



Companion animals likely do not spread COVID-19 but may get infected themselves

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Abstract Coronavirus disease 2019 (COVID-19) is a highly contagious infectious disease caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). From the epidemiological data, the picture emerges that the more severe etiopathologies among COVID-19 patients are found in elderly people. The risk of death due to COVID-19 increases exponentially with age. Eight out of 10 COVID-19 related deaths occur in people older than 65 years of age. Older patients with comorbid conditions such as hypertension, heart failure, diabetes mellitus, asthma, chronic obstructive pulmonary disease, and cancer have a much higher case fatality rate. Governments and public health authorities all over the world have realized that protections

of vulnerable older adults should be a priority during the COVID-19 pandemic. COVID-19 is a zoonotic disease. The SARS-CoV-2 virus was originally transmitted likely from a bat or a pangolin to humans. Recent evidence suggests that SARS-CoV-2, similar to other coronaviruses, can infect several species of animals, including companion animals such as dogs, cats, and ferrets although their viral loads remain low. While the main source of infection transmission therefore is human to human, there are a few rare cases of pets contracting the infection from a SARS-CoV-2-infected human. Although there is no evidence that pets actively transmit SARS-CoV-2 via animal-to-human transmission, senior pet ownership potentially may pose a small

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risk to older adults by (1) potentially enabling animal-to-human transmission of SARS-CoV-2 in the most vulnerable population and (2) by increasing the exposition risk for the elderly due to the necessity to care for the pet and, in the case of dogs, to take them outside the house several times per day. In this overview, the available evidence on SARS-CoV-2 infection in pets is considered and the potential for spread of COVID-19 from companion animals to older individuals and the importance of prevention are discussed.

Keywords SARS-CoV-2 · Senescence · Aging

Introduction

Coronavirus disease 2019 (COVID-19) is a highly contagious infectious disease caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1, 2]. As of June 4, during the 2019/2020 global pandemic, approximately 6.6 million people have contracted the virus globally resulting in over 390,000 deaths [3]. From the beginning of the outbreak of the pandemic, the Centers for Disease Control and Prevention (CDC) have stated that SARS-CoV-2 is a respiratory virus, and, as such, its main route of transmission is via respiratory droplets when an infected individual coughs, sneezes, or just talks in close proximity of others [1]. Furthermore, the virus may be also spread via contaminated surfaces, when a person touches a contaminated object (e.g., doorknob), then touches their nose, mouth, or eyes [4–6]. The mean incubation period of the disease is 5.1 days with 97.5% of patients producing symptoms by day 11.5 [7]. The most common symptoms include fever, cough, fatigue, and shortness of breath. Most common cause of death is respiratory failure [8, 9]. There is also increasing evidence suggesting that COVID-19 may cause fatal myocardial injury, arrhythmia/cardiac arrest, neurological damage (including stroke), and kidney failure (acute kidney injury occurs in one third of patients) [8]. Currently reported case fatality rates vary from 1% to more than 10%, due to country-to-country differences in screening in the whole population.

Increased COVID-19 mortality in older adults

From the epidemiological data, the picture emerges that severe COVID-19 is primarily a disease of older people [10]. The risk of death due to COVID-19 increases exponentially with age in every country studied [10]. A report of 72,314 cases from the Chinese Center for Disease Control and Prevention [11] shows that case fatality rates by age are as follows: 0.18% (10–19 years of age); 0.32% (20 to 49 years of age); 1.3% (50 to 59 years of age); 3.6% (60 to 69 years of age); 8% (70–79 years of age); 14.8% (≥ 80 years of age). A report of 73,780 cases produced by the Istituto Superiore di Sanità (ISS) showed that the case fatality rates for males by age in Italy are as follows: 0% (10–19 years of age); 0% (20 to 29 years of age); 0.6% (30 to 39 years of age); 1.1% (40 to 49 years of age); 2.4% (50 to 59 years of age); 6.9% (60 to 69 years of age); 19.8% (70–79 years of age); 29.2% (80 to 89 years of age); 30.8% (≥ 90 years of age) [12]. Older patients with comorbid conditions such as hypertension, heart failure, diabetes mellitus, asthma, chronic obstructive pulmonary disease, cancer, and chemotherapeutic treatment have a much higher case fatality rate. Critical cases have a case fatality rate of 49%, whereas mortality is very low in patients with mild symptoms. In the USA, deaths involving COVID-19 by age group are as follows: 1% (≤ 34 year of age), 2% (35–44 years of age), 5% (45–54 years of age), 13% (55–64 years of age), 22% (65–74 years of age), 28% (75–84 years of age), 30% (≥ 85 years of age) [13]. In total, 79% of all COVID-19 related deaths occurred in people older than 65 years of age. The causes of these age-related differences in mortality rates are not yet fully understood. Possible causes likely include the less efficient functioning and coordination of both cellular and molecular elements of the immune system, the higher number of comorbidities, and the overall frailty and impaired organismal and cellular resilience of elderly patients [2, 11, 14]. Governments and public health authorities all over the world have realized that protections of vulnerable older adults should be a priority during the COVID-19 pandemic. The most effective step to prevent further SARS-CoV-2 infections in older adults is to limit exposure by reducing social activity, avoiding gatherings with many people and public transportation. Accordingly, governments and public health authorities ordered nursing homes and assisted living facilities to limit visits, even by family members. Formal and informal group social and recreational activities and

