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Emergence of Canine Parvovirus - 2 Variants and its Impact on Vaccination

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Abstract: Canine parvovirus-2 (CPV-2) has been considered to be an important pathogen of domestic and wild canids and has spread worldwide since its emergence in 1977. It has been reported from Asia, Australia, New Zealand, the Americas and Europe. There are two distinct parvoviruses known to infect dogs - the pathogenic CPV-2 and CPV-1 or the canine minute virus (CnMV). The disease caused by CPV-2 is characterized by two prominent clinical forms, enteritis with vomition and diarrhea in dogs of all ages and myocarditis and subsequent heart failure in pups of less than 3 months of age with high morbidity (100%) and frequent mortality up to 10% in adult dogs and 91% in pups. The disease condition has been complicated further due to emergence of a number of variants namely CPV-2a, CPV-2b, CPV-2c, New CPV- 2a, New CPV- 2b and Asp 300 (2a/2b) over the years and involvement of domestic and wild canines. Vaccination is the most cost effective and ideal method to control the canine parvovirus infections in canines. Both live attenuated and inactivated vaccines are available to control the disease in animals. Vaccines used during the late 1970s and early 1980s were of feline panleukopenia virus (FPV) origin which was followed by the use of inactivated and live attenuated vaccines of CPV-2 and CPV-2b of canine origin. High-titer, low-passage CPV vaccines containing a canine origin attenuated virus are currently the vaccines of choice for use in pups of any breed. In spite of large scale vaccination to control the disease in dogs, the disease has been reported both in vaccinated and the unvaccinated dogs. Considering the enormous importance of the disease, the article is aimed to discuss the emergence of canine parvovirus -2 variants and its impact on vaccination for the benefit of the scientific fraternity, dog owners, veterinary practitioners, students, researchers and diagnosticians which in turn help in the better and effective management and ultimately control of the disease.

Key words: Canine parvovirus 2 (CPV-2) · CPV-2a · CPV-2b · CPV-2c · New CPV-2a · New CPV-2b · Asp 300 (2a/2b) · Hemorrhagic gastroenteritis · Myocarditis · Vaccination · Vaccination failure · Maternal antibodies · Inactivated vaccine · Live attenuated vaccine

INTRODUCTION

Canine parvovirus - 2 (CPV-2), the causative agent of acute haemorrhagic enteritis and myocarditis in dogs, is one of the most important pathogenic viruses. CPV-2 was first recognized in 1977 and since then it has been well established as an enteric pathogen of dogs throughout the world with high morbidity (100%) and frequent mortality up to 10% [1]. The disease is characterized by two prominent clinical forms (i) enteritis with vomition and diarrhea in dogs of all ages and (ii) myocarditis and subsequent heart failure in pups of less than 3 months of age [2]. The virus was named CPV-2 in order to differentiate it from a closely related parvovirus of canines known as CPV-1 or canine minute virus (CnMV). CPV is believed to have originated as a host range variant from feline panleucopenia virus (FPV), by a series of changes that include a direct mutation from FPV, a mutation from a FPV vaccine virus and the adaptation to the new dog host *via* non-domestic carnivores, like minks and foxes. The original type (CPV-2) which emerged in the late 1970s was rapidly replaced by two antigenic variants, CPV-2a in 1979 and CPV-2b in 1984 [3, 4]. Further in 2000, a third type, CPV-2c, was first detected in Italy and found to be progressively replacing other variants in many countries of the European Union, South America, North America

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and Asia [5-12], but Australia has been declared free of CPV-2c. Subsequently New CPV-2a, New CPV-2b and Asp-300 (2a/2b) have emerged in the canine population [13,14,15].

Vaccination is the most cost effective and efficient method to control the canine parvovirus infections in dogs. Both live attenuated and inactivated CPV vaccines are available to control the disease in dogs. Current vaccinations have helped to control the spread of this disease but despite being vaccinated, some dogs still contract and die from parvovirus infections. Further, a large pool of unvaccinated apparently healthy stray dogs may act as carriers without showing any symptoms and become source of infection to other susceptible dogs. In spite of latest development in the field of virology, immunology, biotechnology, genetics, genomics, proteomics *etc*. many aspects about CPV-2 infections that may help in both preventing vaccination failure and in controlling the disease are still unexplored. There are differences in opinion about the efficacy of the existing CPV vaccine in controlling the new variants of CPV and a variety of vaccination regimes are adopted by the veterinarians against the CPV infections. Some are of the opinion that the current vaccine based on CPV-2 is still effective against all the CPV variants [16,17]. Others opine that as there is no incidence of CPV-2 outbreaks now-a-days, the vaccine strain (CPV-2) must be replaced by new variants of CPV-2a/2b/2c based on the prevalence of the disease in a particular region [18,19]. This article is aimed to provide detailed information about the emergence of new variants of CPV-2 and its impact on vaccination, different causes of vaccine failure and the best ways to control the disease. With a better understanding of the disease, cross protective activity of the different mutants and various causes of vaccine failure, it would be possible for the veterinary practitioners to discharge the best possible management and the immunoprophylactic measures which in turn help in the prevention and the control of the CPV infections in dogs.

