GUIDELINE for SARS-Coronavirus (CoV)-2 and cats

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Key points

- Felids have been shown to be highly susceptible to infection with SARS-CoV-2
- There have been numerous reported cases of human-to-cat transmission of SARS-CoV-2 in COVID-19 households
- Infections in animals should be reported to the World Organisation for Animal Health (WOAH, founded as OIE)
- Infected cats generally display mild respiratory signs and then recover
- Virus can be shed from infected cats for up to one week
- Infected cats develop neutralising antibodies
- People with COVID-19 should avoid contact with cats and observe good hygiene practices
- Veterinarians treating cats from COVID-19 households should wear personal protective equipment that includes eye protection as well as a mask, a gown and gloves

Introduction

SARS-CoV-2, the virus that causes coronavirus disease 2019 (COVID-19) was first isolated in December 2019, in Wuhan City, Hubei province, China. The virus is closely related to the severe acute respiratory syndrome coronavirus (SARS-CoV) that caused a disease outbreak in 2003. SARS-CoV-2 is a member of the genus Betacoronavirus, family *Coronaviridae*, order *Nidovirales* (Table 1), and had not been identified previously in humans or animals. SARS-CoV-2 did not emerge from any companion animal CoV; neither is it related to the commonly occurring feline coronavirus (FCoV) that is associated with feline infectious peritonitis. SARS-CoV-2 infection has spread to many countries worldwide, leading to the pandemic that was declared by the World Health Organisation (WHO) on 11 March 2020 (WHO, 2020). The evolution of SARS-CoV-2 has been monitored since January 2020 and towards the end of 2020, specific variants of interest (VOIs) and variants of concern (VOCs) emerged that posed an increased risk to global public health (WHO, 2023).

Table 1 Classification of coronaviruses (CoVs)

Host	Alpha	Beta	Gamma	Delta
Human	Human CoV-229E, Human CoV-NL63	Human CoV- OC43, Human CoV- HKU1		

Host	Alpha	Beta	Gamma	Delta
Bat origin (outbreaks in humans)		SARS-CoV-2, SARS-CoV, Middle East Respiratory Syndrome-related CoV		
Felids	Feline CoV			
Canines	Canine enteric CoV	Canine respiratory CoV		
Porcines	Porcine epidemic diarrhoea, Porcine respiratory CoV, Transmissible gastroenteritis virus	Porcine haemagglutinating encephalomyelitis virus		Porcine CoV HKU15
Ruminants		Bovine CoV, Antelope CoV, Giraffe CoV		
Equids		Equine CoV		
Bat	Various bat CoVs	Three bat CoVs		
Avian			Turkey CoV, Infectious bronchitis virus	Nine avian CoVs
Rodents		Murine CoV, Rat CoV		
Various		Hedgehog CoV HKU31, Pangolin CoV	Beluga whale CoV-SW1	

Human coronaviruses

To date, seven coronaviruses have been identified (Corman et al., 2018; Cui et al., 2019) in humans, as shown in Table 1. All can cause respiratory illnesses in humans, ranging in severity from asymptomatic infection or mild, common cold symptoms to pneumonia and bronchiolitis.

Prior to the COVID-19 pandemic, there had been two major human disease outbreaks associated with coronaviruses: SARS (Drosten et al., 2003) and middle eastern respiratory syndrome (MERS) (Zaki et al., 2012). Both the SARS and MERS viruses evolved from viruses circulating in bats, the natural reservoir host of many CoV (Li et al., 2005; Ithete et al., 2013). Viruses with highly similar genetic sequences to SARS-CoV-2 have been isolated from horseshoe bats, which indicates that SARS-CoV-2 likely originated in that species (Lytras et al., 2022). It has not yet been resolved whether transmission of SARS-CoV-2 occurred directly from bats to humans, or whether transmission occurred indirectly, via an intermediate host.

