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Full Research Article

CANINE INFECTIOUS RESPIRATORY DISEASE COMPLEX (CIRDC) WORLDWIDE: A REVIEW OF EPIDEMIOLOGY AND DISTRIBUTION

Nemanja KRSTIĆ[1*], Marija GNJATOVIĆ[1], Lidija MLAĐENOVIĆ[1], Sandra RAKIN[1], Aleksandra JOVANOVIĆ[1], Jakov NIŠAVIĆ[2], Diana LUPULOVIĆ[1]

[1]University of Belgrade, Institute for the Application of Nuclear Energy INEP, Belgrade, Serbia
[2]University of Belgrade, Faculty of Veterinary Medicine, Department of Microbiology and Immunology, Belgrade, Serbia

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Abstract

Canine infectious respiratory disease complex (CIRDC), also known as kennel cough, is a highly contagious multifactorial syndrome in dogs, caused by both bacterial and viral pathogens. Disease is predominantly observed in environments with high canine density, such as shelters. Although CIRDC is typically presented with mild to moderate clinical manifestations, in puppies and immunocompromised dogs, CIRDC can lead to severe clinical manifestations.

The present review provides a systematic analysis of 68 peer-reviewed publications and reports from 1965 to 2025, to examine worldwide prevalence rates and geographic distribution of pathogens associated with CIRDC. Data were extracted from five major scientific databases (PubMed, Scopus, Google Scholar, ScienceDirect, and Web of Science), focusing on the frequency of pathogens, their geographical distributions and detection methodologies.

The most frequently identified bacterial agents are *Bordetella bronciseptica* and *Mycoplasma* spp., and among viral agents, canine parainfluenza virus and canine respiratory coronavirus. Canine influenza virus is rarely detected in Europe, but has been detected

*Corresponding author – e-mail: nemanja.krstic@inep.co.rs

in shelter dogs in the U.S. Notably, CIRDC is characterized by a high co-infection rate. The review highlights the importance of updated diagnostics, targeted vaccination strategies and enhanced surveillance systems. Data from Serbia are scarce, underscoring the urgent need for national prevalence studies and improved vaccine coverage.

Key Words: Infectious laryngotracheitis, kennel cough, prevalence, systematic review

INTRODUCTION

Canine infectious respiratory disease complex (CIRDC), also known as kennel cough, is an acute, highly contagious respiratory ailment in dogs that involves multiple bacterial and viral agents (LeRoith et al., 2012). The disease most commonly occurs in environments where dogs are kept in confined places, such as shelters and boarding houses, which contributes to the rapid spread of the disease (Weese & Stull, 2013). CIRDC is present worldwide, with a high prevalence in conditions where the dogs are in contact with large numbers of other individuals, for example, shelters or training centers (Anderson et al., 2012).

The etiology of CIRDC is complex and multifactorial, and is usually associated with cases of co-infections that intensify clinical signs of the disease (Mitchell et al., 2017). The most commonly identified causative agents are *Bordetella bronchiseptica* (Bb), canine parainfluenza virus (PIV5), canid alphaherpesvirus type 1 (CHV-1) and canine adenovirus type 2 (CAdV-2) (Buonavoglia & Martella, 2007). Although these pathogens are still predominant in CIRDC, over the last two decades, new agents have been detected, such as canine respiratory coronavirus (CRCoV), canine influenza virus (CIV), canine pneumovirus, *Mycoplasma cynos* and *Streptococcus equi* subsp. *zooepidemicus* (Priestnall et al., 2010; Renshaw et al., 2010). Some of these pathogens are novel, and their clinical significance has yet to be investigated, but they are increasingly being identified in symptomatic and asymptomatic dogs, suggesting their potential role in the pathogenesis of the CIRDC (Mitchell et al., 2017).

The clinical signs of CIRDC usually involve a sudden onset of dry, "honking" cough, followed by possible sneezing, nasal and ocular discharge (Reagan & Sykes, 2020). In most cases, signs last for a couple of days to a couple of weeks with spontaneous recovery, but in complicated cases, severe respiratory symptoms of bronchopneumonia, productive cough, fever and lethargy may occur (Radhakrishnan et al., 2007). Canine respiratory infection is rarely lethal for dogs, but Adams et al. (2010) reported a mortality rate of 1.2% as a consequence of disease complications.

Due to the complexity of etiology, high prevalence, and potential zoonotic threat of some agents, such as Bb (Kraai et al., 2023), further investigation of the prevalence of CIRDC pathogens worldwide is of crucial importance for a better understanding of epidemiology and for improving diagnostic methods and control of CIRDC.

MATERIALS AND METHODS

The present study consists of a systematic review of the literature considering CIRDC and its prevalence worldwide. A thorough search was conducted in five electronic databases: PubMed, Scopus, Google Scholar, Web of Science, and ScienceDirect. The literature search included the following keywords: (CIRDC OR Kennel Cough) AND (Dog). This review includes 65 papers related to the causative agents of CIRDC in dogs, covering the period from 1965 to 2025. Papers that did not meet the criteria based on title and abstract were excluded from this review. Exclusion criteria were papers that did not address the detection or prevalence of CIRDC pathogens or articles with unclear information. Two investigators screened the electronic databases and found relevant manuscripts.

RESULTS AND DISCUSSION

This section combines results and discussion to facilitate integrated analysis of prevalence data and their epidemiological implications across pathogen groups. Since CIRDC can be caused by several different pathogens, the literature search included findings of single pathogens or combinations of two and three pathogens. For clarity, the organization of the present research is based on bacterial and viral agents.