Etiology: Canine parvovirus belongs to the genus *Parvovirus* and family *Parvoviridae* [20]. CPV has icosahedral symmetry, 25 nm diameter and is nonenveloped with a linear, single stranded DNA genome of 5.2 Kb. The infectious capsid contains about 55 copies of VP2 and about 5 copies of the VP1 protein which contains both the VP2 sequence and 143 additional N-terminal residues [21, 22]. VP2 (64 kDa) is the major component of the capsid. Elaborate loops forming most of the capsid surface make up majority of the functional sites of the capsid, including those involved in receptor and antibody binding [23,24,25,26]. The cell receptor for CPV is the transferrin receptor (TfR) and appropriate TfR binding leads to cell infection followed by generation of large number of progeny virions [27]. The few amino acid differences in CPV-2 and its variants have altered antigenic features of the virus and modified important biological properties such as the *in vivo* and *in vitro* host ranges, interaction with the cellular receptor and virulence [28].

Surface features of the capsid include a raised area (spike) surrounding the threefold axis of symmetry, a depression (dimple) spanning the two-fold axis of symmetry and a further depressed area (canyon) surrounding the five-fold axis of symmetry of the capsid [29]. Two primary antigenic sites on the three-fold spike of the virus were defined using monoclonal antibodies [24,30], although epitopes have also been identified by peptide mapping in other regions of the capsid [31]. The three sites on the capsid that can affect canine host range on the threefold spike are separated from each other by 25 to 30 Å and all affect the folding or flexibility of loops within the capsid structure, suggesting roles in virus-receptor interactions or in capsid uncoating [32].

Phylogenetic analysis revealed that all CPV variants were descended from a single ancestor which emerged during the mid-1970s, which was closely related to the long-known feline panleukopenia virus (FPV) which infects cats, mink and raccoons but not dogs or cultured dog cells [33]. Between these viruses, there is more than 98 per cent nucleotide sequence homology and as few as six coding nucleotide differences in the VP2 gene at positions 3025, 3065, 3094, 3753, 4477 and 4498 [34]. The biological effects of these few genomic changes were sufficient for CPV-2 to acquire canine host range, but it lost the ability to replicate in feline host [35]. Two differences at VP2 residues 93 from Lys to Asn and 323 from Asp to Asn between FPV and CPV could introduce the canine host range [36]. Though FPV and CPV-2 are closely related, the latter did not replicate in cats and this host range was determined at least in part by VP2 residues 80, 564 and 568 which are in close proximity in the capsid structure [37]. CPV-2a contained ?ve substitutions in the capsid sequence compared to CPV-2, including changes of VP2 residues 87 from Met to Leu, 300 from Ala to Gly and 305 from Asp to Tyr [4]. CPV-2a isolates were antigenically different from CPV-2 and also infected and caused disease in cats [37]. An antigenic variant of CPV type 2a namely CPV-2b recognized in 1984 had the substitution in VP2 at residue 426 from Asn to Asp and at

residue 555 from Ile to Val [3]. These CPV-2a and CPV-2b completely replaced the original CPV-2 virus worldwide [4,37]. In 2000, another mutant, CPV-2c, which differed from CPV-2b by one amino acid at 426 position (Asp to Glu), was reported for the first time in dogs from Italy [5]. This mutation affects the major antigenic region (epitope A) located over the three-fold spike of CPV-2 capsid. Subsequently, sequence analysis of the circulating CPV-2a isolates revealed a reversion at position 555 to the sequence of FPV/CPV-2, *viz.* Ile to Val. This mutation restricts the differences among the antigenic variants CPV-2a, 2b and 2c to only one amino acid at position 426, which are Asn in CPV-2a, Asp in CPV-2b and Glu in the CPV-2c. Most CPV-2 strains which spread in Italy differed only in this residue [8]. Mutations in CPV-2a and 2b gave rise to New CPV-2a and New CPV-2b from CPV-2a and 2b respectively. Again based on mutation of amino acid 300 (Gly300Asp), variants of New CPV 2a and 2b were described and are known as Asp 300(2a/2b) [13,14,15]. The variants (New CPV-2a, New CPV-2b, Asp 300(2a/2b) and CPV-2c) have Ser 297 Ala mutation. Mutation in residue 297 is thought to influence changes in antigenicity of the CPV variants as it is located in the middle of epitope B [33].