Three of the seven human coronaviruses (causing MERS, SARS and COVID-19) can cause severe illnesses and death, although sometimes infections in some individuals can be mild, or asymptomatic. The other four common human coronaviruses typically cause only mild respiratory illnesses in healthy human adults. Nevertheless, these viruses contribute to a third of common cold infections and can cause life-threatening illnesses in immunocompromised people.

A novel canine-feline recombinant alphacoronavirus was isolated from a child with pneumonia, potentially representing an eighth human coronavirus. Designated CCoV-HuPn-2018, the virus was detected in 8 of 301 patients hospitalised with pneumonia in 2017-2018 in Sarawak, Malaysia, mostly children from rural areas with frequent exposure to domesticated animals and wildlife (Vlasova et al., 2022).

Host range of SARS-CoV-2

The host range of a virus depends on several factors. The first step of viral infection occurs when the virus particle binds to a susceptible host cell via specific interactions between the receptor binding site on a viral protein and the virus receptor molecules on the host cell and is a key determinant of the host range and tissue tropism of a virus.

Both SARS-CoV and SARS-CoV-2 utilise the angiotensin-converting enzyme 2 (ACE-2) molecule, a single-pass type I membrane protein, as the virus receptor for infection. ACE-2 is an important protein involved in blood pressure regulation that is highly expressed in the lungs, arteries, heart, kidney and intestines. The high overall sequence identity of ACE-2 amongst different species explains the relatively broad host range of SARS-CoV-2, which is illustrated by the large number of susceptible species that have been reported by the World Organisation for Animal Health (WOAH); by 31 December 2022, 26 different animal species (cat, dog, mink, otter, ferret, lion, tiger, puma, snow leopard, gorilla, white-tailed deer, fishing cat, Binturong, South American coati, spotted hyena, Eurasian lynx, Canada lynx, hippopotamus, hamster, mule deer, giant anteater, West Indian manatee, black-tailed marmoset, common squirrel monkey, mandrill, red fox) had been infected (WOAH, 2022). Approximately 30% (8/26) of the susceptible species are felids. Reports describing the detection of SARS-CoV-2 in animals that are available from WOAH and ProMED have been integrated into SARS-ANI, which is a global, open access dataset that is interactive and can be accessed at https://vis.csh.ac.at/sars-ani/ (Nerpel et al., 2022). Animal infections result from human-to-animal transmission (spillback infections) and can lead to animal-to-animal transmission, as has been shown in mink (Oreshkova et al., 2020), hamsters (Sia et al., 2020) and white-tailed deer (Kuchipudi et al., 2022). There have also been reports of animal-to-human transmission of SARS-CoV-2 (spillover infections) from farmed mink (Oreshkova et al., 2020), pet hamsters (Yen et al., 2022), free-ranging white-tailed deer (Pickering et al., 2022) as well as a domestic cat (Sila et al., 2022).

Human-to-cat transmission of SARS-CoV-2

Naturally occurring SARS-CoV-2 infections in domestic cats have been reported in numerous countries, including Belgium (Garigliany et al., 2020), Switzerland (Klaus et al., 2021a), Italy (Patterson et al., 2020; Musso et al., 2020), Germany (Klaus et al., 2021b), France (Sailleau et al., 2020; Fritz et al., 2021), Hong Kong (Barrs et al., 2020), the USA (Goryoka et al., 2021; Hamer et al., 2021), Spain (Ruiz-Arrondo et al., 2020; Segalés et al., 2020; Barroso-Arevalo et al., 2022), Portugal (Barroso et al., 2022), Poland (Pomorska-Mol et al., 2021), Thailand (Jairak et al., 2021), the United Kingdom (Hosie et al., 2021) and The Netherlands (Kannekens-Jager et al., 2022). These reports indicate that human-to-cat transmission of SARS-CoV-2 occurs relatively frequently in COVID-19 households.

