Narrative Review Article

Prevention and Control of Canine Parvovirus

Hanzhi Zhang

Shanghai World Foreign Language Academy, Lumiere Education,
No. 59, Pingyang Road, Minhang District, Shanghai, China

ABSTRACT

Since its discovery in 1978, Canine Parvovirus (CPV-2) has become one of the most life-threatening pathogens for dogs. The high mutation rate of CPV-2 has led to the rapid emergence of three main variants and widespread transmission. Therefore, the prevention and control of CPV is important. CPV vaccination is the mainstay for the prevention of the disease in dogs. However, the efficacy of vaccine can be undermined by the poor coverage and the maternally derived antibodies (MDAs). This article summarizes the current status of CPV prevention and control, including vaccines, methods of disinfection, diagnosis, and potential treatment, with a focus on vaccines. It outlines the development of vaccines, their efficacy, and drawbacks. The review also discusses the different methods for diagnosis of the disease and how to inactivate the virus in the environment using disinfectants. This article aims to provide a comprehensive overview of CPV control to enhance public awareness of CPV.

Keywords: CPV; prevention; control; vaccine; diagnosis

INTRODUCTION

Since its emergence in 1978, canine parvovirus type 2 (CPV-2) has become one of the most common and widespread causes of death in dogs, particularly puppies. The virus is very small (25 nanometers in diameter), non-enveloped with a single-stranded DNA genome that is known for its high mutation rate. This fast genetic evolution has given rise to so far three viral variants (CPV-2a, CPV-2b, and CPV-2c), which co-circulate in the global dog population nowadays (1).

CPV-2 replicates in multiple tissues within the dog's body, primarily lymphoid organs, intestinal crypt epithelial cells, and cardiac muscle cells, eventually spreading to all tissues and causing a systemic disease. This process results in symptoms such as myocarditis, hemorrhagic gastroenteritis, diarrhea, and leukopenia, and eventually death in most cases (2). The virus is transmitted from an infected dog to a healthy one directly via fecal-oral route, or indirectly via the licking, or inhaling contaminated surfaces. Additionally, CPV-2 is highly resistant to common disinfectants like alcohol and inactivated at very high temperature. Without inactivation, CPV-2 can remain infectious in the infected premises for up to six months, capable of infecting new susceptible dogs (3).

Despite this lethality, no medication for CPV infection has been approved as foolproof, and only general supportive treatment can be used after infection. The only effective method to protect dogs is to prevent infection mainly via vaccination. Vaccination of the dam during pregnancy stimulates the mother's immune system to produce antibodies against the virus. These antibodies are secreted in the milk, and hence are termed maternally derived antibodies (MDAs). MDAs

Corresponding author: Hanzhi Zhang, E-mail: zhanghanzhi3342@126.com.

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protect the newborn suckling puppies against the lethal infection, till they are old enough to be vaccinated (4).

Given the significant impact of CPV in dogs and its high environmental resistance, it is essential to implement effective control measures against CPV. This review summarizes the status of CPV-2 prevention and control, with emphasis on vaccination, which is the major method for the protection of our dogs.

STRATEGIES FOR CPV PREVENTION

Vaccines

CPV vaccination aims to induce a safe primary immune response against the virus, activating the immune system to produce CPV-2-specific antibodies, memory B cells, and memory T cells, thereby establishing immune memory (5). When dogs that have successfully acquired immunity are later naturally exposed to CPV-2 wild-type strains, these pre-existing memory immune cells can rapidly recognize the virus and be activated, triggering a faster, stronger, and more persistent secondary immune response. This highly efficient secondary response can quickly clear the invading virus, prevent disease onset or significantly reduce disease severity (5, 6).

Besides individual protection of the vaccinated dog, widespread vaccination against CPV in a population can protect vulnerable animals in the herd. When sufficient vaccination coverage is achieved and maintained within a dog population, the majority of individuals acquire immunity. These immune dogs have a greatly reduced risk of infection upon exposure to the virus, and even if infected, viral replication is suppressed, resulting in a significant reduction in the amount of virus shed in feces and a shorter duration of shedding. This effectively blocks the primary transmission route of CPV-2: fecal-oral transmission. As a result, the transmission chain of the virus within the dog population is significantly weakened or even interrupted. Dogs that are too young to complete the vaccination schedule, have health issues preventing vaccination, or have inadequate immunity due to poor vaccine response can indirectly be protected, greatly reducing their risk of exposure and infection (7, 8).

Initial vaccine design based on the original strain

CPV-2 is believed to be a host variant of feline parvovirus (FPV) (9–11). The amino acid sequences of the capsid proteins of the two viruses show similarities. Accordingly, FPV vaccines were the first vaccines used for the prevention of CPV infection. Inactivated or modified live FPV vaccines provide some level of cross-protection against CPV (12, 13). In 1982, C. Povey tested three types of vaccines using formalin-inactivated CPV-2. 1) The viral antigen without any immune enhancer (adjuvant), 2) the viral antigen with adjuvant, 3) two different viral antigens (bivalent) with adjuvant. The three vaccines' efficacies were compared with unadjuvanted, the inactivated FPV vaccines. The bivalent vaccine surpassed the other vaccines in terms of efficacy. It produced tenfold antibody titers in the dog sera, and drastically reduced the shedding of the virus when the vaccinated dogs got challenged with a wild type virus (14). Despite being so efficient, the inactivated vaccine also showed low durability and a slow onset of protection.

On the other side, modified live CPV vaccines produce faster immunity that lasts for a longer time compared to the inactivated vaccine (15). Live vaccines, however, have more severe adverse immune reactions, and need specific storage conditions to maintain their efficacy. CPV-2 capsid protein (VP2) mutations drifted the circulating strains toward a new variant: CPV-2a and CPV-2b. These new strains differ from the parental strain (CPV-2) primarily at two amino acid sites within the VP2 protein (16). In 2001, with further mutation of the capsid protein, CPV-2c emerged in Italy and spread worldwide (17). As a result, these three different strains (CPV-2a, -2b, -2c) co-circulate in the world. Given that vaccines, whether live or inactivated, rely on a viral capsid matched to circulating CPV-2 strains as the core immunogenic protein, continuous structural changes in the VP2 major capsid protein over time have the potential to impact long-term vaccine protective efficacy.