Prevalence of bacterial pathogens

Two important bacteria involved in CIRDC are *B. bronchiseptica* and *Mycoplasma* spp. (Shang et al., 2024; Yondo et al., 2023).

Bb remains one of the most important bacterial pathogens in CIRDC. The prevalence of Bb significantly differs among regions, populations, age, and environments, but also depends on the diagnostic methods used, health and immune status of the animal, reflecting both biological diversity and methodological differences (which are presented in Table 1). Over a 3-year period (2021–2023), the incidence of Bb in healthy and dogs with CIRDC in several Chinese provinces ranged from 15.47% to 36.23%, among which a higher positivity rate was found in dogs with CIRDC than in healthy dogs. Such findings proved the importance of Bb as one of the main contributors to CIRDC, but also the fact that it can be present in the population even without any clinical signs of disease, which is critical for disease transmission. Strains of Bb that cause subclinical forms of disease possess the adenylate cyclase-hemolysin enzyme (Shang et al., 2024). A study in Sweden in healthy non-vaccinated dogs reported a seroprevalence of 22% (Englund et al., 2003). In a survey of Bb conducted in the U.K., a prevalence of 14.5% was reported in respiratory samples collected from dogs with clinical signs from four veterinary laboratories (Singleton et al., 2019). High variability was reported to be associated with sample type and detection method (Stejskal et al., 2017; Schulz et al., 2014b). In the study of Stejskal et al. (2017), Bb was detected in only 3.3% of

analyzed specimens. On the other hand, Schulz et al. (2014b) reported a Bb prevalence of 78.7%. The difference in findings could be due to the younger population of participants in the latter study, different detection methods, and a possible seasonal effect. The prevalence of Bb in Italy was 52% in dogs with CIRDC, and the most affected animals were younger than one year old (Corona et al., 2013). In Japan, Bb was the most frequently detected pathogen in the complex, found in 40.3% of pet dogs with CIRDC, while the prevalence in shelter dogs with CIRDC was 28.6%. These findings showed no obvious geographical distribution of Bb, but the pathogen seemed to spread in facilities with dense populations (Matsuu et al., 2020). In Serbia, Milanov et al. (2018) described isolation and molecular detection of Bb in a case report of a four-month-old dog with symptoms of respiratory disease. In the majority of Bb-infected cases, other pathogens were also found. The most commonly observed combinations were Bb + PIV5 and Bb + *Mycoplasma* spp. + PIV5; however, other combinations may emerge. These findings underscore how co-infection influences CIRDC, revealing that several pathogens frequently act synergistically. As a result, disease progression is often complex and can result in serious complications, with pneumonia among the most concerning (Yondo et al., 2023; Priestnall et al., 2014).

Table 1. Prevalence of *Bordetella bronchiseptica* in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Sweden	2000-2001	Healthy non-vaccinated dogs	ELISA	22	Englund et al. (2003)
Italy	/	Dogs with CIRDC	RT-PCR	52	Corona et al. (2013)
Germany	2011-2012	Healthy and dogs with CIRDC	RT-PCR	78.7	Schulz et al. (2014b)
Austria	2013-2015	Healthy and dogs with CIRDC	RT-PCR	3.3	Stejskal et al. (2017)
U.K.	2016-2019	Dogs with CIRDC	qPCR	14.5	Singleton et al. (2019)
Japan	2017-2018	Pet and shelter dogs with CIRDC	qPCR	40.3 28.6	Matsuu et al. (2020)
China	2021-2023	Pet and shelter dogs with and without CIRDC	RT-PCR	15.47 – 36.23	Shang et al. (2024)

ELISA: Enzyme-linked immunosorbent assay; **RT-PCR:** Reverse transcription polymerase chain reaction; **qPCR:** Quantitative polymerase chain reaction; **CIRDC:** Canine infectious respiratory disease complex.

Mycoplasma spp. infections are common in dogs, particularly in the upper respiratory tract. Two *Mycoplasma* species are significant in CIRDC, M. *cynos* and M. *canis*. The prevalence and role of these microorganisms in respiratory diseases in dogs are complex and depend on several different factors (Yondo et al., 2023; Matsuu et al., 2020). Table 2 presents the prevalence of *Mycoplasma* spp. in dogs.

Table 2. Prevalence of *Mycoplasma* spp. in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Finland	2011-2013	Dogs with bacterial pneumonia Dogs with chronic Bb infection	RT-PCR	40 23.1	Viitanen et al. (2015)
Germany	2010-2012	Dogs with respiratory distress Healthy dogs	PCR	91.7 86.7	Schulz et al. (2015)
Belgium	2006-2014	Dogs with Bb infection Healthy dogs	*M. cynos* in BALF by culture and qPCR	53 20	Canonne et al. (2016)
Italy	2011-2013	Dogs with CIRDC	RT-PCR	7.69	Decaro et al. (2016)
Slovenia	2008-2013	Healthy dogs	DIBA	70.5 (*M. cynos*) 67.6 (*M. canis*)	Scolten et al. (2017)
European Union	2011-2013	Dogs exposed to CIRDC	PCR ELISA	0.9 20.7 – 69.1 (overall 45)	Mitchell et al. (2017)
U.S.	2018-2022	Dogs with respiratory signs	PCR	21 (*M. cynos*) 24 (*M. canis*)	Yondo et al. (2023)
Japan	2017-2018	Household dogs with CIRDC	PCR	4.5	Matsuu et al. (2020)

Bb: *Bordetella bronchiseptica*; **RT-PCR:** Reverse transcription polymerase chain reaction; **BALF:** bronchoalveolar lavage fluid; **CIRDC:** Canine infectious respiratory disease complex; **DIBA:** Dot immunobinding assay; **ELISA:** Enzyme-linked immunosorbent assay.