Human-to-non-domestic cat transmission of SARS-CoV-2

SARS-CoV-2 infection of captive wild felids has been reported; lions and tigers are the zoo species that have most frequently been reported to be infected with SARS-CoV-2 (Bartlett et al., 2021), which could be related either to their high susceptibility or because these species are commonly housed in zoos.

Nasal and oropharyngeal swabs and tracheal wash samples collected from a 4-year-old female Malayan tiger (*Panthera tigris jacksoni*) with respiratory signs tested positive for SARS-CoV-2 RNA (McAloose et al., 2020). The tiger was kept in the Wildlife Conservation Society's (WCS) Bronx Zoo, where two Malayan tigers, two Amur tigers (*Pantheratigris altaica*), and three African lions (*Panthera leo*) had developed respiratory signs over the course of a week and showed clinical improvement following supportive treatment. It was presumed that SARS-CoV-2 was transmitted to the tiger from a SARS-CoV-2-infected keeper who was either asymptomatic or pre-symptomatic at the time of exposure. Subsequently faecal samples from all the tigers and lions in the group tested positive.

In a Zoo in Tennessee, one of two Malayan tigers tested positive for SARS-CoV-2 infection when the animals displayed mild coughing, lethargy and decreased appetite (ProMED, 2020). SARS-CoV-2 infection was also reported in two tigers and four lions from a Swedish Zoo that were displaying respiratory symptoms. One tiger, a 17-year-old female with co-morbidities, first displayed a loss of appetite and then rapidly deteriorated, developing severe respiratory and neurological signs, and the animal was euthanised. SARS-CoV-2 infection was confirmed in this tiger and the faeces of the lions tested positive. The zookeepers caring for the animals were symptomatic and COVID-19 had been confirmed in one of them (ProMED, 2021a). Four lions (*Panthera leo*) at the Barcelona Zoo and their three zookeepers developed respiratory signs and tested positive for SARS-CoV-2 antigen. SARS-CoV-2 RNA was detected in nasal samples from three lions for up to two weeks after the initial positive test, but virus isolation was successful from respiratory samples of only two lions in the early stages of infection. All the lions had neutralising antibodies four months after the initial diagnosis and genomic data was consistent with human-to-lion transmission (Fernández-Bellon et al., 2021). Other wild felid species held in captivity have also been reported to be infected with SARS-CoV-2; a comprehensive list is available at the SARS-ANI website https://vis.csh.ac.at/sars-ani/.

Mink-to-human transmission

In addition to human-to-cat transmission, human-to-mink transmission has been recorded in farmed mink in the Netherlands, Denmark, Italy, Spain, USA, Sweden, Greece, France, Poland and Lithuania. It was generally reported that COVID-19 symptoms were present in farm workers before clinical signs were observed in the mink, and infection was confirmed in one hospitalised person (Oreshkova et al., 2020). Widespread infection amongst farmed mink following the introduction of the virus by humans and subsequent transmission between the mink leading to mink-to-human transmission was reported in both the Netherlands (Oude Munnink et al., 2020) and Denmark (Larsen et al., 2021). The large-scale outbreak in Denmark led to an estimated 4000 mink-associated human COVID-19 cases (Larsen et al., 2021), posing a serious threat to human health and led the Danish government culling the entire population of 17 million farmed mink. In the Netherlands, the proposed ban on mink farming scheduled for 2024 was brought forward so that mink farming ceased in March 2021. These actions were taken in response to the emergence of SARS-CoV-2 variants in mink that contained three amino acid substitutions and one deletion in the spike (S) protein. Since the S protein contains the receptor-binding domain and is a major target for the immune response, the emergence of these variants raised concerns that such mutations could, in theory, influence the transmissibility and antigenicity of the virus (Bayarri-Olmos et al., 2021) and evade vaccine-induced immunity (Hoffmann et al., 2021).