Although antigenic drift in VP2 may lead to a reduction in vaccine efficacy, most CPV vaccines currently on the market are still based on the original CPV-2 strain or the globally prevalent CPV-2b strain; both strains have demonstrated clear cross-protective efficacy against the three commonly circulating variants. A study by Yule *et al*. (1997) demonstrated that the modified live vaccine CPV-2 provides strong cross-protection against CPV-2a and CPV-2b, resulting in a fourfold or greater increase in serum neutralizing antibody titers, and completely preventing severe clinical symptoms and viral shedding following exposure to variant strains. (18). Spibey *et al*. (2008) further confirmed that the CPV-2 vaccine also provides effective protection against the newly emerging CPV-2c variant (19).

In summary, although the CPV-2a, 2b and 2c variants exhibit antigenic differences, these do not significantly affect the protective efficacy of the original modified live CPV-2 vaccine. However, it is worth noting that

both studies only assessed short-term protection. As immune responses weaken over time, the CPV-2 vaccine may become less effective against CPV-2 variants over time. Moreover, the puppies in the Spibey *et al*. (2008) study lacked MDAs, so the results only reflect the ideal protective effect of the modified live CPV-2 vaccine against CPV-2c.

New vaccine design based on variant strains

Apart from live CPV-2 vaccine, the modified live CPV-2b vaccine is another widely used option; it not only provides more targeted protection against the CPV-2b strain but also induces similar neutralizing antibody titers across different strains (20–22). This vaccine elicits a strong and rapid memory immune response for up to one year after vaccination and effectively overcomes the interference of MDAs (20). In summary, vaccines made from the currently prevalent CPV-2b strain are more effective providing in cross-protection, overcoming the interference of MDAs, and providing long-lasting protection.

Vaccine failure

Maternally derived antibodies (MDAs) are one of the primary causes of clinical vaccine failure. MDAs are primarily passed on to newborn puppies via colostrum; whilst they provide crucial early passive protection against canine parvovirus, they also neutralize the vaccine strain, thereby preventing the development of the puppy's own active, long-term immunity. As puppies grow, MDAs titers gradually decline, creating a high-risk interference window—a period during which MDAs levels are insufficient to protect against wild-type CPV infection but remain high enough to interfere with vaccine efficacy, leading to vaccination failure. Consequently, MDAs concentration serves as a key reference standard for determining the timing of the final CPV-2 vaccination in puppies. Research by Altman *et al*. (2017) showed that the final vaccination should be administered at 16 weeks of age or later. By this age, MDAs levels in almost all puppies will have fallen to a level that no longer interferes with the vaccine (23).

At the same time, low concentrations of MDAs may not be detectable, but can still affect the effectiveness of vaccination. Therefore, when determining the impact of MDAs and the timing of vaccination, a more sensitive detection method, such as a serum neutralization test (SNA), should be selected (24). In addition to the timing of vaccination, maintaining vaccine efficacy also requires immunogenicity, which refers to the ability of the viral antigens in the vaccine to stimulate the dog's immune system. This depends on the antigenic similarity between the vaccine strain antigens and the circulating wild-type viral antigens (23). Too many differences from wild-type viral antigens can result in low immunogenicity, leading to reduced efficacy (22). Because vaccines stimulate the immune system, this process takes time until an adequate protective number of antibodies is produced in the blood. It is important to avoid exposing the dog to susceptible environments during this period (at least 14 days post-vaccination) (23).

Novel vaccines and administration methods

To overcome the effects of MDAs and improve cross-protection, many researchers are also working on new CPV vaccines to address these issues. A new recombinant vaccine uses the original CPV-2 vaccine strain as a genetic backbone and replaces specific key amino acids in the capsid protein (VP2) to introduce characteristics of the new CPV-2c variant. This not only preserves the safety of the parent vaccine strain, which has been proved through long-term clinical use, but also significantly enhances the vaccine's cross-protective efficacy against currently circulating new variants of the virus. Experimental results have also demonstrated its effectiveness in overcoming the effects of MDAs (25).

Multi-epitope vaccines are group of vaccines that are designed by tailoring many epitopes from different viruses into a single viral antigen. For instance, Paul *et al*. (2023) used computer simulation methods to identify conserved regions in VP2 of CPV-2 and its variants, and selected 10 epitopes based on binding affinity with T cell, accessibility to B cell and antigenicity (26). Consequently, the vaccine designed in this way can produce broader protection and is safer than the modified live vaccine, without the concern that the vaccine strain may become a new source of infection (27). Similarly, Lopes *et al*. (2024) targeted field strains prevalent in Brazil, designing a vaccine based on the common protein sequences of these strains to enhance protection against multiple strains in the region (28).

Canine parvovirus-like particle (VLP)-based vaccine is a novel vaccine strategy. These vaccines are based on empty viral capsids, without viral genomes inside. The produced vaccine is replicative-deficient and therefore safer. The main capsid protein (VP2) can be produced in the baculovirus expression system, a system that allows big scale expression of foreign proteins inside insect-derived cells in the labs, and allows the proteins to self-assemble into empty protein particles (29, 30).

DNA vaccines against CPV are gaining more attention nowadays. DNA vaccine relies on the introduction of a particular viral gene into the dog cells to allow expression of this introduced viral gene only, and hence this vaccine is safer as it does not allow whole viral replication inside the cells, and therefore is much safer than live vaccines and does not produce new virus in the environment. A study comparing a replicon-based CPV DNA vaccine with traditional vaccines demonstrated that this vaccine induced stronger humoral and cellular immune responses in experiments and effectively overcame MDAs interference. However, DNA vaccines also have limitations: they may integrate into the animal's own genome or trigger autoimmune reactions, and sustained antigen expression could lead to tolerance or adverse reactions (31).

In terms of administration, in addition to the more traditional injection route, an oral route has been developed. Its mechanism may be related to the unique induction pathway of the intestinal mucosal immune system, which can partially avoid MDAs in serum. Furthermore, oral vaccines are absorbed through the digestive tract, allowing them to act more directly on the cells of the small intestinal wall, which are one of the primary target cells for CPV-2. Previous studies have demonstrated that intranasal administration of the modified live CPV vaccine is also more effective than traditional injection methods at overcoming MDAs interference, and achieves efficacy at lower doses (32). However, the oral route avoids potential dose loss compared to the intranasal route. Additionally, oral administration is more animal-friendly and less likely to cause stress responses during vaccine administration. However, it may also encounter issues such as animal refusal to ingest the vaccine (33, 34).

In summary, with the emergence of new technologies, research on CPV vaccines is no longer limited to the traditional inactivated and modified live vaccines. DNA and VLP vaccines also exist. Nevertheless, they have not been directly tested by challenge tests, or require data accumulation with regional specificity, making them difficult to expand on a large scale. Therefore, most of them have not yet been approved and entered the market.