church services were canceled. Although these steps are effective, additional measures are needed to limit spread of COVID-19. Staying at home all day however is impossible if seniors actually possess a dog as the animal will have to be taken out regularly. Yet, pet owners usually take their dogs out alone and social distancing may be well doable.

Potential role for zoonotic spread of COVID-19 in older adults?

As coronaviruses generally are zoonotic (i.e., they are transmitted between animals and people), COVID-19 as well is a zoonotic disease just like SARS. Whether the novel coronavirus causing COVID-19 came from a bat or a pangolin is still uncertain. The initial event where the virus may have jumped to humans seem to have happened in a so-called “wet” market [15, 16], where fresh meat as well as living wild animals are commonly sold. Because of the observed accumulation of infected people by January 2020 who were in some relation to the “Hua Nan” market in Wuhan, this town of 11-million inhabitants located at the Yangtze river in central China is commonly considered the “ground zero” for the global pandemic [16, 17]. It should be noted that our understanding of the origin of the pandemic may evolve. A recent phyloepidemiologic analysis of sequenced genomic data of close to 100 SARS-CoV-2 samples by Chinese researchers (published in a non-peer reviewed pre-print form [18]) suggested that while the crowded market may have boosted spread of the novel virus to the whole city, it may have not originated there. The possibility that the virus may have been introduced from elsewhere clearly warrants more research in the upcoming months.

Genetic sequence data reveals that the SARS-CoV-2 virus is closely related to coronaviruses found in *Rhinolophus* bat (horseshoe bat) populations [19]. Although bats may be the primary reservoir, the original route of transmission to humans is currently unknown and may have involved an intermediate host, probably a pangolin [20]. SARS-CoV-2, similar to other coronaviruses, can infect several species of animals. Initial data suggested that the SARS-CoV-2 virus can bind to receptors and infect cells of horseshoe bats and civets, whereas mice are not susceptible. In vivo studies suggest that several species, including cats, can be

infected with SARS-CoV-2 virus, whereas chickens, pigs, and ducks are not susceptible [21].

It is estimated that there are currently 135 to 184 million pet dogs and cats in the USA (according to the US Pet Ownership & Demographics Sourcebook by the American Veterinary Medical Association (AVMA) and the biennial APPA National Pet Owners Survey by the American Pet Products Association, respectively). Accordingly, 38–48% of US households own at least one dog or cat. Studies, including the National Poll on Healthy Aging (https://deepblue.lib.umich.edu/bitstream/handle/2027.42/148428/NPHA_Pets-Report_FINAL-040319.pdf?sequence=3&isAllowed=y), demonstrate the multifaceted health benefits of senior pet ownership (including increased physical activity such as walking, higher emotional well-being, and significant stress reduction). Despite these advantages, pet ownership potentially may pose a minor risk to older adults by enabling animal-to-human transmission of SARS-CoV-2 in the most vulnerable population. Here, we summarize the available evidence about SARS-CoV-2 infection in pets.

In late March 2020, the Federal Agency for the Safety of the Food Chain (FASFC) in Belgium reported that a pet cat was diagnosed to be infected with SARS-CoV-2 [21, 22], showing that felines living in the household of people with COVID-19 are at risk of contracting the disease and may potentially spread the virus. The cat became ill 1 week after its owner’s return home from Italy [22]. Susceptibility of cats to SARS-CoV-2 infection is supported by a recent experimental observation [15]. Specifically, it was demonstrated that cats exposed to SARS-CoV-2 under laboratory conditions can be infected and are able to transmit the disease to other felines. On April 23, it was reported that two pet cats in New York state have tested positive for the SARS-CoV-2, which are the first confirmed COVID-19 cases in companion animals in the USA [22]. One of these two cats became sick approximately a week after a person in its household developed respiratory symptoms. The other cat’s owner tested positive for SARS-CoV-2 before the cat fell ill. Both cats developed symptoms of upper respiratory disease, including coughing and nasal discharge. In June 2020, a French study reported that screening of 22 cats and 11 dogs from owners previously infected or suspected of being infected by SARS-CoV-2 identified a per cat infected by SARS-CoV-2 [23]. For each animal, rectal, nasopharyngeal swabs, and serum were taken. The infected cat, which exhibited

