new cases, the shelter continued the previously designated diagnostic protocol for population management until all cases resolved. All shelter dogs were eventually adopted, with the majority adopted within one month of the start of the case. A summary of case resolution is as follows:

Table 15. Qualitative and Quantitative* Results of CDV Real-Time PCR for Nonclinical, CDV Antibody Titer-Positive, Low-Risk Dogs – 6/1/15 (Outside Laboratory[g])

Animal I.D.	CDV PCR
MAM	NEGATIVE
MAN	NEGATIVE
RAB**	NEGATIVE
ROC	NEGATIVE
SCO	NEGATIVE
CAH	NEGATIVE
DEE**	NEGATIVE
DUK	NEGATIVE
GRA	NEGATIVE
KHL	NEGATIVE
MUR	NEGATIVE
PEA	NEGATIVE
ROL**	NEGATIVE
CAR	NEGATIVE
FINN	NEGATIVE
OZZ	NEGATIVE
PET	NEGATIVE
EMM	NEGATIVE
LUK	NEGATIVE
MIK**	NEGATIVE
MIY	NEGATIVE
EIG	NEGATIVE

Table 15 (cont.). Qualitative and Quantitative* Results of CDV Real-Time PCR for Nonclinical, CDV Antibody Titer-Positive, Low-Risk Dogs – 6/1/15 (Outside Laboratory[g])

LLI	NEGATIVE
REK	NEGATIVE
SRE	NEGATIVE
REP	NEGATIVE
EIH	NEGATIVE
NEL	NEGATIVE
EVO	NEGATIVE

* Explanation from laboratory:
Real-Time PCR provides a relative value (cycle threshold (CT)), which indicates the amount of target nucleic acid in the sample. CT is inversely proportional to the amount of target present in the sample (lower CT value indicates more nucleic acid). Values < 36 are positive. Values from 37-40 indicate minimal amounts of target nucleic acid, which could represent early or late infection, residual vaccine, or environmental contamination.

**These patients were CDV PCR-negative on 5/19/15 on the comprehensive panel performed at a different, outside laboratory.

- All stray dogs admitted during the case were nonclinical, CDV antibody titer-positive, and CDV PCR-negative. They were cleared for adoption by June 1, 2015.
- Both CDV antibody titer-negative dogs (MIA and SRE) were cleared from quarantine by June 3, 2015.
- Excluding two dogs (MAI and REP), all low-risk, nonclinical, CDV antibody titer-positive dogs remained nonclinical and were eventually determined to be PCR-negative. Accordingly, they remained low-risk and were cleared for adoption by June 1, 2015. Of the two dogs that were initially nonclinical but developed clinical signs, one dog (MAI) tested CDV PCR-weak positive but was eventually cleared for adoption after clinical resolution and two negative CDV PCR tests by June 15, 2015. The other dog (REP) never tested CDV-PCR positive and remained in the home of its owner, a staff member. All three CDV PCR tests were negative.
- All clinical dogs that were initially CDV PCR-negative but considered high-risk remained PCR-negative and were cleared for adoption after clinical resolution and a final negative PCR result by June 1, 2015.
- All clinical, CDV PCR-positive dogs but two (MOL and JEF), who were lost to follow-up, reached clinical resolution and were cleared by two negative PCR tests by September 21, 2015.

With the mitigation of CDV transmission within the shelter, the author concurrently began addressing the shelter risk factors contributing to infectious disease. Shelter-specific protocols for biosecurity processes were developed and implemented. Vaccination protocols were implemented first. Other than the two puppies who were transferred at three months of age, all other dogs involved in this case were considered adults. Accordingly, if vaccination on

admission had been practiced consistently, the risk of CDV in the shelter would have been low, even with the transfer of high-risk dogs. However, the majority of CDV PCR-positive dogs that were owner surrenders or strays had not been vaccinated on admission to the shelter, indicating that some dogs acquired CDV at the shelter. A vaccination protocol was established in which every dog over four weeks of age was administered an MLV DAPP vaccination immediately upon intake regardless of vaccination history. The only exceptions were dogs that had received a documented vaccine within the past two weeks or dogs that were severely ill. If a severely ill dog presented to the shelter, it was taken to a local practitioner immediately. To facilitate routine practice of vaccination on intake, a schedule was created to ensure that at least one animal care team member was assigned to intake processing. On days that an additional animal care team member was scheduled, this staff member was assigned to assist in intake processing as well.

To improve the shelter staff's response to subsequent CIRDC outbreaks, a protocol for the recognition and reporting of infectious diseases and appropriate action steps was established. A list of clinical signs that should raise suspicion for infectious disease was provided to the shelter staff. Daily rounds were implemented and the shelter was encouraged to use its data management software program[b] for population disease tracking, which would enable more efficient decision-making in outbreak situations. In addition, a recommendation to hire a full-time veterinarian to oversee population health was made.