Potential feasible approaches on vaccine design

Additionally, the potential of mRNA vaccines against CPV has recently emerged (35). mRNA vaccines are just RNA sequences that can be translated directly into protein in the cell. They are neither protein nor DNA. Being non-protein is advantageous as it reduces the neutralization of the existing antibodies in the dogs, especially MDAs. Not being DNA reduces the chances of viral DNA integration into the dog DNA, making them superior in safety and overcoming the effects of MDAs. For instance, previous studies in mice have demonstrated that a nucleoside-modified mRNA encapsulated in lipid nanoparticles (LNP) vaccine can partially overcome the effects of influenza MDAs and induce protective antibody responses (36). However, their high cost poses significant challenges for further research and practical application (Figure 1).

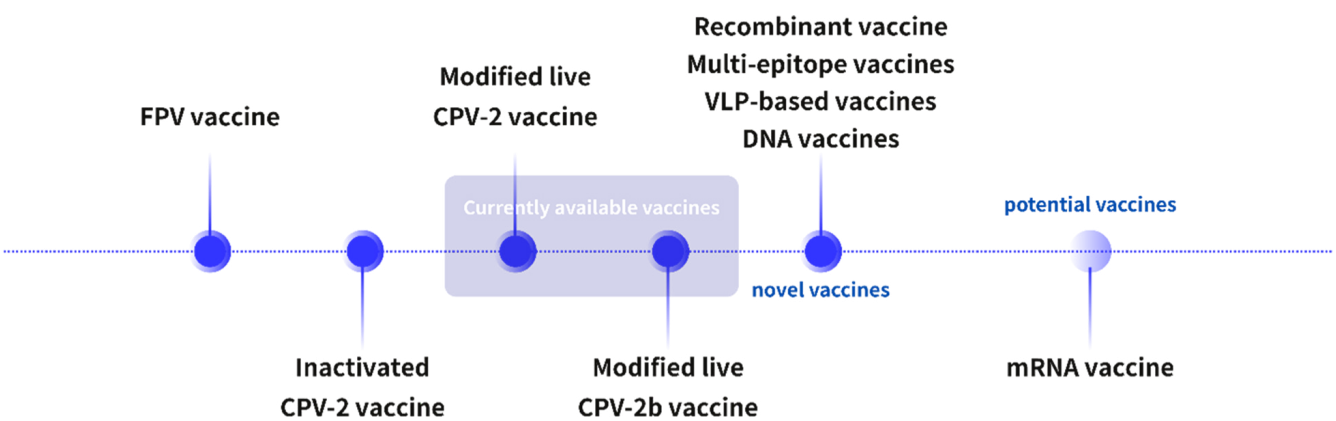

Figure 1. *Timeline of canine parvovirus (CPV) vaccine development. This diagram illustrates the development of canine parvovirus (CPV) vaccines, including early vaccines offering cross-protection, currently available inactivated and live attenuated vaccines, new vaccines under development, and promising candidates. The image was created using the 'Canva' software, downloaded from https://www.canva.cn/.*

Disinfection Methods

Preventing CPV infection involves not only improving a dog's immunity through vaccination, but also breaking the virus's transmission cycle. This necessitates inactivating the virus in the environment where the dog lives. CPV-2 has strong environmental resistance. At room temperature, the CPV-2 virus can remain infectious for up to six months (37). Additionally, the survival time of CPV-2 in the environment is influenced by humidity conditions. In shaded outdoor areas, the virus can persist for up to seven months (38).

Physical disinfection

A commonly used disinfection method is high temperature. CPV-2 can be completely killed within two minutes at 100°C (39), so boiling of CPV-2 contaminated items like utensils, is good practice. The virus is relatively heat resistant, however. High titers of the virus can survive at 80°C up to seven hours, especially if protected by organic matter shed with the virus in the feces.

CPV-2 has good heat resistance due to the structure of the capsid protein. At 80°C, CPV-2 can maintain high titers for one hour and can only be completely killed after seven hours (40), while at 56°C, CPV-2 can maintain its infectivity for at least three days. Additionally, CPV-2 is typically shed through feces, where organic matter, salts, and sulfides can also affect the effectiveness of high temperatures in sterilizing CPV-2 (39).

Chemical disinfection

Because CPV-2 is a non-enveloped virus (without an outer phospholipid cover), disinfectants that dissolve the envelope, such as commonly used household detergents and alcohol, cannot effectively kill it. Furthermore, organic matter in feces can react with many disinfectants, such as formaldehyde, iodine, and chlorine. This reduces the actual disinfectant concentration reaching the CPV-2, thus failing to kill the virus. Therefore, it is essential to clean thoroughly before applying the disinfectant to the contaminated surfaces (39).

Sodium hypochlorite has been proven to be effective against CPV-2. A concentration of 0.75% for 1 minute or 0.37% for 15 minutes can inactivate the virus completely. The short time of use is an advantage of this disinfectant, but it is irritating to mucous membranes, eyes, and skin, and is still affected by organic matter (41). Other disinfectants such as iodine, glutaraldehyde, and chloramine are less sensitive to organic materials interference (39). Sodium hydroxide is also an effective disinfectant, but a high concentration of sodium hydroxide is required due to CPV-2's resistance to pH changes, which results in strong corrosivity to metals and wood and chemical burns on the skin or mucous membranes (42).

In summary, common CPV-2 disinfection methods include high temperatures and chemical disinfectants. The former requires ensuring a temperature of 100°C to guarantee disinfection efficacy and efficiency, which can be achieved easily in clinics using appliances for sterilization like autoclaves and hot air ovens. In houses, contaminated toys and premises can be cleaned by washing thoroughly in detergent, like household soap, to remove the organic matter from around the virus, followed by boiling or soaking in diluted sodium hypochlorite solution.

DISEASE MANAGEMENT AND CONTROL

Diagnosis

Preliminary diagnosis

Although vaccination is the mainstay to prevent the virus infection, vaccines must be administered a long time before exposure to the virus, and they are ineffective if the dog has already got the infection. So early diagnosis is critical to start treating the infected dog. It also helps to isolate these dogs, therefore reducing the load of the virus in the environment where other dogs can catch the infection.

Diagnosis not only identifies the specific virus but also largely determines the severity of the disease. The most basic method of identifying CPV-2 is to observe the symptoms in animals. These symptoms include severe vomiting, severe bloody stools, diarrhea, weakness, weight loss due to dehydration, and fever(43). Although indicative, these clinical signs can be misdiagnosed with many other gastrointestinal infections.