Monoclonal antibodies have been developed and used for the detection of some of the mutants of CPV-2 [7]. Apart from monoclonal antibodies, these variants can be differentiated by DNA sequence analysis and PCR along with RE analysis [38,39].

Epidemiology of CPV: Canine parvovirus infection occurs worldwide in domestic dogs and other members of the dog family. Incidence is higher in animal shelters, pet shops and breeding kennels. CPV can affect dogs at any age. Severe infection is most common in puppies between 6 weeks and 4 months of age. All breeds of dogs are susceptible. The crossbreds are less susceptible in comparison to pure breeds like Rottweilers, Doberman Pinchers, English Springer Spaniels and German Shepherd, the exception to this being Toy Poodles and Cocker Spaniels [40]. The CPV infection is more severe in young puppies especially those younger than three months of age [41,42]. All infected dogs may not necessarily exhibit clinical manifestations but they may shed the virus in feces during the acute phase of enteric fever and show significant rise in the serum antibody titers [43].

The different antigenic variants of CPV-2 are prevalent in varying proportion in different countries. The prevalence of CPV-2b has been reported by various authors in several countries namely Brazil [44], USA [45], Japan [46], Switzerland [47] and South Africa [48]. Contrastingly, CPV-2a was found to be the prevalent antigenic type in France, Taiwan and Italy [6,36]. However both CPV-2a and CPV-2b have been found to be distributed in equal proportion in Spain [49] and U.K. [50]. CPV-2c has also been found in Vietnam [7], Spain [8], United Kingdom [51], South America [9] and North America [52].

CPV-2 was isolated for the first time in India in 1982 [53]. After that, the incidence of CPV-2 variants in dogs were reported from different states *viz.* Kerala [54], Orissa [55], Assam [56], West Bengal [57], Tamil Nadu [58], Pondicherry [59], Haryana 60] and Uttar Pradesh [61,62]. The prevalence of CPV-2a [63,64] and New CPV-2a [65] has been documented in Southern India. In North India, the prevalence of CPV-2b is more compared to the other mutants [61,62,66]. However, recent studies have established that New CPV-2a has replaced CPV-2b as the major circulating variant in North India [67]. Occurrence of CPV-2c was first reported in India by [12] based on the sequence analysis of a CPV-2b positive sample. Its presence in India supports the assumption that CPV-2c is going to reach a worldwide distribution and provides new information to understand the evolution of antigenic variants of CPV-2 [12].

Symptoms: There is a broad range in the severity of symptoms shown by dogs infected with parvovirus. Many adult dogs exposed to the virus remain apparently healthy but act as a carrier to transmit the virus to the susceptible animals. The disease in majority of the cases is seen in dogs less than 6 months of age with severe symptoms in puppies younger than 3 months of age. The most common form of the disease is enteritis. It is characterized by vomition, diarrhea, dehydration, dark or bloody faeces and in severe cases fever and lowered WBC counts. Early symptoms are depression, loss of appetite, vomition, high fever and severe diarrhea. There is slight rise of temperature in the initial stage of the disease but gradually turn to subnormal level with advancement of vomition and diarrhea [68]. There is no consistent character of the stool, it may be watery, yellow in color or tinged with frank blood in severe cases. Rapid dehydration is a danger and dogs may continue to vomit and have diarrhea until they die, usually three days after onset of symptoms. The course of illness is also highly variable depending on the infectious dose of the virus and clinical signs usually develop from 3 to 5 days following infection and typically persist for 5 to 7 days

[69]. The disease will progress rapidly and death occurs as early as 2 days after the onset of the disease. The presence of Gram negative bacteria, parasites or other viruses can worsen the condition and slow down the process of recovery.

The second form of CPV is cardiac syndrome, or myocarditis, which can affect puppies under three months of age [41]. Within an infected litter, 70% pups will die in heart failure by 8 weeks of age and the remaining 30% will have pathological changes which may result in death many months or even years later. The most dramatic manifestation of CPV-2 myocarditis is the sudden death in young pups usually about 4 weeks of age [70].