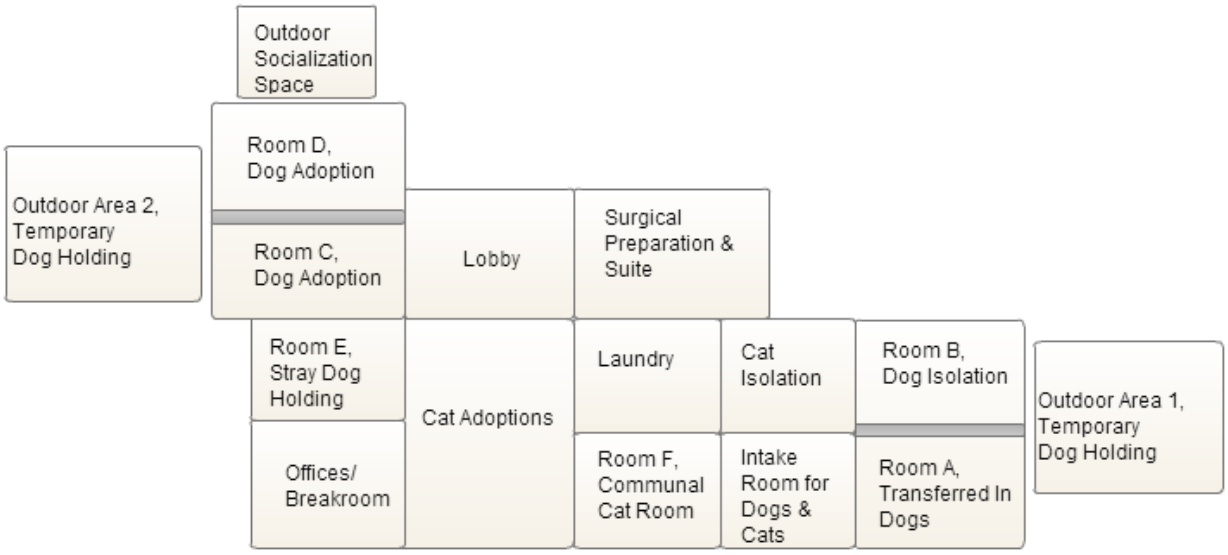
To facilitate vaccination and disease recognition on admission, the shelter's cat quarantine room was repurposed into an intake room and outfitted with all necessary equipment for intake processing. Staff, already trained to recognize infectious concerns, were trained to examine, microchip scan, vaccinate, and deworm every newly admitted dog in the new intake room. If an infectious disease concern was noted, the staff was instructed to move the dog

directly into a kennel within isolation until the veterinary technician or veterinarian was able to examine it. Room B, one of the newly designated isolation rooms, was designated as the permanent isolation room. Because Room B shared a ventilation system with Room A, a recommendation was made to install a separate ventilation system for Room B. Updated, permanent housing designations, as well as the intake room are shown in Figure 5.

The shelter's unofficial protocol for managing puppies, a population vulnerable to disease, was formalized, and an administrative staff member, who typically coordinated foster care, was designated the official foster coordinator. Two CDV PCR-positive dogs (IRI and ROS) were three-month old littermates when admitted. These dogs were transferred from an out-of-state municipal source shelter and were not sent to foster upon admission because they were over two months of age. However, due to the lack of an official protocol for puppy management, both puppies remained within the shelter until they were sent to foster one month after their admission. Although it is unclear whether these puppies arrived at the shelter with CDV or acquired CDV on-site, housing them on-site for an extended period resulted in increased infectious disease transmission and/or exposure. Accordingly, a policy was established for puppies that included immediate relocation to foster for any puppy less than two months of age, as well as for any puppy less than five months of age admitted from a high-risk source shelter.

Additional protocols to reduce disease transmission included the establishment of a new cleaning and disinfection protocol, as well as the designation of specific animal care team members to handle clinically affected dogs. A one-step cleaning and disinfection process using an accelerated hydrogen peroxide product[i] was introduced, and the shelter staff were trained on using the new product and its equipment by the product manufacturer through teleconference.

Figure 5. Schematic of updated, permanent dog housing areas and intake room.



This new product and refined process resulted in effective sanitation and increased staff compliance. In addition, at least one animal care team member was assigned to handle all dogs in isolation, including morning sanitation, feeding, and medicating on a daily basis. The animal care team member was instructed to utilize full-body PPE, including designated footwear, when working in isolation. If the same animal care team member was needed to handle nonclinical dogs in same day, this was completed before handling clinical dogs.

The shelter had not considered that transferred dogs could increase the risk of bringing infectious diseases into the shelter. Accordingly, biosecurity protocols were created specifically for transferred dogs. The veterinary technician, along with one animal care team member, were specifically designated to oversee the intake of transfers. On admission, a thorough screening for infectious disease through physical examination by the veterinary technician and animal care team member and was implemented for every transferred dog. In addition, after the case resolved, Room A was permanently designated the housing room for future dog transports. These dogs were to be housed and adopted from Room A, thereby ensuring they were never exposed to the general shelter population. Designating Room A for transferred dogs also limited the shelter to admitting only 15 dogs at a time. This allowed for all-in/all-out management of the transferred population. In addition, the shelter agreed to admit dogs from only one source shelter at a time. By admitting dogs from only one potentially high-risk source, instead of multiple potentially high-risk sources, the shelter reduced the likelihood of admitting a high-risk dog. If a dog appeared clinically affected on admission, the medical staff was notified and it was immediately isolated in Room B. In addition, if foster care was required for a transferred dog, it was sent to a home without other dogs to prevent disease exposure.