Clinical pathology can aid in more accurate diagnosis. This kind of diagnosis aims at looking for changes in the concentration of specific biomarkers and cells in the body fluids. Serum creatine kinase-MB (CK-MB) concentration, ceruloplasmin (Cp), and total neutrophil count are important biomarkers for assessing the severity of CPV and treatment outcomes(44). CPV-2 targets cardiac muscle cells, where CK-MB is primarily found, leading to myocarditis. When these cells are infected by CPV-2 and undergo apoptosis, CK-MB is released into the bloodstream(45). Therefore, serum CK-MB levels reflect the severity of CPV. Similarly, increased Cp levels, due to CPV-2 attacking intestinal epithelial

cells and causing an inflammatory response, are also an important indicators of CPV severity. CPV-2 targets rapidly dividing lymphocytes and bone marrow cells, causing leukopenia. Thus, assessing total white blood cell count is a highly effective method to evaluate CPV severity and predict treatment outcomes.

Although these clinical methods are used to diagnose CPV infection, they should only be used as a preliminary step, as these clinical signs as well as the body marker changes could also be noticed with some other infectious or non-infectious diseases. More confirmative tests are used to detect the virus specifically, giving no chance for misdiagnosis. These methods either look for the immunological response against the virus (antibodies detection), or detect the virus itself.

Immunological methods

Immunological methods detect CPV-2 by identifying viral proteins in a sample. One of these assays is the latex agglutination test, which uses latex beads coated with antibodies against viral antigens. When the coated latex beads are incubated with an infected sample, the antibodies on the different beads bind to the same viral particle, causing agglutination of the beads. As this reaction can be visually observed without the need for instruments, the slide test is suitable for point-of-care testing and field research (46). Latex agglutination can also be used to quantify the viral load in a sample relatively, by counting the unbound beads automatically, but this requires an automated counter.

The enzyme-linked immunosorbent assay (ELISA), on the other hand, does not require a counter. ELISA is a test that uses highly specific anti-CPV-2 monoclonal antibodies, which are coated onto a solid surface (such as a plate), to which the sample is subsequently added. If the sample contains the virus, the antigen will bind to the fixed antibody on the surface. Enzymatically labelled anti-CPV antibodies is then added to the plate to bind specifically to the trapped antigens on the surface. The labelled antibodies can then be easily detected by adding substrates that interact with the labelled enzyme. ELISA can be used on a large scale, but it can only be used in laboratories as it requires a machine called an ELISA reader (47). However, a simpler form of ELISA is now available that can be performed on a strip, with results visible to the naked eye within minutes, similar to pregnancy test strips. Furthermore, double antibody sandwich ELISA, which uses two specific monoclonal antibodies, can further prevent false positives and has a higher level of specificity and sensitivity (48).

Molecular biological methods

Molecular biological methods detect CPV-2 via detection of CPV-2 DNA in the sample using CPV-2-specific small chain of nucleotides called oligonucleotide primers. These methods include PCR and loop-mediated isothermal amplification (LAMP). After amplification, the DNA must be analyzed in gel electrophoresis to visualize the size (in base pairs) of the amplified DNA. Therefore, although PCR is highly sensitive and specific, it takes longer than the previous methods (49). Real-time PC utilizes fluorescent CPV-2-specific molecular probes that release fluorescence upon amplification of the specific DNA target (the viral DNA). It achieves higher sensitivity, specificity, and faster results (50), as it does not require any gel analysis after the PCR reaction is done. However, PCR method is only restricted to labs for CPV diagnosis and cannot be used in clinics, as it needs complicated expensive equipment.

Loop-mediated isothermal amplification (LAMP) is a newer method that can serve as an alternative to PCR, as it does not require temperature changes, making the equipment simpler and the process faster. Results can be directly observed with the naked eye as a color change in the tubes or fluorescent signals that are interpreted as a millivoltage curve on screen (51).

To further simplify the process, improve speed and accuracy, numerous new versions of these molecular biological detection methods have been studied. A novel CRISPR-Cas13a-mediated molecular diagnosis system has been developed, offering high sensitivity, specificity, speed, portability, and low cost (52). Furthermore, an improved polymerase cross-linking spiral reaction (PCLSR) method, which adds a pair of cross-linking primers to the PSR method, allows results to be observed with the naked eye (53). It only requires constant temperature, making it simple to operate, faster, and highly sensitive. Furthermore, there is a real-time PCR technology based on a one-step multiplex TaqMan probe, capable of simultaneously detecting multiple viruses with high efficiency and sensitivity (54).

Antibody testing

There are also detection methods that can diagnose the infection indirectly via the detection of antibodies against the virus in the infected dog's blood. Hemagglutination inhibition (HI) is one of these techniques. In HI, anti-CPV-2 antibodies from the suspected dog serum are incubated with CPV-2 antigens in the lab to form an antigen-antibody complex. After that a droplet of red blood cells (RBCs) suspension (usually cat RBCs)

is added to the antigen-antibody mix. If the dog has specific antibodies in the serum, they will neutralize the hemagglutinating activity of the antigen, and hence the RBCS will not be agglutinated, indicating that this dog has generated an antibody response against the viral infection. Different dilution concentrations can be used to determine antibody concentration. This method is simple, inexpensive, and provides intuitive results, and has acceptable sensitivity, but it takes relatively longer (55, 56) (Figure 2).

Supportive Treatment

Currently, treatment methods are mainly focused on supportive therapy to alleviate symptoms.

CPV-2 primarily infects intestinal epithelial cells, causing vomiting, diarrhea, fluid imbalance and electrolyte loss, which in turn lead to hypovolemia and hypokalemia. The cornerstone of supportive care is fluid therapy: intravenous or subcutaneous administration of crystalloid solutions (lactated Ringer's solution) to correct dehydration and maintain balance, supplemented with potassium chloride as required to prevent complications associated with hypokalemia; for patients with severe hypovolemia or hypoalbuminemia, synthetic colloid solutions are used to maintain osmotic pressure. Adjuvant therapies include the appropriate use of antiemetics to control vomiting, the appropriate use of antibiotics to prevent secondary bacterial infections and sepsis resulting from compromised intestinal barrier function, the appropriate use of suitable anthelmintics and analgesics, and the early initiation of nutritional support once vomiting has subsided to promote recovery (57–59).