However, European studies show inconsistent *Mycoplasma* spp. detection in healthy and sick dogs (Mitchell et al., 2017). There is limited information in regard to *Mycoplasma* spp. seroprevalence. A study in Slovenia showed that more than two-thirds of clinically healthy working dogs have antibodies against M. *cynos* and M. *canis*

(Scolten et al., 2017). Seropositivity was reported to range from 20.7% to 61.9% in a European study in dogs with CIRDC, with an overall estimated seroprevalence of 45% (Mitchell et al., 2017). Dogs that develop respiratory signs were reported to be more likely to become seropositive for M. *cynos* than those that did not (Rycroft et al., 2007), indicating an association between this bacterium and CIRDC. *Mycoplasma* spp. is commonly detected in samples from the respiratory tract, including clinically healthy animals, and rates of detection can range from 0.9% to 91.7%. It was reported that *Mycoplasma* spp. were recovered from 78% to 93% of oral swabs from healthy dogs. (Mitchell et al., 2017; Schulz et al., 2015). Since *Mycoplasma cynos* can be detected in both healthy dogs and those with CIRDC, it remains unclear whether it acts as a primary or secondary pathogen in the animals (Chalker et al., 2004). *Mycoplasma* spp. is commonly found in co-infections with other respiratory pathogens, such as Bb and respiratory viruses (PIV5, CRCoV) (Canonne et al., 2016; Schulz et al., 2015). Furthermore, in an Italian study, together with PIV5, CRCoV and Bb, the leading cause of CIRDC was M. *canis* and M. *cynos* (Decaro et al., 2016). In Japan, M. *cynos* was also identified as one of the causative agents in dogs with CIRDC. In the study by Matsuu et al. (2020), 4.5% of household dogs with CIRDC were positive for M. *cynos*. Active circulation of M. *cynos* was observed in asymptomatic shelter dogs in a study from the U.S. (Lavan and Knesl, 2015). Another study from the U.S. showed that M. *canis* and M. *cynos* were the predominant bacteria in dogs tested, with a positivity rate of 24% and 21%, respectively (Yondo et al., 2023). The majority of dogs in that study that had *Mycoplasma* spp. were puppies and young dogs, and these results were consistent with those previously published (Mitchell et al., 2017).

Prevalence of viral pathogens

The most important viral pathogens that participate in CIRDC are canine influenza virus (CIV), canine parainfluenza virus (PIV5), canine respiratory coronavirus (CRCoV), canine distemper virus (CDV), canine adenovirus type 2 (CAdV-2), and canid alphaherpesvirus 1 (CHV-1).

CIV is a significant respiratory pathogen in dogs, although its presence is geographically limited. CIV frequently appears in co-infections with other respiratory viruses, notably CRCoV, which could contribute to more severe clinical outcomes (Piewbang et al., 2019). Tables 3 and 4 present the molecular prevalence and seroprevalence of CIV in dogs, respectively. So far, two strains of Influenza A in dogs have been identified, H3N8 and H3N2. The prevalence differs depending on the region, the population studied, and the diagnostic methods used for detection (Pecoraro et al., 2014; Zhou et al., 2024). In Europe, CIV is rarely detected. A broader literature review found an overall seroprevalence of approximately 2.7% across several European countries (Mitchell et al., 2017). A study from Italy and two studies from Germany reported seroprevalences of 0.7%, 0.13%, and 0%, respectively (Schulz et al., 2014a; Damiani et al., 2012; Dundon et al., 2010). Between 2010 and 2019, there was no evidence of CIV circulation among either healthy or infected dogs in Europe, and its role in CIRDC

appeared minimal (Decaro et al., 2016; Viitanen et al., 2015; Schulz et al., 2014a). In China, Zhou et al. (2024) also reported a low detection rate of 2.3% for CIV in swab samples using multiplex PCR.

Table 3. Molecular prevalence of canine influenza virus in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Germany	2010-2011	Healthy dogs Dogs with CIRDC	FAT	0	Schulz et al. (2014a)
Finland	2011-2013	Dogs with bacterial pneumonia Dogs with chronic infection	RT-PCR	0	Viitanen et al. (2015)
Italy	2011-2013	Dogs with CIRDC	RT-PCR	0	Decaro et al. (2016)
European Union	2011-2013	Dogs exposed to CIRDC	RT-PCR	0	Mitchell et al. (2017)
U.S.	2018-2022	Dogs with respiratory signs	PCR	2	Yondo et al. (2023)
China	/	Dogs with and without respiratory signs	Multiplex qPCR	2.3	Zhou et al. (2024)

CIRDC: Canine infectious respiratory disease complex; **FAT:** Fluorescent antibody test; **RT-PCR:** Reverse transcription polymerase chain reaction; Multiplex **qPCR:** Multiplex quantitative polymerase chain reaction.