Mink-to-cat transmission

Mink-to-cat transmission was reported on infected mink farms (Van Aart et al., 2021), with evidence of SARS-CoV-2 infection in 12 feral cats and 2 dogs. It was not determined whether virus transmission to the dogs was from the mink or humans on these farms. However, as all the infected cats were feral, mink-to-cat transmission was suspected rather than human-to-cat transmission. Furthermore, sequence data generated from the cat samples clustered with mink sequences from the same farm, consistent with mink-to-cat transmission.

Experimental infections in animals

Cats, ferrets and Golden Syrian hamsters can be infected experimentally with SARS-CoV-2 (Shi et al., 2020; Chan et al., 2020; Richard et al., 2020). Shi et al. (2020) demonstrated that cats, ferrets, and (to a lesser extent) dogs were susceptible to infection, but not pigs, chickens or ducks. When 8-month-old domestic cats were infected intranasally with 10^5 PFU of SARS-CoV-2 isolated from a human patient, viral RNA was detected in the upper respiratory tract, small intestine and faeces; infectious virus was found only in the upper respiratory tract, but not from other tissues. When the same high dose of virus was used to infect 10-14-week-old kittens, viral RNA and infectious virus was detected in the upper respiratory tract, lung, small intestine and nasal washes, and histopathological changes were observed in the lungs, suggesting that SARS-CoV-2 replicates more efficiently in younger cats. One of three 10-14-week-old kittens died on day 3 after virus exposure. Three infected 10-14-week-old kittens and three infected 8-month-old domestic cats were housed individually in cages adjacent to uninfected cats. Subsequently, two animals that were in cages adjacent to experimentally infected cats became infected and developed antibodies; the exposed cats that became infected were one 10-14-week-old kitten and one 8-month-old domestic cat.

In another experimental study, three cats were inoculated with SARS-CoV-2 on day 0 and then cohoused, in pairs, with uninfected cats starting one day after inoculation (Halfmann et al., 2020). The inoculated cats shed infectious virus in nasal swabs from day 1 to 3, until day 6 and the in-contact cats started shedding virus from day 3 to day 5. No virus was detected in rectal swabs and none of the cats displayed clinical signs, although all cats developed antibodies, confirming infection.

Experimental studies demonstrated that cats develop a robust neutralising antibody response that prevented cats from being re-infected following a second viral challenge 28 days after the first exposure (Bosco-Lauth et al., 2020). Another study demonstrated that cats previously infected with SARS-CoV-2 could be experimentally re-infected 3 weeks after the first challenge. Prior infection induced partial immune protection against reinfection, and viral shedding was supressed to levels that were insufficient for transmission to co-housed naïve sentinel animals (Gaudreault et al., 2020). Further studies will be required to determine how readily SARS-CoV-2 is transmitted between cats under natural conditions.

Clinical signs associated with SARS-CoV-2 infection in cats

Experimental infections of cats with SARS-CoV-2 have generally shown that infected cats developed no or mild clinical signs (Gaudreault et al., 2020; Halfmann et al., 2020; Shi et al., 2020; Bosco-Lauth et al., 2020; Braun et al., 2021). However, both respiratory and gastrointestinal signs have been reported in naturally infected cats from COVID-19 households (Garigliany et al., 2020; Segalés et al., 2020; Curukoglu et al., 2021; Ferasin et al., 2021; Hosie et al., 2021; Keller et al., 2021; Klaus et al., 2021b; Neira et al., 2021; Zoccola et al., 2021; Barroso-Arévalo et al., 2022). A national surveillance study conducted in the US reported that 50% of cats (n=55) infected with SARS-CoV-2 displayed clinical sings, with sneezing and lethargy being the most common signs (Liew et al., 2023).