The tissue distribution of CPV was found to have similar patterns in dogs infected by types 2a, 2b and 2c revealing that the variants have the same biological behavior. Parvovirus replication in dogs and cats takes place mainly in highly mitotically active tissues, such as bone marrow, lymphoid organs and intestinal crypts [2]. Involvement of the nervous tissue has been described in cats [71,72,73]. In dogs CPV antigen has never been detected in neurons, despite the presence of neurodegeneration [74,75]. But Decaro and co-workers could demonstrate the presence of CPV nucleic acid in all tissues including brain and cerebellum [76].

Vaccines and Immunity: Effective vaccines are available for the prevention of CPV-2 infections. Both modified live (ML) and inactivated parvovirus vaccines have been used to fully protect susceptible seronegative pups. Attenuated strains of CPV have been derived by repeated passage of the viruses in cell culture. The vaccine viruses are shed at much lower titres in the faeces suggesting that the absence of enteritis results from decreased viral replication in the intestine. Experimentally live virus vaccines have been shown to protect dogs for at least 2 years or longer [77,78,79,80] and in exceptional cases for 9 year and more [81]. Schultz and his team reported that even a single dose of ML virus when administered at 16 weeks or older, could provide long-term immunity in a very high percentage of animals, while also increasing herd immunity [82]. Inactivated vaccines however, provide only a limited duration of immunity to infection and dogs are protected against disease for several months [77,81].

Puppies get protected during the first few weeks of their life through colostrum. The duration of immunity depends on how much colostrum a puppy has received in its first 2-3 days of life with an average half life of 9.5 days [83]. The decline of maternal antibody level starts from first week to 13 weeks in the pups. Vaccines used to date are unreliable when given in the presence of maternal antibodies.

There is a strong correlation between HI or serum neutralizing antibody titers and resistance to infection with CPV. The HI test has been useful to measure antibodies which correlated with immunity. Dogs vaccinated with killed vaccine developed a serum antibody titre of less than 1:80 in HI test and shed virulent CPV when challenged orally. It is indicated that dogs with low antibody titre support viral replication in the intestine and are a source of infection for susceptible contacts. Dogs that recover from the infection have standard HI titres ranging from 1: 2,560 to 1: 20,480 which persist for at least one year and are solidly immune [77,84].

The HI titre of 80 or more is considered protective although some authors set the threshold for protection at 100 or above [85,86]. The highest rate of infection is reported in pups older than 6 weeks of age [87]. Pups are fully susceptible to challenge CPV infection when the HI titre falls below 80 [77] and such low titres commonly interfere with vaccination. This leaves a period of several weeks where the young pups are susceptible to infection but refractory to vaccination. This period has been termed as “immunity gap”. About 60% of all puppies seroconvert after a single vaccination either at 6 weeks of age with a CPV monovalent vaccine or at 8 weeks of age with a multivalent vaccine. At 12 weeks of age when the pups had received 2-3 inoculation about 90% of the pups respond to vaccination [81,83,87]. The principal reason for the non-responders was the persistence of interfering levels of maternal antibodies. None of the vaccines tested were capable of breaking through a maternal antibody titer of 1:160 or higher, regardless whether the vaccines were high titered or not [83].

Vaccination of dogs is generally performed using multivalent vaccines, which contain canine parvovirus along with canine distemper virus (CDV), canine adenovirus (CAV), rabies virus and leptospira bacterin. Monovalent CPV-2 vaccines are also available, some of them containing very high titer (10^7 $TCID_{50}$) virus and widely recommended for initial vaccination of pups. The American Animal Hospital Association (AAHA) recommends vaccinating dogs at 6 to 8 weeks of age, with repeat vaccination performed every 3 to 4 weeks until the age of 16 weeks and possibly 24 weeks in high risk breeds. All dogs should receive a booster one year after completion of the initial series followed by booster every 3 years [88].

If it is necessary to develop an individual vaccination schedule, determination of the antibody titer of one or two pups in the litter should be done at 5 or 6 weeks of age, then time of vaccination of the litter may be calculated on the basis of titer, using an estimated antibody half life of 9.5 days. Vaccination is likely to be successful when the maternal antibody titer has declined to less than 1:10.