Table 4. Seroprevalence of canine influenza virus in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Italy	2009	Healthy dogs	cELISA	0.7	Dundon et al. (2010)
Germany	2010-2011	736 dogs sera	cELISA	0.13	Damiani et al. (2012)
European Union	2011-2013	Dogs exposed to CIRDC	cELISA	2.7	Mitchell et al. (2017)
U.S.	2009-2012	Healthy dogs	HI assay	10	Pecoraro et al. (2014)

cELISA: competitive ELISA**; CIRDC:** Canine infectious respiratory disease complex; **HI:** Hemagglutination inhibition.

In contrast, CIV is more commonly detected in the U.S., particularly in shelter environments. Seropositivity in these settings is influenced by the length of the dogs' stay and the close contact that facilitates virus transmission. These findings highlight the relevance of CIV in specific high-risk populations. In samples (swabs

and sera) from shelters dogs with respiratory signs in the U.S., the frequency of CIV detection in New York, Colorado, and South Caroline was 4.4%, 4.7%, and 3.2%, respectively. Seroprevalence in dogs from Colorado and New York was 10% and 8.5%, respectively (Pecoraro et al., 2014). Another study also suggested that female dogs are more commonly infected, while older dogs have a lower risk of infection (Yondo et al., 2023). Puppies and young dogs are especially vulnerable to CIRDC pathogens, including CIV (Yondo et al., 2023).

Although CIV is significant respiratory pathogen in dogs, its role in CIRDC is geographically variable and context-dependent. Currently, CIV is neither widespread nor an important pathogen in Europe (Day et al., 2020). Influenza A viruses, particularly H3N8, have been associated with CIRDC in the U.S., especially in high-risk populations. Additionally, other Influenza A subtypes have been detected in dogs.

PIV5 is another important viral agent in the CIRDC, contributing significantly to respiratory infections in dogs (Appel and Bemis, 1978). The virus is spread worldwide, and it demonstrates cross-reactivity with human parainfluenza virus, which is the reason for suspecting a zoonotic potential (Valčić et al., 2014). Its incidence differs depending on the region, the population studied, and the diagnostic methods used (Zhou et al., 2024; More et al., 2021; Matsuu et al., 2020) (Table 5).

Table 5. Prevalence of canine parainfluenza virus in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Japan	2006-2007	Household dogs with respiratory signs	RT-PCR	7.4	Mochizuki et al. (2008)
Germany	2011-2012	Healthy dogs and dogs with CIRDC	RT-PCR	37.7	Schulz et al. (2014b)
Italy	2011-2013	Dogs with CIRDC	RT-PCR	21	Decaro et al. (2016)
Canada	2013-2014	Dogs with CIRDC Healthy dogs	PCR	42 0	Joffe et al. (2016)
New Zealand	2012-2013	Dogs with respiratory signs Healthy dogs	PCR	6 0	Sowman et al. (2018)
Japan	2017-2018	Household dogs with CIRDC Asymptomatic household dogs	PCR	4.9 0	Matsuu et al. (2020)
New Zealand	2014-2016	Dogs with CIRDC Healthy dogs	RT-qPCR	3.6	More et al. (2021)
China	/	Dogs with and without respiratory signs	m-PX-qPCR	15.8	Zhou et al. (2024)

RT-PCR: Reverse transcription polymerase chain reaction; **CIRDC:** Canine infectious respiratory disease complex; **RT-qPCR:** Reverse transcription quantitative polymerase chain reaction; **m-PX-qPCR:** Multiplex quantitative polymerase chain reaction.

In Japan, PIV5 was detected in 4.9% of private household dogs with respiratory signs, while a previous study reported a slightly higher prevalence of 7.4% in household dogs (Matsuu et al., 2020; Mochizuki et al., 2008). These relatively low rates could reflect successful vaccination efforts reducing the circulation of classical respiratory viruses (Matsuu et al., 2020; Mochizuki et al., 2008). Similarly, two surveillance studies conducted in New Zealand found PIV5 in 3.6% and 6.0% of dogs with clinical signs, such as nasal discharge, coughing, sneezing, and altered respiration (More et al., 2021; Sowman et al., 2018), consistent with the lower prevalence observed in Japan.

Conversely, remarkably higher prevalence was reported in Europe and North America: 21% in Italy (Decaro et al., 2016), 37.7% in Germany (Schulz et al., 2014), and 42% in Canada (Joffe et al., 2016).

Although PIV5 remains a significant CIRDC pathogen, its prevalence differs widely. Standardized surveillance and sensitive diagnostic methods are essential to better define its role and to optimize vaccination and treatment strategies.

CRCoV is a major pathogen involved in CIRDC. Table 6 presents the prevalence of CRCoV in dogs.

Table 6. Prevalence of canine respiratory coronavirus in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
U.K.	/	Shelter dogs	ELISA RT-PCR	30.1-99.9 26.9	Erles et al. (2003)
U.S. **U.K.** **Ireland**	/	Dogs sera	ELISA	54.7 36 30.3	Priestnall et al. (2006)
Japan	2006-2007	Household dogs with respiratory signs	RT-PCR	1.5	Mochizuki et al. (2008)
Germany	2011-2012	Healthy and dogs with CIRDC	RT-PCR	9.8	Schulz et al. (2014b)
European Union	2011-2013	Dogs exposed to CIRDC	RT-PCR ELISA	7.7 47	Mitchell et al. (2017)
Sweden	2013-2015	Household dogs with CIRDC	RT-PCR	14.7	Wille et al. (2020)
New Zealand	2014-2016	Dogs with CIRDC Healthy dogs	RT-qPCR	0	More et al. (2021)
U.S.	2018-2021	Household dogs with CIRDC	RT-qPCR cELISA	14.4 23.7	De Luca et al. (2024)

ELISA: Enzyme-linked immunosorbent assay; **RT-PCR:** Reverse transcription polymerase chain reaction; **CIRDC:** Canine infectious respiratory disease complex; **RT-qPCR:** Reverse transcription quantitative polymerase chain reaction; **cELISA:** competitive ELISA.