The Alpha SARS-CoV-2 variant was detected in rectal swabs collected from two cats and one dog in the UK with suspected myocarditis, although no causal link could be demonstrated (Ferasin et al., 2021). Similar clinical findings associated with SARS-CoV-2 infection were reported in two case studies. The first described a cat living in a COVID-19 household that was euthanised after developing progressive and severe respiratory disease (Carvallo et al., 2021). High viral loads (viral RNA and infectious virus) were detected in oropharyngeal and tracheal swabs, as well as in the lung and heart of the affected cat, and there was no evidence of chronic underlying disease. The second described a cat that displayed congestive heart failure (Chetboul et al., 2021). This cat had been in close contact with its owner, who was a contact of a co-worker who developed COVID-19; the co-worker tested positive for the Alpha variant. The cat, and a second cat in the same household that did not develop clinical signs, both tested negative by RT-qPCR on rectal, nasal, and oropharyngeal swabs collected one month after the clinical signs developed; however, both cats tested seropositive, indicating previous SARS-CoV-2 infection. The authors concluded that the cat that developed congestive heart failure and showed clinical, radiographic and echocardiographic evidence of myocarditis might have been more predisposed to develop cardiac disease compared to the other cat in the household. The cat was obese, with epicardial adipose tissue, and had closer contact with the infected owner compared to the other cat (Chetboul et al., 2021). Together, these reports suggest that cats with hypertrophic cardiomyopathy might be predisposed to develop more severe disease following infection with SARS-CoV-2.

Infection with different SARS-CoV-2 variants

SARS-CoV-2 VOCs with enhanced transmissibility emerged and led to subsequent waves of the COVID-19 pandemic and further national lockdowns, raising the possibility that cats as well as humans could also be at increased risk of infection from humans infected with new variants. The Alpha variant was first detected in the UK; the Beta variant emerged in South Africa, the Gamma variant in Brazil; the Delta variant in India and the Omicron was detected worldwide in November 2021 (WHO, 2023). Several SARS-CoV-2 VOCs have been reported in cats.

Cats infected with the Alpha variant have been reported in Cyprus (Curukoglu et al., 2021), Italy (Zoccola et al., 2021), Spain (Miro et al., 2021), Germany (Keller et al., 2021), the UK (Ferasin et al., 2021), Thailand (Jairak et al., 2021), the USA (Hamer et al., 2022), and Argentina (Pecora et al., 2022).

The Delta variant rapidly became dominant in the human population and experimental infections in specific pathogen free cats led to pulmonary inflammation and vasculitis, which was more severe than had been observed previously following infection with wild-type SARS-CoV-2 (Tamil Selvan et al., 2022). Naturally occurring Delta infections have been reported in cats in Spain (Barroso-Arévalo et al., 2022), the USA (Lenz et al., 2022), China (Kang et al., 2022) and Switzerland (Kuhlmeier et al., 2023) as well as in Asiatic lions (Mishra et al., 2021).

It is not known whether the VOCs that have arisen are more or less likely to be transmitted from humans to cats, or whether infected cats are more or less likely to develop clinical signs. However, a study conducted in experimental cats showed that cats inoculated intranasally with either the ancestral or the Delta variant became lethargic and pyrexic, whereas Omicron-inoculated cats did not develop any clinical signs and continued to gain weight during the 14-day follow-up. The Omicron-infected cats also showed markedly lower level of viruses shedding compared to the other two groups, suggesting that the Omicron variant might be less pathogenic in cats as well as humans (Martins et al., 2022).

Serological evidence of SARS-CoV-2 infection of cats

As the experimental studies described above demonstrated that virus is shed from infected cats for only a short period, the incidence of domestic cat infections has been estimated using serological tests, which demonstrate past exposure as well as recent infections. Serological assays have been developed to measure antibodies against S1, the receptor binding domain (RBD) or the nucleocapsid protein (N) by ELISA, as well as virus neutralising antibodies using either live virus or pseudotype-based assays. Samples of serum or plasma are generally screened first by ELISA and positive results are usually confirmed using neutralisation assays.