The selection process for transferred dogs also was modified. Previously, the shelter only admitted dogs that had been at a source shelter for two weeks and had received at least two MLV DAPP vaccinations. Because this increased infectious disease exposure at the source shelter, the shelter requested that source shelters transport dogs sooner as long as they appeared healthy. Increased disease exposure at source shelters was compounded by the concern that some source shelters were not administering MLV DAPP vaccination on intake. To address this concern, the shelter discontinued admitting dogs from source shelters that did not vaccinate on intake. The shelter also discontinued transferring puppies less than five months of age. Accordingly, the established protocol for transfers included that dogs over five months of age would be transferred in limited numbers from one source shelter at a time, and only from those shelters whose vaccination protocols were congruent with the shelter's updated vaccination protocol.

Certain housing inadequacies that resulted in increased infectious disease transmission were addressed. Because single-compartment kennels resulted in increased fomite transmission at the shelter, a recommendation was made to convert all dog housing into double-compartments, but had not yet been implemented by the end of the case. In the interim, acute housing improvements were instituted to mitigate infectious disease transmission. To prevent direct contact between dogs, outdoor kennels lacking side-to-side barriers were outfitted with polycarbonate sheets of 1.2 meters height on each side. The open trough drain system in Rooms A and B were concealed with aluminum frame rest benches that doubled as trough covers, thereby reducing cross-contamination of urine and feces. The use of crates for long-term housing of small dogs was discontinued. Dog kennels with defective front gates were repaired to allow for small dogs to be housed in them and Room F was converted into cat communal housing.

Limiting the number of dogs transferred addressed concerns that the shelter was operating beyond its capacity to adequately care for its animals. Since limiting the number of dogs transferred at any one time to 15, the average daily dog population decreased to 45 and the average LOS for dogs decreased to 14 days. Because the average daily population was reduced, an increase in housing or staffing capacity was not required. Even though the number of dogs transferred at one time was reduced, the decrease in the average LOS allowed the shelter to transfer dogs in more frequently. Overall, the shelter was able to transfer the same number of dogs, albeit in smaller numbers at any one time.

Although, the restructured transport program protocol helped reduce both the average daily population and LOS for dogs, the author also recommended that a formal population management team be created to ensure shelter capacity was maintained. A written report detailing different population management techniques to facilitate capacity for care, infectious disease prevention, and medical and behavioral well-being was provided.

Continued communication with adopters, source shelters, and local practitioners ensured that new clinical cases in the community would be promptly identified and also conveyed that the shelter was attempting to proactively address community concerns.

The shelter problem list with solutions is summarized in Table 16.

Table 16. Shelter problem list with solutions.

Risk Factor Category	Specific Concerns	Solutions
Biosecurity	Lack of protocols for: intake, vaccination, cleaning/disinfection, disease surveillance/daily rounds, puppy management	Created individual protocols specifically adapted to the shelter for each area of concern, assigned individual staff members specific duties pertaining to each area of concern
	Inconsistent vaccination on intake	Provided a protocol and assigned at least one staff member to intake processing daily
	Lack of intake room	Converted cat quarantine room into intake room
	Ineffective cleaning and disinfection process	Switch to an accelerated hydrogen peroxide product and all staff were trained on use of new product
	Lack of a consistent isolation ward with separate ventilation system	Converted Room B into permanent isolation ward; recommended installation of separate ventilation system for Room B
	Unrecognized fomite transmission by staff	Trained all staff of fomite control and assigned one staff member to daily handling of all clinically affected animals
Lack of protocols for transferred dogs	Lack of separate housing area	Designated Room A as permanent housing for transferred dogs
	Inconsistent vaccination on intake	Designated two staff members to intake transfers
	Admission of clinical dogs	Altered selection process for transfers to reduce odds of admitting clinically affected transfers
	Dogs awaiting two vaccines at source shelter	Altered selection process for transfers
	Source shelters not vaccinating on intake	Discontinued transferring dogs from such source shelters
	Two additional shelters reported CDV	Altered selection process for transfers

Table 16 (cont.). Shelter problem list with solutions.

Housing	Single-compartment housing resulting in frequent movement of dogs daily	Recommended kennel renovations to convert all housing units into double-compartment units
	Inappropriate use of crates as dog housing	Discontinued use of crates, repaired defective kennel gates so all kennels were functional, and reduced average daily dog population
Shelter Capacity	Inadequate housing unit numbers for small dogs due to kennels in disrepair	Repaired defective kennel gates so all kennels were functional
	Daily dog population beyond adoption driven capacity and required stray holding capacity	Reduced number of dogs transferred through each transport
	Increased average LOS for dogs	Reduced number of dogs transferred through each transport
	Inadequate staff numbers	Reduced number of dogs transferred through each transport
	Lack of population management team	Recommended creation of a team
Delayed recognition and management of outbreak	Lack of disease tracking/daily rounds	Introduced disease surveillance through shelter software program, implemented daily rounds, provided a list of clinical signs to recognize as infectious disease concerns, and recommended hiring of full-time shelter veterinarian
	Increased severity and prevalence of CIRDC	Introduced disease surveillance through shelter software program, implemented daily rounds

Discussion

Resolution of this case took nearly six months (May to October, 2015), but the majority of animals involved were moved through the sheltering system and adopted within one month, due to the implementation of an organized outbreak response. Although CDV was successfully eliminated from this shelter, this case reflects the challenges of managing an infectious disease with high morbidity and mortality potential but with a spectrum of clinical signs that overlap with other pathogens of CIRDC, that are more prevalent in shelters, but cause less severe disease.