The incidence of this virus is influenced by dog population density, environmental conditions, and geographical distribution (More et al., 2021; Erles et al., 2003). A report from Sweden demonstrated that 14.7% of dogs with CIRDC clinical signs tested positive for CRCoV by PCR, indicating the virus`s role in causing the disease (Wille et al., 2020). A study conducted in dogs with CIRDC in the U.S. identified CRCoV in 14.4% of swab samples and found that infection was more common in younger dogs and during the warmer months (De Luca et al., 2024). In the same study, serosurveillance of CRCoV in 540 canine sera resulted in 23.7% positive sera. In Germany, CRCoV was found in 9.8% of cases of CIRDC (Schulz et al., 2014b). It has also been shown that dogs infected with CRCoV are more likely to develop severe clinical signs (De Luca et al., 2024). Additionally, healthy dogs are infrequently positive for CRCoV, which provides additional evidence of association with the CIRDC syndrome (More et al., 2021; Schulz et al., 2014b). The molecular prevalence of CRCoV in dogs with CIRDC in Japan was 1.5% (Mochizuki et al., 2008), while a prevalence of 2% was reported in New Zealand (More et al., 2021).

Anti-CRCoV antibodies were detected in 54.7% of tested dogs in the U.S., 35.6% in the U.K., and 30.3% in Ireland. The high seroprevalence indicates that the virus frequently circulates within the dog population, with subclinical infection as the predominant outcome (Priestnall et al., 2006). In a large study conducted across six European countries, the overall seroprevalence was 47% with higher rates observed in shelters where contact between dogs was more frequent, and the overall molecular prevalence was 7.7% (Mitchell et al., 2017).

The lower detected molecular prevalence in diseased dogs compared to the higher seroprevalence in healthy dogs suggests that dogs were exposed to the virus at some point in time in confined spaces, and the measurement differences could be a result of sporadic shedding, inappropriate timing of sampling, or protective immunity post-infection. This finding indicates that the risk presented by this pathogen may be high, but the prevalence is debatable. From the available evidence, it can be deduced that CRCoV is endemic worldwide and is a significant contributor to the morbidity and mortality of CIRDC.

CDV, also known as canine morbillivirus, causes acute systemic infections in dogs and other carnivores, and vaccination is known to be of great importance for controlling the infection (Di Francesco et al., 2012). In the context of CIRDC, CDV is considered one of the possible pathogens that causes respiratory disease (Buonavoglia & Martella, 2007). Distemper can occur as a post-vaccinal disease in recently immunized puppies, in which case the infection breaks through vaccine-induced immunity, making diagnosis particularly challenging, especially when a live-attenuated strain is used in the vaccine (Valčić et al., 2014). Canine distemper, on the other hand, refers to systemic infection caused by CDV, which can occur in several different forms: ocular, cutaneous (hard pad disease), neurological, and gastrointestinal form (Martella et al., 2008; Beineke et al., 2015). The prevalence of CDV infection differs depending on geographical location, vaccination, and health status of dogs (Table 7).

Table 7. Prevalence of canine distemper virus in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Italy	2005-2008	Pet and kennel dogs with respiratory, gastrointestinal and neurological signs	Hemi-nested RT-PCR	56.6	Di Francesco et al. (2012)
Germany	2011-2012	Healthy and dogs with CIRDC	RT-PCR	0	Schulz et al. (2014b)
Finland	2011-2013	Dogs with bacterial pneumonia Dogs with chronic Bb infection	RT-PCR	0	Viitanen et al. (2015)
Austria	1997-2007	Dogs with CIRDC	IHC	16.1	Woehrer et al. (2016)
Austria	2013-2015	Healthy and dogs with CIRDC	RT-PCR	0.5	Hiebl et al. (2016)
U.S.	2011-2012	Healthy shelter dogs	qPCR	7.4	Lavan & Knesl (2015)
Thailand	2013-2016	Community – acquired infection Hospital – acquired infection	Multiplex RT-PCR	35.3 22.4	Piewbang et al. (2019)
U.S.	2018-2022	Dogs with respiratory signs	ELISA	3	Yondo et al. (2023)
Cambodia	2024	Free-roaming dogs	Antigen rapid CDV Ab test	40	Wheelhouse et al. (2025

RT-PCR: Reverse transcription polymerase chain reaction; **CIRDC:** Canine infectious respiratory disease complex; **IHC:** Immunohistochemistry; **qPCR:** Quantitative polymerase chain reaction; **ELISA:** Enzyme-linked immunosorbent assay; **CDV:** Canine distemper virus.