It was demonstrated that the N protein of SARS-CoV-2 is not suitable for screening cat and dog samples, most likely because of antigenic cross-reactivity between SARS-CoV-2 and FCoV type I N proteins (Zhao et al., 2021). In this study, 500 serum samples, collected from cats and dogs in the Netherlands during April-May 2020, were tested using ELISAs to detect antibodies against S1 and the RBD and positive samples were confirmed by live virus neutralisation assays. Only 0.4% of cats and 0.2% of dogs tested seropositive. The health status and SARS-CoV-2 exposure of these animals was not known and higher estimates of seroprevalence were reported in other studies. For example, a study of 919 companion animals in Northern Italy that were sampled at a time of frequent human infection reported that 3.3% of dogs and 5.8% of cats displayed titres of neutralising antibodies (Patterson et al., 2020). Similarly, a study conducted in Germany tested samples submitted to a diagnostic laboratory for reasons unrelated to SARS-CoV-2 infection from cats in Germany, the UK, Italy, and Spain. The overall SARS-CoV-2 seroprevalence was 4.2% in Germany, 3.3% in the UK, 4.2% in Italy, and 6.4% in Spain (Schulz et al., 2021).

A high SARS-CoV-2 seroprevalence of 7.3% was observed in domestic cats in Brazil during the first year of the pandemic (de Oliveira-Filho et al., 2022). This study also examined the FCoV serostatus and found no evidence of any correlation between pre-existing immunity against FCoV and SARS-CoV-2 infection in cats.

However, a study that tested samples collected in Germany between January and July 2020 reported a lower overall prevalence of 1.9% positive and 0.8% inconclusive results using an ELISA to measure antibodies recognising the RBD. As in previously published investigations, this study demonstrated a correlation between case numbers in humans and antibody prevalence in domestic cats (Adler et al., 2022). A subsequent German study of 920 serum samples collected from domestic cats between April and September 2020 for haematological testing demonstrated that only 0.69% (6/920) samples contained antibodies against SARS-CoV-2; two of the positive sera contained neutralising antibodies (Michelitsch et al., 2020), suggesting that human-to-cat transmission might be relatively infrequent. Furthermore, a study conducted in a veterinary community of 20 students, two of whom tested positive for COVID-19 and eleven of the remaining 18 displayed symptoms of COVID-19, demonstrated that none of the nine cats and none of the twelve dogs living in the community tested positive by RT-PCR and none of the cats or dogs developed antibodies (Temmam et al., 2020), which confirms that human-to-domestic animal transmission is variable and suggests that transmission is likely minimised where good hygiene is practised.

A survey of cats and dogs from confirmed COVID-19 households in France reported a high seroprevalence of SARS-CoV-2 antibodies, ranging from 21-53%, depending on the criteria used to define a positive result (Fritz et al., 2021). In a longitudinal study of 76 cats and dogs living in 39 COVID-19 households in Texas, US, eight of 17 cats and nine of 59 dogs tested positive for SARS-CoV-2 RNA or neutralising antibodies (Hamer et al., 2021). A study conducted in the Netherlands detected SARS-CoV-2 infections in 31 of 152 (20.4%) cats tested from COVID-19 households (Kannekens-Jager et al., 2022).

More recently, a serological study conducted in the UK tested samples submitted to a diagnostic laboratory using a pseudotype-based virus neutralisation assay. Results demonstrated an average seroprevalence of 3.2%, with a peak seroprevalence of 5.3% in autumn 2021 following the Delta wave. Variant-specific neutralising antibody responses were detected, which correlated with and trailed the variants circulating in the human population, indicating multiple ongoing human-to-cat transmissions (Tyson et al., 2022).