This case presented a variety of challenges. Shelter practices and circumstances leading up to the consult facilitated exposure of a large number of animals, including those on-site, in adoptive homes, in foster homes, and in staff members' homes; individual risk assessment was complicated due to CDV's prolonged incubation period; and housing space was inadequate for appropriate population segregation.

Low index of suspicion for CDV delayed outbreak recognition, and disease exposure was enhanced by the lack of routine isolation of clinically affected patients and lack of active disease rate tracking in the shelter. Nonetheless, contacting the author for consultation services initiated prompt outbreak response and establishment of protocols for more effective outbreak prevention. Upon the author's involvement in the case, diagnostic testing of clinically affected dogs was performed to confirm the presence of CDV in the shelter. Once CDV was confirmed, the author arrived on-site, the shelter was closed to adoptions, movement of animals within the shelter was suspended, and a clean break was created. These initial action steps quickly controlled further

spread of disease and facilitated systematic implementation of the remaining outbreak management steps.

Swift measures were taken to address the outbreak once it was recognized; however, this case highlights some of the challenges of preventing and managing infectious diseases in animal shelters. As a consultant, the author was not immediately on-site to implement outbreak management, nor was there a full-time shelter veterinarian on-site to start outbreak management. Because the shelter had no formal population management team, neither the part-time veterinarian nor the veterinary technician provided medical oversight for population-level health care. Without medical oversight, the shelter lacked critical biosecurity policies related to maintaining host and population health, making the shelter vulnerable to an infectious disease outbreak. Ideally, a full-time veterinarian would have been working for the shelter to maintain a comprehensive health care program that promoted animal welfare and medical well-being. In addition, as a consultant, the author believes that having a full-time veterinarian on-site to facilitate outbreak management would have expedited case resolution. For example, physical examination of dogs, an important part of risk categorization, was delayed because the author was not on-site initially and the shelter veterinarian was not readily available. This likely resulted in delayed identification and isolation of clinical dogs, as well as delayed segregation of mildly affected dogs that may have been overlooked.

Delayed outbreak recognition also increased disease prevalence and exposure. All of the dogs on-site were considered exposed, complicating effective population segregation. Although Room D initially was used as isolation, Room C was used as isolation overflow to accommodate the number of affected dogs. Ideally, isolation should be in a separate building to reduce disease transmission, particularly for respirable pathogens, such as CDV, that can be transmitted a long

distance. In this case, clinically affected dogs were housed not only in the same building, but also in the same room as nonclinical dogs. This increased risk the of disease transmission until housing areas were re-designated and dogs were relocated according to risk categories. With the updated housing designations, and the repair of defective kennel gates, all kennels in the shelter became functional again, which encouraged the shelter to permanently discontinue the use of crates for housing of small dogs. Housing designations within the shelter were rearranged based on the feasibility of installation of a separate ventilation system within Room B.

Widespread disease exposure made individual risk assessment challenging. Risk assessment was implemented promptly for the on-site dogs, but was difficult for off-site dogs. Physical examination by a veterinarian was not possible for most off-site dogs, but was indicated when three off-site dogs developed clinical signs after initial risk assessment. One dog (REP) was owned by a staff member who was fostering two CDV PCR-positive dogs (IRI and ROS). This staff member's dog was reportedly apparently healthy and vaccinated for CDV, per the owner/staff member. Although the dog was living with two CDV PCR-positive dogs, it was initially categorized as low-risk because of apparent health and vaccination history. Consequently, only CDV antibody titers were performed initially, which were positive. Ideally, however, a veterinarian should have confirmed REP to be free of clinical signs before being declared low-risk, particularly since it was housed in close proximity to CDV PCR-positive dogs. While subsequent CDV PCR testing was negative and proved the dog to be low-risk, this patient conveys the limitations of risk assessment. The author assumed the dog to be low-risk based on what was reported by its owner, but did not confirm the dog's medical condition or vaccination history. As noted previously, such assumptions limit the usefulness of risk assessment and should be avoided when possible. This patient also highlights the limitations of

serological testing for risk assessment. Although he was CDV antibody titer-positive, he developed clinical signs, highlighting that CDV's prolonged incubation period can confound positive titer results. Fortunately, this patient clinically resolved and remained CDV PCR-negative.