Although a few studies have investigated the prevalence of CDV in healthy animals, the virus has been mainly studied and reported in dogs with clinical signs. In Italy, for instance, a high prevalence (56.6%) of CDV was reported in dogs with respiratory, neurological, and/or gastrointestinal disorders (Di Francesco et al., 2012). In Austria, CDV was found in 16.1% of dogs with pneumonia younger than 12 months of age (Woehrer et al., 2016). Conversely, CDV was not found in healthy dogs or dogs with CIRDC in German and Finnish studies (Viitanen et al., 2015; Schulz et al., 2014b). Although a study in Japan detected CDV in the swab samples of a limited number of diseased dogs (Mochizuki et al., 2008) and a large study from the U.S. observed a 7.4% molecular prevalence in shelter dogs without clinical signs (Lavan and Knesl, 2015), it can be assumed that CDV infection is underdiagnosed. Recent studies substantiate the infrequent diagnosis of CDV as a result of vaccination. Mitchell et al. (2017) demonstrated that vaccination significantly lowered the incidence of CIRDC and severe respiratory signs. Hiebl et al. (2019) and Maboni et al. (2019) reported that

CDV occurs very rarely in vaccinated dogs, whereas in unvaccinated young puppies, the disease has an extremely severe course, with gastrointestinal symptoms present. A similar result was also described in a study in Thailand, in which 35.3% of patients with community-acquired infections and 22.4% of those with hospital-acquired infections were found to have CDV (Piewbang et al., 2019). On the other hand, in an investigation performed from 2018 and 2022, CDV was only diagnosed in 3% of cases, and positive dogs were mostly males (Yondo et al., 2023). The situation in Cambodia, with particular relevance to Asian epidemiological settings, was notably worrying, where a seroprevalence of 40% was found in dogs living near protected areas which harbor threatened species like wild dogs, and potential areas for the introduction of tigers and leopards. The majority of the seropositive dogs had low titers, suggesting that protection had waned or that these animals had been very recently infected (Wheelhouse et al., 2025). Although the overall incidence in the majority of reports is rather small, CDV continues to be a major pathogen, inducing fatal epizootics in domestic as well as wild hosts. The virus in wild populations (e.g., foxes, golden jackals) suggests a lasting threat for the dog population as a significant vector for the transmission of the disease (Garigliany et al., 2018; Glišić et al., 2024).

CAdV-2 is another relevant virus in CIRDC, although its prevalence differs depending on the dog population and region. Table 8 presents the prevalence of CAdV-2.

Table 8. Prevalence of canine adenovirus type 2 in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Japan	2006-2007	Household dogs with respiratory signs	PCR	2.9	Mochizuki et al. (2008)
Italy	2012	Dogs with respiratory signs Healthy dogs Dogs with other than respiratory signs	PCR	100 50 63.2	Balboni et al. (2014)
Japan	2017-2018	Household dogs with CIRDC	PCR	1.5	Matsuu et al. (2020)
U.S.	2018-2022	Dogs with CIRDC	ELISA	4	Yondo et al. (2023)
Germany	2011-2012	Dogs with CIRDC Healthy dogs	PCR	0 1.1	Schulz et al. (2014b)

PCR: Polymerase chain reaction; **CIRDC:** Canine infectious respiratory disease complex; **ELISA:** Enzyme-linked immunosorbent assay.

In a study conducted in the U.S., CAdV-2 was diagnosed in only 4% of dogs with respiratory signs (Yondo et al., 2023). In New Zealand, a similar pattern was reported, with CAdV-2 detected more often in healthy animals than in those affected by clinical

evidence of CIRDC, suggesting that a vaccine or latent strain is present without clinical disease (More et al., 2021). Balboni et al. (2014) stated that vaccination protects against development of the disease, but infection and shedding of CAdV-2 seem possible. The prevalence of CAdV-2 differs across European studies. In Germany, CAdV-2 was detected in 1.1% of healthy dogs (Schulz et al., 2014b), which was considerably lower than in Italy, where the virus was found in 50% of healthy dogs, in 63.2% of dogs with other than respiratory signs and in 100% of dogs with respiratory disease (Balboni et al., 2014). These differences could be related to distinct detection assays used, seasonality and vaccination status. In two studies from Japan, CAdV-2 was an uncommon contributor to CIRDC in dogs, with a prevalence of 1.5% and 2.9%, while PIV5 and Bb were identified as the dominant etiological factors (Matsuu et al., 2020; Mochizuki et al., 2008). CAdV-2 can be difficult to detect because of the short duration of virus shedding; thus, clinical samples should be collected within the first few days of disease to diagnose the virus (Buonavoglia and Martella, 2007). Furthermore, considering the antigen similarity between CAdV-1 and CAdV-2, seroprevalence studies may not adequately diagnose CAdV-2 infection (Radalj et al., 2024). In addition, vaccination is highly effective at preventing population virus circulation (Erles et al., 2004), which could result in the low detection rates as shown in most studies, with the exception of the study conducted by Balboni et al. (2014).