Antigenic Variation and Cross-Protection: There is a growing concern that the vaccines used currently to prevent CPV infection in dogs may fail to effectively protect pups against the new CPV antigenic variants [33,89]. Although the original CPV-2 was completely replaced by the antigenic variants a few years after its appearance, the original CPV-2 is still used in most commercial vaccines [62]. Several studies have demonstrated that CPV-2 vaccines are still effective to induce protection against CPV variants [38]. When antigenic relationships among the original CPV-2 and the variants CPV-2a, CPV-2b and CPV-2c were evaluated by haemagglutination inhibition (HI) and serum neutralization (SN) test, it was observed that former test was not adequate to evaluate the real protective immunity of dogs, in particular against the antigenic variants [28]. This is important in the sense that HI is the gold standard test used in diagnostic laboratories for evaluation of humoral immunity to CPV-2 [90].

The greatest antigenic differences are found between the original CPV-2, which is still largely employed in vaccine formulations and the variants. The original CPV-2 differs in at least five or six amino acid changes from the recent CPV-2 variants [4]. However, it was also possible to observe antigenic differences among the CPV-2a, CPV-2b and CPV-2c variants, which may differ from each other even by a single amino acid change [89]. In the animals immunized with CPV-2, the SN titers to the antigenic variants CPV-2a, CPV-2b and CPV-2c were significantly lower than the homologous titers [28]. It is improbable that these differences may account for decreased protection against the variants in dogs that are protected by a strong active immune response, since after repeated immunizations the antibody titers in young dogs appear to be markedly higher than the minimum levels required for protection against disease and infection. However, it is possible that these differences may allow escape from the limited antibody repertoire of maternal origin in young, unvaccinated pups [28].

Severe parvovirus outbreaks have been observed in pups with HI titers of maternally derived antibodies above the threshold (1:80) related to protection against disease and infection. Likewise, experimental infection by virulent CPV-2b strains of unvaccinated pups with high maternally derived antibody HI titers (>1:80) which are usually expected to prevent CPV infection and disease, resulted in clinical signs, virus shedding and an antibody response [84,91]. Although animals immunized correctly with CPV-2 vaccines are fully protected clinically, there is evidence that the active immunity elicited by the vaccines may sometimes fail to protect adult dogs and the reasons for this may rely on a physiological decline of the protective immunity or on the increased virulence/tropism inherent to some CPV strains [38].

The CPV-2c variant was less effectively recognized by SN by the sera of dogs inoculated with the heterologous (CPV-2, CPV-2a and CPV-2b) viruses. In dogs infected/inoculated with CPV-2c, the homologous titers tended to be lower than the heterologous titers, notably against CPV-2b. The antigenic paradox exhibited by CPV-2c may generate a different selective pressure in the dog population and may have contributed to the spread of the variant CPV-2c. These findings warrant studies to evaluate the opportunity to develop ML vaccines based on the CPV-2c variant [28]. Disease outbreak caused by CPV-2c in adult dogs immunized 3 times with a vaccine containing the original CPV-2 has been reported [19].

Vaccine Failure: The primary cause of CPV vaccine is an interfering level of maternally derived antibodies (MDA) against CPV transmitted by bitches to their offspring through colostrum and at a lesser extent *via* milk. Thus, in order to avoid the interference with active immunization, vaccines should be administered to pups only after waning of MDA [92]. Different strategies have been proposed to overcome the MDA interference, including high-titer vaccines [93] and intranasal vaccination [89]. The Vaccination Guidelines Group of the World Small Animal Veterinary Association also recommends delaying finish of primary CPV-2 vaccination course to 14-16 weeks of age to ensure protection even in pups with long lasting MDA. The genetic constitution of dogs also influences the susceptibility of particular breeds to CPV infections. Further, immunocompetence of the host at the time of vaccination influences the effective immune response. Mismatching between vaccine strain and field strain of CPV may have variable protection level against various strains prevailing in the field. Maintenance of cold chain is an important parameter particularly in the tropical conditions to maintain the potency and efficacy of the vaccines. Improper

administration of vaccine in the host may also play an important role in the vaccine failure. Other reasons behind vaccine failure in canine parvovirus infections may be improper zoosanitory measures, disinfection practices, follow up of improper vaccination schedule, presence of other intercurrent diseases of bacterial and viral origin, inadequate antigenic mass present in the vaccine etc. Onset of parvo-like disease following vaccination is most likely due to infection with field strains of CPV prior to or at the time of vaccination rather than due to the reversion of the vaccine strain [18].