Various adjunctive therapies have demonstrated clinical efficacy. Ozone therapy, administered via intravenous infusion of ozonated lactated Ringer's solution, exerts antibacterial, anti-inflammatory, analgesic and tissue regeneration effects, thereby promoting recovery (60). Human-derived leukocyte extract as an immunomodulator can suppress excessive pro-inflammatory responses, thereby reducing mortality (61); antioxidants and probiotics have also been shown to alleviate intestinal damage, improve oxidative stress and promote recovery (62, 63).

In summary, supportive therapy is the primary treatment method for CPV at present. These methods should be adjusted based on diagnosed severity and combined with appropriate adjunctive therapies, while maintaining monitoring of animal symptoms and adjusting strategies as needed. However, supportive therapy addresses symptoms rather than the underlying cause and is not a direct antiviral treatment.

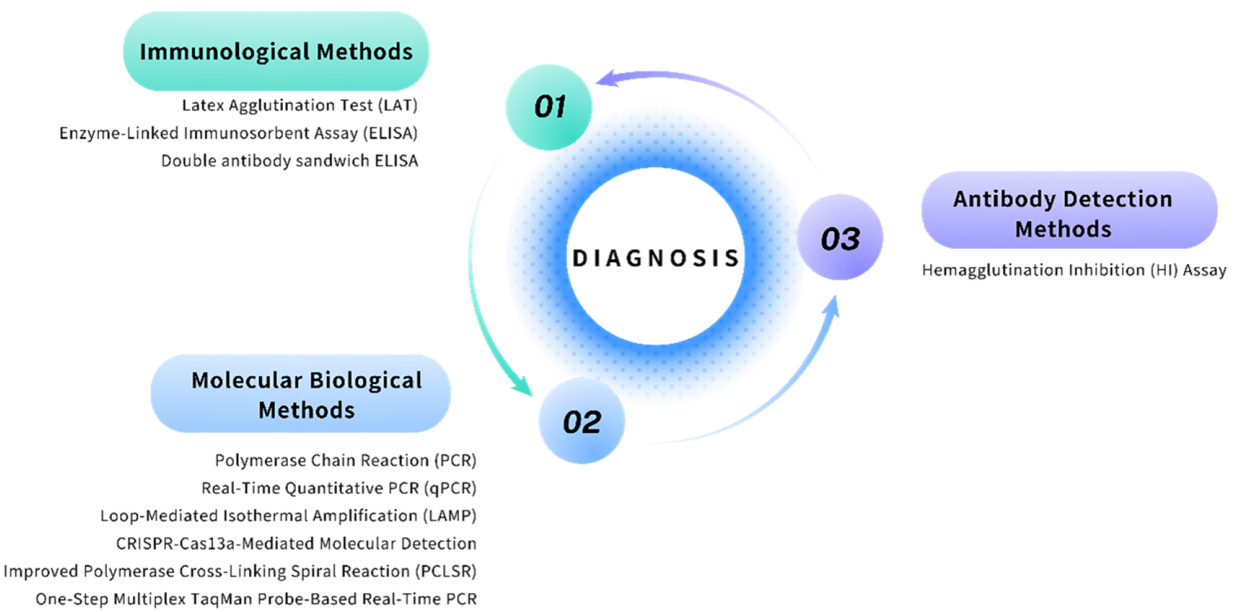

Figure 2. *Classification of diagnostic methods for CPV infection. Diagnostic methods for CPV-2 are broadly categorized into three types: immunological methods, molecular biological methods and antibody testing methods. The image was created using the 'Canva' software, downloaded from https://www.canva.cn/.*

Antiviral Drug

Currently, there are no licensed antiviral drugs for CPV. This is partly because viral replication depends on host cell mechanisms, making it difficult to target specific cells. Additionally, while the viral structure is simple, it has a high mutation rate, further making target identification difficult. Furthermore, the market lacks sufficient research motivation, as the widespread vaccination reduces the demand for treatment, and supportive therapies are economically effective. Under these circumstances, sales and profits are unlikely to cover research and development costs.

Nevertheless, research on CPV-2 antiviral drugs continues. One study uses a small binding protein (TAT-scFv) that can be produced in bacteria to target some conserved regions of CPV-2's major capsid protein (VP2), successfully inhibiting CPV-2 replication in mammalian cells in the lab (64). This reduction of viral replication rate was also noticed when the cells were transduced to express canine interferon λ3 (65). Other studies have used the soluble form of canine transferrin receptor as an antiviral drug. CPV-2 binds to the canine transferrin receptor and enters cells via endocytosis. sTfR, the extracellular domain of TfR, can prevent CPV-2 from binding to TfR by competitively binding to the VP2 protein, thereby blocking CPV-2 (66).

Aside from the antiviral proteins, chemotherapy was also tested. Lithium chloride, when it is used in tissue culture medium, is observed to reduce viral entry and therefore prevent replication inside the infected cells in the lab (67). Oseltamivir, a widely known anti-flu drug, has also been tested, but this time in animals, not in the lab. Oseltamivir-treated dogs after infection gained weight faster than the control ones. In addition, the oseltamivir administered to dogs did not experience a huge reduction in the number of white blood cells (Leucopenia) (68). Overall, most CPV antiviral drugs are still in the very early research stage. With further research into the viral structure, CPV antiviral drugs could become an important area of future research.

CONCLUSION

This review summarizes the current status of prevention, control, diagnosis, and treatment of canine parvovirus (CPV-2). Although currently available commercial CPV-2 vaccines provide reliable cross-protection against all circulating strains worldwide, their practical effectiveness remains constrained by two interrelated and unresolved obstacles: maternal antibody (MDA) interference leading to vaccine failure in puppies, and insufficient vaccination coverage resulting in regional sporadic outbreaks. Vaccination alone cannot achieve sustained control; it must be supplemented by standardized disinfection protocols and early diagnostic testing to break transmission chains and reduce community viral load. For confirmed infections, clinical care remains limited to supportive treatment, and there are currently no approved antiviral therapies.

Based on these findings, future research directions may include: first, advancing vaccines capable of overcoming MDA interference and providing long-lasting, broadly protective immunity; second, developing targeted antiviral drugs and validating adjunctive therapies to reduce mortality from infection; and third, expanding access to field-deployable diagnostic tools and continuing global genomic monitoring of prevalent viral strains.

CONFLICT OF INTEREST

The author(s) declare that there are no conflicts of interest regarding the publication of this article.