CHV-1 is a DNA virus of the family Herpesviridae which infects dogs. It was originally described in the 1960s, when it was associated with neonatal mortality of puppies (Carmichael et al., 1965). Considering the clinical importance of the virus, particularly in pregnant bitches and newborn puppies, understanding its prevalence across different dog populations is essential. This is especially relevant as herpes establishes a latent infection, leading to a high expected seroprevalence, while the detection of the virus in clinical samples remains challenging in the absence of clinical signs (Ronsse et al. 2005). The seroprevalence of CHV-1 differs greatly with regard to geographic area and dog population (Table 9). In Croatia, the overall seroprevalence was 32.02% in dogs from breeding kennels (Gracin et al. 2023), and this was in accordance with data previously found in the literature. In the above-mentioned study, PCR testing conducted on 203 nasal swab samples provided negative results, which was expected, as nasal swabs would only yield positive results during the acute phase of infection (Gracin et al. 2023). In Norway, CHV-1 seroprevalences ranged between 58.5% and 98% in different regions (Krogenæs et al., 2012), in England, seroprevalences were as high as 94% by at least one of two indirect ELISA tests and serum neutralizing test (SN) (Reading and Field, 1998), and in Belgium, 45.75% of dogs were CHV-1-seropositive by ELISA and SN (Ronsse et al., 2002). In Australia, a lower 13% prevalence was reported (Joone et al., 2024), as in Italy, where overall CHV-1 seroprevalence ranged between 14.6% and 50.3%, depending on the test, region and population sampled (Rota et al., 2020; Pratelli et al., 2014). In some cases, CHV-1 seropositive compared to seronegative bitches had a lower stillbirth rate, indicating a potential protection from antibodies (Ronsse et al., 2005). Investigations in Japan

revealed the molecular presence of CHV-1 in healthy dogs, as in sick dogs with respiratory symptoms, with a mean prevalence of 7.5% (Matsuu et al., 2020).

Table 9. Prevalence of canine alphaherpesvirus type 1 in dogs

Country/ Region	Year	Population	Methods	Detection rate (%)	Reference
Croatia	2014-2017	Breeding kennel dogs	Virus neutralizing test PCR	32.02 0	Gracin et al. (2023)
Norway	/	Healthy dogs	IPMA	58.5-98	Krogenæs et al., (2012)
England	/	Healthy dogs	IgG and IgM ELISA and SN	94	Reading and Field (1998)
Belgium	2000	Pet dogs and breeding dogs	ELISA and SN	45.75	Ronsse et al. (2002)
Australia	2022	Dogs living in suburbs Dogs from dog shows	ELISA	13	Joone et al. (2024)
Italy	/	Kennel dogs and pet dogs	SN IF	14.6 18.6	Pratelli et al. (2014)
Italy	2018	Breeding kennel dogs	SN	50.3	Rota et al. (2020)
Japan	2017-2018	Household dogs with CIRDC	PCR	7.5	Matsuu et al. (2020)

PCR: Polymerase chain reaction; **IPMA:** Immunoperoxidase monolayer assay; **IgG:** Immunoglobulin G; **IgM:** Immunoglobulin M; **ELISA:** Enzyme-linked immunosorbent assay**; SN:** Serum neutralization test; **IF:** Immunofluorescence; **CIRDC:** Canine infectious respiratory disease complex**.**

In summary, CIRDC is highly complex and variable, both in pathogen involvement and disease severity. Two bacterial agents, namely, Bb and *Mycoplasma* spp. are the most commonly implicated pathogens causing CIRDC. The prevalence of Bb has been reported to differ widely according to region, age of the population, and detection methods, with estimates as low as 3.3% in German dogs with respiratory signs and up to 78.7% in dogs in specific European studies, especially in younger and more severely affected dogs (Stejskal et al., 2017; Schulz et al., 2014b).

Mycoplasma spp., notably *M. cynos* and *M. canis*, are commonly found in both healthy and ill dogs. The molecular prevalence in dogs ranges from 0.9% to 91.7%, while seroprevalence ranges from 20.7% to 70.5%, reflecting the high circulation of these pathogens in the canine respiratory system (Mitchell et al., 2017; Scolten et al., 2017; Canonne et al., 2016; Schulz et al., 2015).

CIV is geographically restricted, from no or low seroprevalence in European dogs (2-3%), to higher seroprevalences of up to 10% in U.S. dogs, particularly in shelter settings (Mitchell et al., 2017; Pecoraro et al., 2014). The high circulation of H3N2 CIV in dogs in the U.S. and Canada could be due to the unrestricted importation of rescue dogs from Korea and China, while the movement of infected dogs from Asia and North America to Europe is likely very limited (Wasik et al., 2025). The CIV genome is detected only in the U.S., where puppies and young dogs are more likely to be affected by the virus (Yondo et al., 2023).

PIV5 is also a major pathogen causing CIRDC, but the reported molecular prevalence rates differ extremely, ranging from 3.6% in New Zealand to over 40% in Canada, likely due to the heterogeneity of vaccination, population, and diagnostic sensitivity (More et al., 2021; Joffe et al., 2016). Advancements in diagnostic technologies, such as multiplex real-time RT-PCR, have significantly improved the detection of co-infections (Zhou et al., 2024).

CRCoV is known as an endemic virus throughout the world, with seroprevalence in European dogs between 23.7% and 54.7%, and this virus is known to circulate among confined dog populations. CRCoV prevalences in dogs with CIRDC episodes range from 0% to 26.9% worldwide, and this virus has been linked with more severe clinical disease presentation (De Luca et al., 2024; More et al., 2021; Priestnal et al., 2006). Such high variability in seroprevalence and molecular prevalence could be a result of underrecognized exposure.

CDV has been diagnosed less frequently recently, due to vaccination, but outbreaks still occur in immunosuppressed or unvaccinated groups. Prevalences differ greatly worldwide, with some areas detecting high serological and molecular prevalences and others detecting no or low prevalences in dogs (Schulz et al.,2014b; Di Francesco et al., 2012).