Stability of coronaviruses

Coronaviruses are enveloped viruses and once the envelope is damaged or destroyed, the virus is no longer infectious, which is why handwashing for at least 20 seconds (the WHO recommends washing for at least 40 seconds (WHO: Save lives)) with soap and water can prevent transmission of SARS-CoV-2. However, CoVs appear to be more stable in dry conditions compared to many other enveloped viruses, remaining infectious for longer periods of time on surfaces. In addition, extraneous proteins in blood or faeces can protect viruses from inactivation, prolonging viral infectivity (Scott, 1988). A study comparing the stability of SARS-CoV and SARS-CoV-2 in aerosols and on surfaces found virtually identical results (van Doremalen et al., 2020), with both viruses remaining infectious on dry surfaces for up to 72 hours. The nature of the surfaces, however, is crucial, and SARS-CoV-2 remains infectious for longer on plastic and stainless-steel compared to cardboard or copper surfaces (24-72 hours versus 8-24 hours, respectively (van Doremalen et al., 2020)). SARS-CoV and SARS-CoV-2 remained viable and infectious in aerosols for hours and on different surfaces for days; these results indicate that aerosol as well as fomite transmission of these viruses can be expected (van Doremalen et al., 2020). Data suggest that SARS-CoV-2 transmission between cats can be sustained (Ro>1); however, the infectivity of a contaminated environment decays rapidly (Gerhards et al., 2022).

As with all other known enveloped viruses, CoV are highly susceptible to common chemical disinfectants and are readily inactivated by alcohols, household bleach, benzalkonium, aldehydes, and others (Rabenau et al., 2005; Kampf et al., 2020). Differences have been observed between cat litters concerning reduction of the alpha-coronavirus FCoV load, which might apply to inactivation of SARS-CoV-2. One study revealed that some cat litters, particularly those based on bentonite, can bind and might inactivate FCoV shed in faeces and could help to reduce the FCoV load within infected households (Addie et al., 2020).

It was suggested that cats might act as fomites for a short period when living in households with COVID-19 owners since it was shown that SARS-CoV-2 survived on mink fur for at least 10 days (Virtanen et al., 2021). Cutaneous and interdigital swabs collected from 48 dogs and 15 cats owned by COVID-19 patients were tested for SARS-CoV-2 by RT-qPCR. The time elapsed between owner swab positivity and sample collection from pets ranged from 1 to 72 days, with a median time of 23 days for dogs and 39 days for cats. All samples tested negative, suggesting that SARS-CoV-2 is not carried passively on pet hair and pads, and thus fomites likely do not play an important role in the virus transmission to humans (Lauzi et al., 2021). Cats should never be disinfected under any circumstances, as toxicity and burns can result from the inappropriate use of disinfectants, which could be ingested by cats during self-grooming.

Diagnosis

At present, it is recommended that cats should be tested for SARS-CoV-2 infection only following consultation with the appropriate public health authority, since recommendations vary between countries. In general, testing should only be considered in cats with signs of respiratory disease that have tested negative for more common respiratory infections and that have been exposed to people with known or suspected COVID-19. Testing is available in several European countries, using RT-PCR to detect viral RNA in swabs and ELISA tests to detect antibodies in serum or plasma as well as virus neutralising antibody tests. Virus isolation from swabs is restricted to specialist laboratories with containment level 3 facilities, as the isolation of SARS-CoV-2 poses a risk to laboratory staff. When collecting samples from a cat with suspected SARS-CoV-2 infection, personal protective equipment (PPE) including gloves, mask, gown and eye protection should be worn.

Risk Factors

Data from several studies indicate that cats in COVID-19 households are likely to become infected with SARS-CoV-2 (Goryoka et al., 2021; Bienzle et al., 2022; Kannekens-Jager et al., 2022; Liew et al., 2023) and a similar trend was observed in a study conducted in France, although the results were not statistically significant (Bessière et al., 2022). Risk factors for SARS-CoV-2 infection of cats in COVID-19 households include frequent daily contact (Goryoka et al., 2021), higher numbers of household members with COVID-19 (Kannekens-Jager et al., 2022), cats sleeping in their owners' beds (Bienzle et al., 2022) and cats that have developed new clinical signs (Bienzle et al., 2022).