REFERENCES

1. Miranda C, Thompson G. Canine parvovirus: The worldwide occurrence of antigenic variants. *Journal of General Virology*. 2016 Sep 1; 97 (9): 2043-57. https://doi.org/10.1099/jgv.0.000540
2. Tuteja D, Banu K, Mondal B. Canine parvovirology - A brief updated review on structural biology, occurrence, pathogenesis, clinical diagnosis, treatment and prevention. *Comp Immunol Microbiol Infect Dis*. 2022 Mar 1; 82. https://doi.org/10.1016/j.cimid.2022.101765
3. Gordon JC, Angrick EJ. Canine parvovirus: Environmental effects on infectivity. *Am J Vet Res*. 1986 Jul 1; 47 (7): 1464-7. https://doi.org/10.2460/ajvr.1986.47.07.1464
4. Decaro N, Desario C, Campolo M, Cavalli A, Ricci D, Martella V, *et al*. Evaluation of lactogenic immunity to canine parvovirus in pups. *New Microbiol*. 2004 Oct 1; 27 (4): 375-9.
5. Sprent J. T and B memory cells. *Cell*. 1994 Jan 28; 76 (2): 315-22. https://doi.org/10.1016/0092-8674(94)90338-7
6. Pulendran B, Ahmed R. Immunological mechanisms of vaccination. *Nat Immunol*. 2011 Jun 18; 12 (6): 509-17. https://doi.org/10.1038/ni.2039
7. Desai AN, Majumder MS. What Is Herd Immunity?

JAMA. 2020 Nov 24; 324 (20): 2113-2113. https://doi.org/10.1001/jama.2020.20895
8. John TJ, Samuel R. Herd immunity and herd effect: New insights and definitions. *Eur J Epidemiol.* 2000; 16 (7): 601-6. https://doi.org/10.1023/A:1007626510002
9. Decaro N, Buonavoglia C. Canine parvovirus-a review of epidemiological and diagnostic aspects, with emphasis on type 2c. *Vet Microbiol*. 2012; 155 (1): 1-12. https://doi.org/10.1016/j.vetmic.2011.09.007
10. Parrish CR, Have P, Foreyt WJ, Evermann JF, Senda M, Carmichael LE. The global spread and replacement of canine parvovirus strains. *Journal of general virology.* 1988; 69 (5): 1111-6. https://doi.org/10.1099/0022-1317-69-5-1111
11. Parrish CR. Mapping specific functions in the capsid structure of canine parvovirus and feline panleukopenia virus using infectious plasmid clones. *Virology*. 1991; 183 (1): 195-205. https://doi.org/10.1016/0042-6822(91)90132-U
12. Wierup M, Olson P, Hedhammar A, Klingeborn B, Karlsson KA. Evaluation of a killed feline panleukopenia virus vaccine against canine parvoviral enteritis in dogs. *Am J Vet Res*. 1982; 43 (12): 2183-7. https://doi.org/10.2460/ajvr.1982.43.12.2183
13. Pollock RVH, Carmichael LE. Use of modified live feline panleukopenia virus vaccine to immunize dogs against canine parvovirus. *Am J Vet Res.* 1983; 44 (2): 169-75. https://doi.org/10.2460/ajvr.1983.44.02.169
14. Povey C. Development of a vaccine incorporating killed virus of canine origin for the prevention of canine parvovirus infection. *The Canadian Veterinary Journal.* 1982; 23 (1): 15.
15. Carmichael LE, Joubert JC, Pollock R V. A modified live canine parvovirus vaccine. II. *Immune response. Cornell Vet*. 1983; 73 (1): 13-29.
16. Truyen U. Evolution of canine parvovirus-a need for new vaccines? *Vet Microbiol*. 2006; 117 (1): 9-13. https://doi.org/10.1016/j.vetmic.2006.04.003
17. Buonavoglia C, Martella V, Pratelli A, Tempesta M, Cavalli A, Buonavoglia D, *et al*. Evidence for evolution of canine parvovirus type 2 in Italy. *Journal of General Virology.* 2001; 82 (12): 3021-5. https://doi.org/10.1099/0022-1317-82-12-3021
18. Yule TD, Roth MB, Dreier K, Johnson AF, Palmer-Densmore M, Simmons K, *et al*. Canine parvovirus vaccine elicits protection from the inflammatory and clinical consequences of the disease. *Vaccine*. 1997; 15 (6-7): 720-9. https://doi.org/10.1016/S0264-410X(96)00232-0
19. Spibey N, Greenwood NM, Sutton D, Chalmers WSK, Tarpey I. Canine parvovirus type 2 vaccine protects against virulent challenge with type 2c virus. *Vet Microbiol*. 2008; 128 (1-2): 48-55. https://doi.org/10.1016/j.vetmic.2007.09.015
20. Wilson S, Illambas J, Siedek E, Stirling C, Thomas A, Plevová E, *et al*. Vaccination of dogs with canine parvovirus type 2b (CPV-2b) induces neutralising antibody responses to CPV-2a and CPV-2c. *Vaccine*. 2014; 32 (42): 5420-4. https://doi.org/10.1016/j.vaccine.2014.07.102
21. Pratelli A, Cavalli A, Martella V, Tempesta M, Decaro N, Carmichael LE, *et al*. Canine parvovirus (CPV) vaccination: Comparison of neutralizing antibody responses in pups after inoculation with CPV2 or CPV2b modified live virus vaccine. *Clin Diagn Lab Immunol*. 2001; 8 (3): 612-5. https://doi.org/10.1128/CDLI.8.3.612-615.2001
22. Glover S, Anderson C, Piontkowski M, Ng T. Canine Parvovirus (CPV) Type 2b Vaccine Protects puppies with Maternal Antibodies to CPV when Challenged with Virulent CPV-2c Virus. *Int J Appl Res Vet Med*. 2012; 10 (3).
23. Altman KD, Kelman M, Ward MP. Are vaccine strain, type or administration protocol risk factors for canine parvovirus vaccine failure? *Vet Microbiol*. 2017 Oct 1; 210: 8-16. https://doi.org/10.1016/j.vetmic.2017.08.019
24. Pollock RVH, Carmichael LE. Maternally derived immunity to canine parvovirus infection: transfer, decline, and interference with vaccination. *J Am Vet Med Assoc.* 1982; 180 (1): 37-42. https://doi.org/10.2460/javma.1982.180.01.37
25. Pearce J, Spibey N, Sutton D, Tarpey I. Development of a Novel Canine Parvovirus Vaccine Capable of Stimulating Protective Immunity in Four-Week-Old Puppies in the Face of High Levels of Maternal Antibodies. *Vaccines (Basel)*. 2023 Sep 1; 11 (9). https://doi.org/10.3390/vaccines11091499
26. Paul B, Alam J, Hossain MMK, Hoque SF, Bappy MNI, Akter H, *et al*. Immunoinformatics for Novel Multi-Epitope Vaccine Development in Canine Parvovirus Infections. *Biomedicines*. 2023 Aug 1; 11 (8). https://doi.org/10.3390/biomedicines11082180
27. Johnson RH, Spradbrow PB. Isolation from dogs with severe enteritis of a parvovirus related to feline panleucopaenia virus. 1979. https://doi.org/10.1111/j.1751-0813.1979.tb15259.x
28. Lopes TS, Gheno BP, Miranda L dos S, Detofano J, Khan MAA, Streck AF. In silico designing of multi-epitope vaccine against canine parvovirus using reverse vaccinology. *Brazilian Journal of Microbiology.* 2024 Sep 1; 55 (3): 2953-68. https://doi.org/10.1007/s42770-024-01442-7
29. Jin H, Xia X, Liu B, Fu Y, Chen X, Wang H, *et al*. High-yield production of canine parvovirus virus-like particles in a baculovirus expression system. *Arch Virol*. 2016 Mar 1; 161 (3): 705-10. https://doi.