Therapy: The survival rate in parvoviral enteritis is more if adequate supportive treatment is given to the affected animals [94]. Symptomatic treatment with fluid and electrolytes, steroids and broad spectrum antibiotics may save the life of the animal [95,96]. Restoration of the electrolyte and fluid balance is the most important goal of therapy. This is usually done under administration of broad spectrum antibiotics (Ampicillin, Chloramphenicol, Erythromycin, Gentamicin etc.). Norfloxacin and Nalidixic acid have also been proved to be effective against canine haemorrhagic gastroenteritis. During the early phase of the disease, the application of hyperimmune serum may help to reduce the virus load and render the infection less dramatic. Such treatment has been shown to reduce the mortality and shorten the length of the disease however hyperimmune serum is difficult to obtain. In case of vomition, metaclopromide, phenothiazine derivatives, serotonin antagonists and neurokinin (NK-1) receptor antagonists may be administered [96]. However there are also reports that antiemetic drugs do not control vomition in CPV infection [97]. Recombinant feline interferon-omega given intravenously for 3 successive days to dogs was seen to be beneficial in CPV enteritis management [98,99,100]. The use of neuraminaidase inhibitors such as oseltamivir (Tamiflu) in the treatment of CPV is with the view that it prevents neuraminidase dependent bacteria from entering into the blood stream from the gut [101].

To correct the gastric problem Cimetidine, Ranitidine, Famotidine and to check diarrhea, Loparamide or bismuth subnitrate or other astringent preparations may be given [68]. A dog with persistent vomition should not be given any food until the diarrhea and vomition subsides.

Prevention and Control: As the canine parvovirus is not enveloped, it is highly resistant to physical and chemical agents. It is able to withstand winter freezing temperatures in the ground outdoors and many household disinfectants are not capable of killing it indoors. Infected dogs shed virus in their stool in gigantic amounts during the 2 weeks following exposure. A typical/average infectious dose for an unvaccinated dog is 1000 viral particles. An infected dog sheds 35 million viral particles (35,000 times the typical infectious dose) per ounce of stool. CPV-2 loses its infectivity within a month, therefore, it should be safe to introduce a new puppy indoors one month after the active infection has ended. If the outdoor is contaminated and frozen, one must wait for it to thaw out before safely introducing a new puppy. Shaded areas should be considered contaminated for seven months. Areas with good sunlight exposure should be considered contaminated for five months. Although most disinfectants cannot kill it, household bleach (sodium hypochlorite) is quite effective [102]. Chlorine dioxide and potassium peroxymonosulfate have also been reported to effectively kill the virus [103]. There is no way to completely disinfect contaminated dirt and grass, although sunlight and drying has some effect. Mechanical decontamination through irrigation may also be helpful, but the area must be allowed to dry thoroughly between applications.

Good zoosanitary practices in kennels, dog shelters including thorough disinfection of surfaces and personnel are important to control of CPV-2 infection [104]. Another strategy to reduce risk for parvoviral outbreaks is to segregate juvenile animals from adults. Puppies and kittens should not be housed with adults. Puppies or kittens can be housed together using a planned all in-all out co-housing approach. In this approach, littermates can be housed together in small groups (3 per group) and unrelated puppies or kittens that were already living together before admission can also be housed together. Dogs and cats should be housed in separate areas because CPV-2b has the potential to infect cats and cause panleukopenia. Finally, all efforts to reduce stress should be pursued. The most effective way to reduce stress on animals is to prevent crowding by practicing population management principles. Limiting run and cage occupancy to 1-2 compatible animals each results in less stress and substantially reduces risk of contracting infectious.

CONCLUSION

Canine parvovirus-2 is one of the most important viruses infecting dogs. The factors that make the virus a dreadful pathogen are its high morbidity rate, its nature to change continuously paving way for emergence of new variants which may not be effectively neutralized by the currently used vaccines, its alarmingly high resistance to

physical and chemical agents and its capacity to spread rapidly in the susceptible population. The high rate of infection in both vaccinated and unvaccinated dogs questions the relevance of the present day vaccines which in most countries contain old variants. Though some believe that the heterologous protection offered by these old strains against the new variants is good enough, a growing proportion think that the time has come to manufacture vaccines incorporating the variant(s) prevalent in a country. This has lead to the use of vaccines based on variants being released in some countries. Undertaking a proper vaccination schedule coupled with maintenance of good zoosanitary measures will go a long way in reducing the incidence of this dreaded disease in human being's most faithful companion animal.

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