When two more off-site dogs (SEL and JEF) and one on-site dog (MAI) were recognized to be clinically affected after initial risk assessment, there was additional concern regarding the serology results. The on-site patient was physically examined by the author and deemed low-risk because it was nonclinical. Accordingly, it was only CDV antibody titer tested. Prior to developing clinical signs, this dog was tested through the comprehensive respiratory panel and tested positive for *M. cynos* but negative for CDV. When the dog subsequently developed clinical signs, it was CDV PCR tested, which revealed a weak positive result. Although it may have been clinical due to *M. cynos* infection and, theoretically, it may have been CDV PCR-positive due to recent vaccination, it was still considered high-risk for CDV infection due to the outbreak scenario. This patient's case, however, highlights the importance of using a comprehensive risk assessment model that includes both subjective and objective analyses. A review of the case shelter's records revealed that the dog was admitted to the shelter just as the outbreak was recognized. Although the dog had received an MLV DAPP vaccine, a clean break had not yet been established, so the dog was housed in the general population. Because all dogs were considered exposed, serology was the primary risk assessment tool; however, in using serology results alone for risk assessment, it was not recognized that this dog may have been exposed before it was protected by vaccination. Therefore, the dog's positive titer may have been due to infection rather than protection. Ideally, vaccination and intake/housing information

should be considered in conjunction with serology result when assessing risk level. Fortunately, this dog also clinically resolved and was not CDV PCR-positive in subsequent tests.

Both off-site dogs (SEL and JEF) that developed clinical signs had been transferred from the same source shelter. Review of source shelter records for both dogs revealed a lack of vaccination on intake, development of CIRDC signs, which resolved, and then transport to the case shelter. This sequence reflected significant deficiencies in case management. It highlighted that the case shelter transferred dogs without considering infectious disease risk at the source shelter. Transferring dogs from source shelters that do not practice adequate infectious disease prevention is a risk factor is readily avoided.

Of note, although serology is typically used for risk assessment in nonclinical dogs, it was performed on all dogs in this outbreak for academic learning purposes. It was understood that serological results of clinically affected dogs would not be used for risk assessment.

Despite its limitations, this case illustrates that serological risk assessment is an invaluable tool for guiding population management decisions during a CDV outbreak. All dogs that initially were considered low-risk based on CDV serology were CDV-negative when PCR tested. With both serological and PCR results confirming nonclinical dogs as low- risk, these dogs were moved promptly through the sheltering system and adoption was reopened.

Although the financial costs associated with diagnostic testing may seem prohibitive for some institutions, this case demonstrates that effective use of diagnostic testing in risk assessment can mitigate shelter capacity concerns during an outbreak. By expediting the flow of most animals involved in this case, diagnostic testing reduced the daily animal care costs that can be associated with prolonged quarantine or isolation. Therefore, appropriate use of diagnostic

tests like serology and PCR can be more cost-effective than population management techniques uninformed by such tests.

More importantly, diagnostic testing for risk assessment ensured that each individual's behavioral well-being was optimized by avoiding unnecessarily prolonged isolation or quarantine in the shelter. The two animals (MIA and SRE) that were considered high-risk for acquiring CDV were promptly identified through serology and temporarily quarantined within off-site homes. Serial serological testing resulted in a two-week quarantine for both dogs, as opposed to a six-week quarantine associated with CDV's incubation period. Three of the 10 CDV PCR-positive dogs were in adoptive homes. Although these dogs posed a risk to community animals, the shelter regularly communicated with their owners to ensure that the dogs were not exposed to other pets, particularly puppies. Of the seven CDV PCR-positive dogs housed in the shelter for isolation, one dog was euthanized shortly after initial presentation of the case. The remaining six CDV PCR-positive dogs were isolated in the shelter for an average of six weeks before being adopted. Without the use of serial PCR testing, the shelter LOS for these dogs would likely have been longer.

While diagnostic testing facilitated the flow of animals through this outbreak, this case highlights the ethical concerns that are associated with management of CDV. Euthanasia of dogs clinically affected by CDV may be necessary in resource-limited shelters that cannot safely treat affected dogs without potentially exposing other dogs. As noted previously, shelters should have established policies regarding the decision to treat highly transmissible infectious diseases that can result in significant morbidity and mortality. Such policies ensure that population-based euthanasia decisions are made promptly during an outbreak, preventing the unnecessary suffering of animals. In this case, the shelter was committed to treating clinically affected

animals; however, an isolation space was not designated. Although this posed a significant threat to the remaining shelter population, shelter management chose to endure this risk. As a consultant, this outbreak management decision was beyond the control of the author. To mitigate this risk, the author designated Room B as isolation for CDV PCR-positive dogs and emphasized the importance of increased biosecurity measures such as fomite control, effective cleaning and disinfection, and prompt recognition of disease.

Similarly, defined humane endpoints for treatment should be established and used to direct individual-based euthanasia decisions. In this case, the use of a defined humane endpoint facilitated the decision to euthanize one severely affected, CDV PCR-positive patient (GUS). However, there were welfare concerns for the other clinically affected, CDV PCR-positive patients that were treated. These patients remained in the shelter for an average length of six weeks, which undoubtedly impacted their behavioral well-being. Upholding biosecurity concerns during an outbreak is an additional challenge to optimizing behavioral well-being. Although the shelter was made cognizant of the importance of maintaining behavioral well-being for dogs in confinement, the author was unable to guarantee that their behavioral health was not adversely affected. In addition, the development of late-onset neurological signs of CDV is unpredictable, raising ethical concerns regarding the adoption of recovered dogs. Although shelter leadership collectively decided that the shelter would provide financial support if a recovered dog developed neurological signs, they did not address the significant emotional burden on adopters that can accompany the adoption of a dog recovered from CDV. Such scenarios may also result in negative publicity for a shelter, particularly given the easy access to social media forums and rapid online spread. This shelter ensured that every adopter of a recovered dog was made aware of the possible long-term consequences of CDV infection; however, proactive communication

may not protect the reputation of the shelter if a recovered dog does develop signs. Accordingly, the financial, emotional, and public relations aspects of adopting CDV-recovered dogs should be discussed and shelter-specific policies established.