org/10.1007/s00705-015-2719-1
30. Xu J, Guo HC, Wei YQ, Dong H, Han SC, Ao D, *et al*. Self-assembly of virus-like particles of canine parvovirus capsid protein expressed from Escherichia coli and application as virus-like particle vaccine. *Appl Microbiol Biotechnol.* 2014; 98 (8): 3529-38. https://doi.org/10.1007/s00253-013-5485-6
31. Dahiya SS, Saini M, Kumar P, Gupta PK. Immunogenicity of a DNA-launched replicon-based canine parvovirus DNA vaccine expressing VP2 antigen in dogs. *Res Vet Sci*. 2012 Oct; 93 (2): 1089. https://doi.org/10.1016/j.rvsc.2012.01.017
32. Martella V, Cavalli A, Decaro N, Elia G, Desario C, Campolo M, *et al*. Immunogenicity of an intranasally administered modified live canine parvovirus type 2b vaccine in pups with maternally derived antibodies. *Clin Diagn Lab Immunol.* 2005 Oct; 12 (10): 1243-5. https://doi.org/10.1128/CDLI.12.10.1243-1245.2005
33. Cavalli A, Desario C, Marinaro M, Losurdo M, Camero M, Decaro N, *et al*. Oral administration of modified live canine parvovirus type 2b induces systemic immune response. *Vaccine*. 2020 Jan 10; 38 (2): 115-8. https://doi.org/10.1016/j.vaccine.2019.10.016
34. Buonavoglia C, Tollis M, Buonavoglia D, Puccini A. Response of pups with maternal derived antibody to modified-live canine parvovirus vaccine. *Comp Immunol Microbiol Infect Dis*. 1992; 15 (4): 281-3. https://doi.org/10.1016/0147-9571(92)90007-E
35. Zhou H, Cui K, Su X, Zhang H, Xiao B, Li S, *et al*. Overview of Recent Advances in Canine Parvovirus Research: Current Status and Future Perspectives. *Microorganisms*. 2025; 13 (1). https://doi.org/10.3390/microorganisms13010047
36. Willis E, Pardi N, Parkhouse K, Mui BL, Tam YK, Weissman D, *et al*. Nucleoside-modified mRNA vaccination partially overcomes maternal antibody inhibition of de novo immune responses in mice. *Sci Transl Med*. 2020 Jan 8; 12 (525). https://doi.org/10.1126/scitranslmed.aav5701
37. Pollock R V. Experimental canine parvovirus infection in dogs. *Cornell Vet*. 1982; 72 (2): 103-19.
38. Gordon JC, Angrick EJ. Canine parvovirus: environmental effects on infectivity. *Am J Vet Res.* 1986; 47 (7): 1464-7. https://doi.org/10.2460/ajvr.1986.47.07.1464
39. McGAVING D. Inactivation of canine parvovirus by disinfectants and heat. *Journal of Small Animal Practice*. 1987; 28 (6): 523-35. https://doi.org/10.1111/j.1748-5827.1987.tb01446.x
40. 后藤仁, 平野稔泰, 内田英二, 渡邊清香, 品川森一, 一條茂, *et al*. Comparative studies of physicochemical and biological properties between canine parvovirus and feline panleukopenia virus. 日本獣醫學雜志 *(The Japanese Journal of Veterinary Science).* 1984; 46 (4): 519-26. https://doi.org/10.1292/jvms1939.46.519
41. Cavalli A, Marinaro M, Desario C, Corrente M, Camero M, Buonavoglia C. In vitro virucidal activity of sodium hypochlorite against canine parvovirus type 2. *Epidemiol Infect*. 2018; 146 (15): 2010-3. https://doi.org/10.1017/S0950268818002431
42. Brown TT. Laboratory evaluation of selected disinfectants as virucidal agents against porcine parvovirus, pseudorabies virus, and transmissible gastroenteritis virus. *Am J Vet Res*. 1981; 42 (6): 1033-6. https://doi.org/10.2460/ajvr.1981.42.06.1033
43. Nandi S, Kumar M. Canine parvovirus: Current perspective. *Indian Journal of Virology*. 2010 Jun; 21 (1): 31-44. https://doi.org/10.1007/s13337-010-0007-y
44. Eregowda CG, De UK, Singh M, Prasad H, Akhilesh, Sarma K, *et al*. Assessment of certain biomarkers for predicting survival in response to treatment in dogs naturally infected with canine parvovirus. *Microb Pathog.* 2020 Dec 1; 149. https://doi.org/10.1016/j.micpath.2020.104485
45. Gillum RF, Fortmann SP, Prineas RJ, Kottke TE. International diagnostic criteria for acute myocardial infarction and acute stroke. *Evaluation*. 1984; 2 (3): 4.
46. Bodeus M, Cambiaso C, Surleraux M, Burtonboy G. A latex agglutination test for the detection of canine parvovirus and corresponding antibodies. *J Virol Methods*. 1988; 19 (1): 1-12. https://doi.org/10.1016/0166-0934(88)90002-X
47. Waner T, Mazar S, Nachmias E, Keren-Kornblatt E, Harrus S. Evaluation of a dot ELISA kit for measuring immunoglobulin M antibodies to canine parvovirus and distemper virus. *Veterinary Record*. 2003; 152 (19): 588-91. https://doi.org/10.1136/vr.152.19.588
48. Rimmelzwaan GF, Juntti N, Klingeborn B, Groen J, UytdeHaag F, Osterhaus A. Evaluation of enzyme-linked immunosorbent assays based on monoclonal antibodies for the serology and antigen detection in canine parvovirus infections. *Veterinary Quarterly.* 1990; 12 (1): 14-20. https://doi.org/10.1080/01652176.1990.9694236
49. Hirasawa T, Kaneshige T, Mikazuki K. Sensitive detection of canine parvovirus DNA by the nested polymerase chain reaction. *Vet Microbiol*. 1994; 41 (1-2): 135-45. https://doi.org/10.1016/0378-1135(94)90143-0
50. Decaro N, Elia G, Martella V, Desario C, *et al*. A real-time PCR assay for rapid detection and quantitation of canine parvovirus type 2 in the feces of dogs. *Vet Microbiol*. 2005; 105 (1): 19-28. https://doi.org/10.1016/j.vetmic.2004.09.018, https://doi.org/10.1016/j.vetmic.2005.05.014
51. Kang JI, Park NY, Cho HS. Detection of canine parvovirus in fecal samples using loop-mediated