The prevalence of CAdV-2 in dogs ranges from low (1.1%) in most cases to relatively high levels (63.2%) in healthy dogs and those with respiratory or other clinical signs. While CAdV-2 is one of the traditional causative agents involved in CIRDC, this virus is more detectable in healthy dogs, which suggests the presence of vaccine or latent strains are involved (More et al., 2021; Schulz et al., 2014b; Balboni et al., 2014).

CHV-1 is widely spread across the world and is particularly dangerous for pregnant bitches and newborn puppies. Molecular detection of CHV-1 is low, with only 0% to 7.5% prevalence worldwide. On the other hand, CHV-1 seroprevalence ranged between 13% to 98% in healthy dogs, as described in a study from Norway (Krogenæs et al., 2012). Some studies indicate that the presence of antibodies in seropositive pregnant bitches could result in a lower stillbirth rate than in non-seropositive counterparts (Gracin et al. 2023).

CONCLUSION

CIRDC is a multifactorial ailment involving various bacterial and viral pathogens, the prevalence and clinical significance of which differ depending on geographic region, population characteristics, and the diagnostic methods applied. Bb and *Mycoplasma* spp. are the most clinically relevant bacterial agents, while CIV, PIV5, CRCoV and CDV are the most important viral etiological pathogens. The most frequently detected pathogens are Bb, *Mycoplasma* spp., CRCoV and PIV5. The least diagnosed pathogen is CIV, which has not been found in any study in Europe. The high rate of co-infections among the CIRDC cases suggests the complicated nature of the disease and the important role of improved diagnostic methods and comprehensive surveillance in the prevention, early detection, and treatment of the disease. The disease causes problems in kennels with valuable animals, and it is believed that existing vaccines do not provide sufficient protection and fail to induce adequate immunity (Mitchell et al., 2017). Targeted vaccination methods and improved surveillance methods are necessary to control the spread and effects of CIRDC in dog populations.

Data for Serbia are very scarce. Apart from a few studies in recent years, there are no data on the occurrence and prevalence of the disease, or any CIRDC-associated pathogen, except Bb. Only a few vaccines for canine respiratory viruses have been registered in Serbia, and we stress the concerns about vaccine efficacy. Moreover, these vaccines do not provide complete protection because they do not cover all pathogens involved in CIRDC. Unfortunately, evidence on the molecular or serological prevalence of CIRDC pathogens in Serbia is also lacking, and therefore, it is necessary to conduct further investigations.

Limitations of this study were the number of available studies published in peer-reviewed literature and the choices the author team made with regard to literature selection, as well as publication bias, because positive results are published more often than negative results.

Authors' contributions

Conceptualization: NK and DL; methodology: LM and MG; investigation: AJ and SR; data curation: SR and AJ; writing and draft preparation: NK and MG; writing – review and editing: AJ, JN and DL; supervision: JN and DL. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare that they have no competing interests.

ORICD iDs

Nemanja Krstić https://orcid.org/0000-0001-5679-1970
Marija Gnjatović https://orcid.org/0000-0001-8233-1636
Lidija Mlađenović https://orcid.org/0009-0004-2941-188X
Sandra Rakin https://orcid.org/0009-0007-4016-3882

Aleksandra Jovanović https://orcid.org/0000-0001-5394-0125
Jakov Nišavić https://orcid.org/0000-0003-4590-4428
Diana Lupulović https://orcid.org/0000-0002-2476-4887

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KOMPLEKS ZARAZNIH RESPIRATORNIH BOLESTI PASA (CIRDC) U SVETU: PREGLED EPIDEMIOLOGIJE I RASPROSTRANJENOSTI

Nemanja KRSTIĆ, Marija GNJATOVIĆ, Lidija MLAĐENOVIĆ, Sandra RAKIN, Aleksandra JOVANOVIĆ, Jakov NIŠAVIĆ, Diana LUPULOVIĆ

Kratak sadržaj

Kompleks zaraznih respiratornih bolesti pasa (CIRDC), takođe poznat kao zarazni kašalj, je visoko zarazan multifaktorski sindrom kod pasa, uzrokovan i bakterijskim i virusnim patogenima. Bolest se pretežno javlja u sredinama sa velikom gustinom pasa, kao što su prihvatilišta za pse. Iako se CIRDC obično javlja sa blagim do umerenim kliničkim manifestacijama, kod štenaca i pasa sa oslabljenim imunitetom CIRDC može dovesti do teških kliničkih manifestacija.

Ovaj pregled pruža sistematsku analizu 68 recenziranih publikacija i izveštaja od 1965. do 2025. godine, kako bi se ispitale stope prevalencije širom sveta i geografska distribucija patogena. Podaci su preuzeti iz pet glavnih naučnih baza podataka, fokusirajući se na učestalost patogena, njihovu geografsku distribuciju i metodologije detekcije. Najčešće identifikovani bakterijski agensi su *Bordetella bronchiseptica* i *Mycoplasma* spp., a među virusnim agensima virus parainfluence pasa i respiratorni koronavirus pasa. Virus influence pasa je retko detektovan u Evropi, ali je otkriven kod pasa iz prihvatilišta u SAD. Primetno je da CIRDC karakteriše visoka stopa koinfekcije.

Ovaj revijalni rad ističe važnost ažurirane dijagnostike, ciljanih strategija vakcinacije i poboljšanih sistema nadzora. Podaci iz Srbije su oskudni, što naglašava hitnu potrebu za nacionalnim studijama prevalencije i poboljšanim pokrivenošću vakcinacijom.

Ključne reči: infektivni laringotraheitis, zarazni kašalj, prevalenca, sistematski pregled