This case illustrates that implementation of a systematic outbreak response strategy is an effective and humane alternative to depopulation. Depopulation of clinically affected animals in a CDV outbreak is not an effective management tool due to the probable presence of animals that are subclinically shedding virus. Accordingly, the effective management of this case can be applied to other shelter settings.

It is the resources available to a shelter that determine how a CDV outbreak will be handled. The primary considerations regarding resources include cost, housing, staffing, and capacity for care. In this case, the shelter was limited by all of these factors, but based on the shelter's commitment to resolve the case without depopulation, the author guided the shelter through a systematic outbreak response. Initial consultation with the author helped shelter leadership and staff recognize the operational deficiencies that were contributing to the outbreak. With guidance, the shelter was willing and able to readily mitigate and eventually reverse many of these deficiencies.

This case documents both the limitations and successes of managing a CDV outbreak as a veterinary consultant. The challenges of serving as a consultant were associated primarily with the inability to be on-site at all times. However, the author's role in the case led to the successful elimination of CDV in the shelter, as well as the ability to institute permanent, positive changes beyond infectious disease control at the shelter. Of particular importance, is that the shelter has made permanent population management changes to ensure it operates within its capacity for care at all time.

Summary

This report documents the successful diagnosis, outbreak management, and elimination of canine distemper virus in an animal shelter. It highlights the biological characteristics of CDV that make disease diagnosis and outbreak control difficult to manage; the inherent characteristics of animal sheltering that make shelters vulnerable to outbreaks; as well as the more manageable characteristics of animal sheltering that can be proactively addressed to reduce the likelihood of an outbreak occurring. Nonetheless, this case also conveys that significant positive changes can be made to ensure the future health of animals, if a shelter is willing to recognize and reverse its deficiencies and practice proactive population management.

References

1. Sykes JE. Canine Distemper Virus Infection. In: Sykes, Jane E., ed. Canine and Feline Infectious Diseases. Elsevier/Saunders; 2014:154–165.

2. Newbury S, Larson LJ, Schultz RD. Canine Distemper Virus. In: Miller L, Hurley KF, eds. Infectious Disease Management in Animal Shelters. Wiley-Blackwell; 2009:161–172.

3. Martella V, Elia G, Buonavoglia C. Canine Distemper Virus. Vet Clin North Am Small Anim Pract 2008;38:787–797.

4. Baldwin CJ. Canine Kennel Cough Complex. In: Miller L, Hurley K, eds. Infectious Disease Management in Animal Shelters. Wiley-Blackwell; 2009:147–159.

5. Vandevelde M. Canine Distemper. In: Greene CE, ed. Infectious Diseases of the Dog and Cat. 4th ed. Elsevier/Saunders; 2012:25–42.

6. Gingrich E, Lappin M. Practical Overview of Common Infectious Disease Agents. In: Miller L, Zawistowski S, eds. Shelter medicine for veterinarians and staff. Wiley-Blackwell; 2013:297–328.

7. Ford RB. Canine Infectious Respiratory Disease. In: Greene CE, ed. Infectious Diseases of the Dog and Cat. 4th ed. Elsevier/Saunders; 2012:55–65.

8. Buonavoglia C, Martella V. Canine respiratory viruses. Vet Res 2007;38:355–373.

9. Priestnall SL, Mitchell JA, Walker CA, et al. New and Emerging Pathogens in Canine Infectious Respiratory Disease. Vet Pathol 2014;51:492–504.

10. Griffin J. Stress and immunity: A unifying concept. Vet Immunol Immunopathol 1988;20:263–312.

11. Pesavento PA, Murphy BG. Common and Emerging Infectious Diseases in the Animal Shelter. Vet Pathol Online 2014;51:478–491.

12. Erles K, Dubovi EJ, Brooks HW, et al. Longitudinal Study of Viruses Associated with Canine Infectious Respiratory Disease. J Clin Microbiol 2004;42:4524–4529.

13. Sykes JE. Canine Viral Respiratory Infections. In: Sykes, Jane E., ed. Canine and Feline Infectious Diseases. Elsevier/Saunders; 2014:170–180.

14. O'Quin J. Outbreak Management. In: Miller L, Zawistowski S, eds. Shelter medicine for veterinarians and staff. 2nd ed. Ames, Iowa: Wiley-Blackwell; 2013:349–367.

15. Hurley KF. Outbreak Management. In: Miller L, Hurley KF, eds. Infectious Disease Management in Animal Shelters. Wiley-Blackwell; 2009:39–48.

16. Anon. Length of Stay (LOS). UC Davis Koret Shelter Med Program. Available at: http://www.sheltermedicine.com/library/length-of-stay-los. Accessed January 6, 2016.