Conclusion

Given the susceptibility of animals to SARS-CoV-2 infection and the rapid adaptation reported following *in vivo* passage in cats, dogs and hamsters (Bashor et al., 2021), there is potential for reverse zoonosis to accelerate variant emergence for SARS-CoV-2 and other viruses. Therefore, it will be important to monitor SARS-CoV-2 evolution in animals in close contact with humans, to detect new variants or recombinants that could show increased transmissibility or evade vaccine immunity (Prévost and Finzi, 2021). However, when a qualitative risk assessment focusing on the potential of cat-to-human transmission of SARS-CoV-2 was conducted (Allendorf et al., 2022), based on a consensus of expert opinion, it was concluded that the risk of infection of a person in a household associated with keeping a domestic cat is very low to negligible, depending on the intensity of cat-to-human interactions. Furthermore, stray cats with no or minimal contact with humans are at negligible risk of SARS-CoV-2 infection (van der Leij et al., 2021; Kuhlmeier et al., 2022) and therefore stray cats present no or negligible risk to public health.

In light of numerous reports of SARS-CoV-2 infections in cats living in households with SARS-CoV-2 infected people, and non-domestic cats presumed to have become infected from their zookeepers, ABCD recommends that close contact with cats should be avoided in households where people are infected with SARS-CoV-2 or have symptoms of COVID-19. If an owner who is ill with COVID-19 must continue to have close contact while caring for their pet, they should maintain basic hygiene measures. Such measures include handling animals only when wearing a mask, washing their hands with soap and water for at least 20 seconds before and after being near or handling their animals, their food, or their supplies, as well as avoiding kissing their pets or sharing food, towels or the bed with them.

Indoor-only cats, particularly those that sleep in their owners' beds, are more likely to be infected from their owners compared to free-roaming cats or cats that have access to outdoors. Therefore, ABCD recommends that cats from COVID-19 household that usually have outdoor access should continue to be allowed outside, even if their owners are self-isolating. This will avoid causing stress to both the owner(s) and their cat(s) and will decrease the likelihood of human-to-cat transmission. Even if a cat from a COVID-19 household becomes infected, there is a negligible risk of transmission to other cats or to humans outside the household as close contact is required for transmission.

A One Health approach should be fostered, with Public Health and Veterinary Services sharing information and investigating situations where a person who is infected with SARS-CoV-2 reports being in contact with companion or other animals. ABCD emphasises that transmission of SARS-CoV-2 from cats to humans is rare, although (for ethical reasons and limitations on study design) it is difficult to obtain direct evidence of cat-to-human transmission (Totton et al., 2020). Nevertheless, there is strong evidence that a veterinarian was infected with SARS-CoV-2 after the infected cat she was treating (the cat had a high viral load following recent exposure to its infected owners) sneezed in her face; she was wearing PPE that did not include eye protection (Sila et al., 2022). This report highlights the importance of wearing eye protection as well as gloves, a mask and a gown when veterinarians are examining or treating cats that might be infected with SARS-CoV-2.

An experimental SARS-CoV-2 spike protein-based veterinary vaccine has been developed that induced a robust immune response to the SARS-CoV-2 spike protein in experimental cats following two doses of vaccine three weeks apart, with neutralising antibodies against the SARS-CoV-2 Wuhan strain and variant B.1.617.2 at similar levels (Hoyte et al., 2022). A veterinary SARS-CoV-2 vaccine has been distributed to zoos in the US for emergency use to vaccinate endangered large felids (ProMED, 2021b) and, in future, its use could be extended to companion animals. At present, however, there is insufficient evidence of a need for SARS-CoV-2 vaccination of companion animals for ABCD to recommend SARS-CoV-2 vaccination of pets.

This guideline will continue to be updated regularly as new data become available.

Pet owners should always maintain good hygiene practices and under no circumstances should cats be abandoned.

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