isothermal amplification. Journal of veterinary diagnostic investigation. 2006;18(1):81-4. https://doi.org/10.1177/104063870601800111

52. 52. Khan H, Khan A, Liu Y, Wang S, Bibi S, Xu H, *et al*. CRISPR-Cas13a mediated nanosystem for attomolar detection of canine parvovirus type 2. *Chinese Chemical Letters*. 2019; 30 (12): 2201-4. https://doi.org/10.1016/j.cclet.2019.10.032
53. Xu X, Wang X, Hu W, Wu Q, Yao L, Kan Y, *et al*. An Improved Polymerase Cross-Linking Spiral Reaction Assay for Rapid Diagnostic of Canine Parvovirus 2 Infection. *Front Vet Sci*. 2020; 7: 571629. https://doi.org/10.3389/fvets.2020.571629
54. Wang R, Zhang W, Ye R, Pan Z, Li G, Su S. One-step multiplex TaqMan probe-based method for real-time PCR detection of four canine diarrhea viruses. *Mol Cell Probes*. 2020; 53: 101618. https://doi.org/10.1016/j.mcp.2020.101618
55. Senda M, Hirayama N, Yamamoto H, Kurata K. An improved hemagglutination test for study of canine parvovirus. *Vet Microbiol*. 1986; 12 (1): 1-6. https://doi.org/10.1016/0378-1135(86)90035-0
56. Muthuraj PG, Thomas J, Verma S, Sharma C, Goswami TK, Singh M. Usefulness of haemagglutination test for screening of canine parvovirus infection in dogs. 2016. https://doi.org/10.5958/0973-9149.2016.00025.3
57. Prittie J. Canine parvoviral enteritis: a review of diagnosis, management, and prevention. *Journal of veterinary emergency and critical care*. 2004; 14 (3): 167-76. https://doi.org/10.1111/j.1534-6935.2004.04020.x
58. Horecka K, Porter S, Amirian ES, Jefferson E. A decade of treatment of canine parvovirus in an animal shelter: a retrospective study. *Animals*. 2020; 10 (6): 939. https://doi.org/10.3390/ani10060939
59. Kalli I, Leontides LS, Mylonakis ME, Adamama-Moraitou K, Rallis T, Koutinas AF. Factors affecting the occurrence, duration of hospitalization and final outcome in canine parvovirus infection. *Res Vet Sci*. 2010; 89 (2): 174-8. https://doi.org/10.1016/j.rvsc.2010.02.013
60. Dos Santos TG, Orlandin JR, de Almeida MF, Scassiotti RF, Oliveira VC, Santos SIP, *et al*. Ozone therapy: protocol for treating canine parvovirus infection. *Brazilian journal of veterinary medicine*. 2023; 45: e004622. https://doi.org/10.29374/2527-2179.bjvm004622
61. Muñoz AI, Vallejo-Castillo L, Fragozo A, Vázquez-Leyva S, Pavón L, Pérez-Sánchez G, *et al*. Increased survival in puppies affected by Canine Parvovirus type II using an immunomodulator as a therapeutic aid. *Sci Rep*. 2021; 11 (1): 19864. https://doi.org/10.1038/s41598-021-99357-y
62. Chethan GE, De UK, Singh MK, Chander V, Raja R, Paul BR, *et al*. Antioxidant supplementation during treatment of outpatient dogs with parvovirus enteritis ameliorates oxidative stress and attenuates intestinal injury: A randomized controlled trial. *Vet Anim Sci*. 2023; 21: 100300. https://doi.org/10.1016/j.vas.2023.100300
63. Schmitz SS. Value of probiotics in canine and feline gastroenterology. *Veterinary Clinics: Small Animal Practice*. 2021; 51 (1): 171-217. https://doi.org/10.1016/j.cvsm.2020.09.011
64. Liu K, Xu P, Li Y, Qin J, Zhu J, Microbiologica YLN, *et al*. Inhibition of canine parvovirus 2 (CPV-2) replication by TAT-scFv through targeting of the viral structural protein VP2 of CPV-2. *New Microbiol*. 2024; 46 (4): 381-389
65. Kim DH, Han SH, Go HJ, Kim DY, Kim JH, Lee JB, *et al*. Antiviral activity of canine interferon lambda 3 expressed using a recombinant adenovirus against canine coronavirus, canine parvovirus, and canine distemper virus. *Vet Res Commun*. 2022; 46 (4): 1363-1368. https://doi.org/10.1007/s11259-022-10000-1
66. Wen J, Pan S, Liang S, Zhong Z, He Y, Lin H, *et al*. Soluble form of canine transferrin receptor inhibits canine parvovirus infection *in vitro* and *in vivo*. *Biomed Res Int*. 2013; 2013. https://doi.org/10.1155/2013/172479
67. Zhou P, Fu X, Yan Z, Fang B, Huang S, Fu C, *et al*. Antiviral effect of lithium chloride on infection of cells by canine parvovirus. *Arch Virol*. 2015 Aug 28; 160 (11): 2799-805. https://doi.org/10.1007/s00705-015-2577-x
68. Savigny MR, Macintire DK. Use of oseltamivir in the treatment of canine parvoviral enteritis. *Journal of Veterinary Emergency and Critical Care*. 2010 Feb; 20 (1): 132-42. https://doi.org/10.1111/j.1476-4431.2009.00404.x