17. Edinboro CH, Ward MP, Glickman LT. A placebo-controlled trial of two intranasal vaccines to prevent tracheobronchitis (kennel cough) in dogs entering a humane shelter. Prev Vet Med 2004;62:89–99.

18. Iemura R, Tsukatani R, Micallef MJ, et al. Simultaneous analysis of the nasal shedding kinetics of field and vaccine strains of Bordetella bronchiseptica. Vet Rec 2009;165:747–751.

19. Sykes JE. Bordetellosis. In: Sykes, Jane E., ed. Canine and Feline Infectious Diseases. Elsevier/Saunders; 2014:372–379.

20. Welborn LV, DeVries JG, Ford R, et al. 2011 AAHA Canine Vaccination Guidelines*†. J Am Anim Hosp Assoc 2011;47:1–42.

21. Gore T, Headley M, Laris R, et al. Intranasal kennel cough vaccine protecting dogs from experimental Bordetella bronchiseptica. Vet Rec 2005;156:482–483.

22. Sykes JE. Mycoplasma Infections. In: Sykes, Jane E., ed. Canine and Feline Infectious Diseases. Elsevier/Saunders; 2014:382–389.

23. Chalker VJ, Owen WMA, Paterson C, et al. Mycoplasmas associated with canine infectious respiratory disease. Microbiology 2004;150:3491–3497.

24. Mannering SA, McAuliffe L, Lawes JR, et al. Strain typing of Mycoplasma cynos isolates from dogs with respiratory disease. Vet Microbiol 2009;135:292–296.

25. Berčič RL, Cizelj I, Benčina M, et al. Demonstration of neuraminidase activity in Mycoplasma neurolyticum and of neuraminidase proteins in three canine Mycoplasma species. Vet Microbiol 2012;155:425–429.

26. Plumb DC. Plumb's veterinary drug handbook. Eighth edition. Stockholm, Wisconsin: PharmaVet Inc; 2015.

27. Sykes JE, Papich MG. Antibacterial Drugs. In: Sykes, Jane E., ed. Canine and Feline Infectious Diseases. Elsevier/Saunders; 2014:66–86.

28. Appel V, Summers B. Pathogenicity of morbilliviruses for terrestrial carnivores. Vet Microbiol 1995;44:187–191.

29. Deem SL, Spelman LH, Yates RA, et al. Canine distemper in terrestrial carnivores: a review. J Zoo Wildl Med 2000;31:441–451.

30. Hurley KF. Canine Distemper in the Shelter: Lessons learned from a Chicago Outbreak. Anim Shelter 2005. Available at: http://www.animalsheltering.org/resources/magazine/sep_oct_2005/canine_distemper_in_shelter.html. Accessed January 3, 2016.

31. Kapil S, Allison RW, Johnston L, et al. Canine Distemper Virus Strains Circulating among North American Dogs. Clin Vaccine Immunol 2008;15:707–712.

32. Summers BA, Greisen HA, Appel MJG. Canine distemper encephalomyelitis: Variation with virus strain. J Comp Pathol 1984;94:65–75.

33. Griffin B. Wellness. In: Miller L, Hurley KF, eds. Infectious Disease Management in Animal Shelters. Wiley-Blackwell; 2009:17–38.

34. Appel, M.J. Pathogenesis of canine distemper. Am J Vet Res 1969;30:1167–1182.

35. Hurley KF. Prevention and Management of Infection in Canine Populations. In: Greene CE, ed. Infectious Diseases of the Dog and Cat. 4th ed. Elsevier/Saunders; 2012:1124–1130.

36. Iwatsuki K, Okita M, Ochikubo F, et al. Immunohistochemical analysis of the lymphoid organs of dogs naturally infected with canine distemper virus. J Comp Pathol 1995;113:185–190.

37. Breazile JE, Blaugh BS, Nail N. Experimental study of canine distemper myoclonus. Am J Vet Res 1966;27:1375–1379.

38. Sips GJ, Chesik D, Glazenburg L, et al. Involvement of morbilliviruses in the pathogenesis of demyelinating disease. Rev Med Virol 2007;17:223–244.

39. Tipold A, Vandevelde M, Jaggy A. Neurological manifestations of canine distemper virus infection. J Small Anim Pract 1992;33:466–470.

40. Abeles V, Harrus S, Angles JM, et al. Hypertrophic osteodystrophy in six weimaraner puppies associated with systemic signs. Vet Rec 1999;145:130–134.

41. Twark L, Dodds WJ. Clinical use of serum parvovirus and distemper virus antibody titers for determining revaccination strategies in healthy dogs. J Am Vet Med Assoc 2000;217:1021–1024.

42. Litster AL, Pressler B, Volpe A, et al. Accuracy of a point-of-care ELISA test kit for predicting the presence of protective canine parvovirus and canine distemper virus antibody concentrations in dogs. Vet J 2012;193:363–366.

43. Kim D, Jeoung S, Ahn S, et al. Comparison of Tissue and Fluid Samples for the Early Detection of Canine Distemper Virus in Experimentally Infected Dogs. J Vet Med Sci 2006;71:877–879.

44. Si W, Zhou S, Wang Z, et al. A multiplex reverse transcription-nested polymerase chain reaction for detection and differentiation of wild-type and vaccine strains of canine distemper virus. Virol J 2010;7:1.

45. Scagliarini A, Dal Pozzo F, Gallina L, et al. TaqMan Based Real Time PCR for the Quantification of Canine Distemper Virus. Vet Res Commun 2007;31:261–263.

46. Elia G, Decaro N, Martella V, et al. Detection of canine distemper virus in dogs by real-time RT-PCR. J Virol Methods 2006;136:171–176.

47. Dal Pozzo F, Galligioni V, Vaccari F, et al. Antiviral efficacy of EICAR against canine distemper virus (CDV) in vitro. Res Vet Sci 2010;88:339–344.

48. Lechner ES, Crawford PC, Levy JK, et al. Prevalence of protective antibody titers for canine distemper virus and canine parvovirus in dogs entering a Florida animal shelter. J Am Vet Med Assoc 2010;236:1317–1321.

49. Schroeder J, Bordt D, Mitchell F. Studies of canine distemper immunization of puppies in a canine distemper-contaminated environment. Vet Med Small Anim Clin 1967;62:782–787.

50. Larson LJ, Schultz RD. Effect of vaccination with recombinant canine distemper virus vaccine immediately before exposure under shelter-like conditions. Vet Ther 2006;7:113.

51. Pardo MC, Tanner P, Bauman J, et al. Immunization of Puppies in the Presence of Maternally Derived Antibodies Against Canine Distemper Virus. J Comp Pathol 2007;137:S72–S75.

52. Anon. Canine Distemper (CDV). UC Davis Koret Shelter Med Program. Available at: http://www.sheltermedicine.com/library/canine-distemper-cdv#Transmission. Accessed January 5, 2016.

53. Newbury S, Blinn MK, Bushby PA, et al. Guidelines for standards of care in animal shelters. Association of Shelter Veterinarians Corning, NY, USA; 2010. Available at: http://www.sheltervet.org/assets/docs/shelter-standards-oct2011-wforward.pdf. Accessed December 16, 2015.

54. Wagner D, Newbury S, Kass P, et al. Elimination Behavior of Shelter Dogs Housed in Double Compartment Kennels. PLoS ONE 2014;9:e96254.

55. Anon. Determining Kennel Staffing Levels - National Animal Care & Control Association. Available at: http://www.nacanet.org/?kennelstaffing. Accessed December 16, 2015.

56. Anon. Calculating shelter capacity - UC Davis Koret Shelter Medicine Program. Available at: http://www.sheltermedicine.com/library/calculating-shelter-capacity. Accessed December 17, 2015.

57. Newbury S, Hurley K. Population Management. In: Miller L, Zawistowski S, eds. Shelter medicine for veterinarians and staff. 2nd ed. Ames, Iowa: Wiley-Blackwell; 2013:93–113.

58. Osterholm MT, Hedberg C. Epidemiologic Principles. In: Mandell GL, Bennett JE, Dolin R, eds. Mandell, Douglas, and Bennett's principles and practice of infectious diseases. 7th ed. Philadelphia, PA: Churchill Livingstone/Elsevier; 2010:146–157.

59. Dvorak G, Peterson LJ. Sanitation and Disinfection. In: Miller L, Hurley KF, eds. Infectious Disease Management in Animal Shelters. Wiley-Blackwell; 2009:49–60.

60. Aaby P, Bukh J, Lisse IM, et al. Overcrowding and intensive exposure as determinants of measles mortality. Am J Epidemiol 1984;120:49–63.

61. Gray LK, Crawford PC, Levy JK, et al. Comparison of two assays for detection of antibodies against canine parvovirus and canine distemper virus in dogs admitted to a Florida animal shelter. J Am Vet Med Assoc 2012;240:1084–1087.

62. Larson LJ, Newbury S, Schultz RD. Canine and Feline Vaccinations and Immunology. In: Miller L, Hurley KF, eds. Infectious Disease Management in Animal Shelters. Wiley-Blackwell; 2009:61–82.

63. Prescott CW. Clinical findings in dogs and cats with lead poisoning. Aust Vet J 1983;60:270–271.

64. Scarlett J. Epidemiology of Infectious Disease in Shelter Populations. In: Miller L, Zawistowski S, eds. Shelter medicine for veterinarians and staff. Wiley-Blackwell; 2013:287–296.

Endnotes:

[a] ImmunoComb Canine VacciCheck IgG Antibody Test Kit, Biogal, Galed Labs. Acs Ltd., Galed, Israel

[b] PetPoint Data Management System, Pethealth, Inc., Rolling Meadows, IL

[c] Washington Animal Disease Diagnostic Laboratory, Pullman, WA

[d] IDEXX Canine Parvovirus Antigen Test Kit, IDEXX Laboratories, Inc., Westbrook, ME

[e] Animal Facility Concentrated Disinfectant Cleaner & Deodorizer, ProVetLogic Professional, Scottsboro, AL

[f] Bleach, Clorox Company, Oakland, CA.

[g] Wisconsin Veterinary Diagnostic Laboratory, Madison, WI

[h] IDEXX Comprehensive Respiratory Disease RealPCR Panel, IDEXX Reference Laboratories, Westbrook, ME

[i] Accel® Concentrate, Ogena Solutions, LLC, Stoney Creek, Ontario, Canada