mild respiratory and digestive symptoms, tested positive by RT-qPCR on the rectal swab, whereas the nasopharyngeal swab was tested negative. Serological analysis confirmed the presence of antibodies against SARS-CoV-2. Additionally, on April 5, 2020, it was reported that a 4-year-old Malayan tiger at the Bronx Zoo in New York City was tested positive for the SARS-CoV-2 virus [24, 25]. In addition, six other big cats (another Malayan tiger, two Amur tigers, and three African lions) were reported to exhibit symptoms, including dry coughs, which are indicative of SARS-CoV-2 infection. Only one tiger was tested for the virus, as collection of the samples in big cats requires anesthesia [25]. It was reported that the felines likely have contracted the virus from a caretaker, who was asymptomatic at the time of contact with the animals [25]. These data support the view that different species of felines are susceptible for SARS-CoV-2 infection.

There are also emerging data that dogs may be also infected by the COVID-19 virus [26, 27]. In February 2020 in Hong Kong, a companion dog was discovered to be positive for SARS-CoV-2 by PCR testing [24]. This animal is thought to have contracted the SARS-CoV-2 from its owner who was diagnosed with COVID-19 [24]. Serological testing on blood samples derived from the dog was performed by a WHO reference laboratory and yielded a positive result [24]. As of March 25, Hong Kong's Agriculture, Fisheries, and Conservation Department had tested 17 dogs and 8 cats, which lived in households with confirmed COVID-19 human cases and, so far, 2 dogs (including the one described above) had tested positive for SARS-CoV-2. Neither of the dogs showed any sign of respiratory disease. One of them, a 17-year-old Pomeranian dog died shortly after the diagnosis was made [24]. It should be noted, that in human COVID-19 disease, the cause of death often is cardiac arrest. The emerging view is that cardiac damage is present in every fifth COVID-19 patients, leading to heart failure and death even among those who do not exhibit respiratory distress syndrome. In addition to hypoxic damage, the heart muscle likely can be infected by the SARS-CoV-2 virus. SARS-CoV-2 utilizes angiotensin converting enzyme-2 (ACE-2) as a cellular entry receptor and cardiac myocytes as well as coronary arterial endothelial cells express ACE-2 abundantly. Of note, heart failure is a leading cause of death among older Pomeranian dogs [28]. Genetically impaired cardiac resilience in this breed may represent increased risk for death associated with COVID-19.

We propose that veterinarians should be aware of SARS-CoV-2-induced cardiac pathologies in dogs and look more closely for cardiac symptoms of SARS-CoV-2 infection in patients, even in the absence of respiratory symptoms. To definitely identify SARS-CoV-2 as cause of heart failure in dogs from households affected by COVID-19, elaborate pathological testing should be performed postmortem in the dogs, most likely without the owners having an interest to cover the costs for these tests.

Besides cats and dogs, ferrets are also common pet animals in several countries. Notably, laboratory animals of the *Mustelidae* family are frequently used models for respiratory diseases [29], including SARS coronavirus. In addition, recent experimental studies verified the possibility of airborne transmission of SARS-CoV-2 between ferrets (published in a non-peer review, pre-print form [30]). Another study reported strong evidence for the possibility of virus transmission from and between these animals. Viral shedding in detectable amount was observed in nasal washes, saliva, urine, and feces of the animals and all of them presented acute bronchitis [31]. Minks are close relative of ferrets and are kept for their fur on large mink farms. It has been recently reported that in the Netherlands, thousands of minks have been gassed on mink farms to prevent infected mink from becoming a viral reservoir that could cause new outbreaks in humans [32]. It is suspected that rapid spread of the infection occurred via infectious droplets, on feed or bedding, or in dust containing fecal matter [32]. Infection in minks looks like COVID-19 in humans, from asymptomatic infection to severe pneumonia [32]. Mortality was reported to be negligible at one farm and close to 10% at another [32]. Alarmingly, feral cats roaming the Dutch mink farms and stealing the mink's food were also found to be infected as well [32]. Minipigs have also become popular pets in recent years [33]. Although recent studies revealed relatively low expression levels of Angiotensin Converting Enzyme2 (ACE2) protein (the docking protein for the viral spike protein) in the swine respiratory tract [34], the susceptibility of pigs to SARS-CoV-2 transmitted from other pets or humans is still controversial [15, 35]. Concluding, there is a small but existing possibility for an animal-human transmission although the main source of infection transmission remains human-human [15].

In theory, a zoonotic disease such as COVID-19 could be directly transmitted from companion animals to humans through media such as air or through saliva

and bites. Contact with pet dogs and cats, including petting, snuggling, being kissed or licked, sleeping in the same location, and sharing food with companion animals is clearly increased during times when the owner is staying at home sick with COVID-19, quarantined, or due to governmentally decreed lockdown measures. This common behavior, which, from a medical point of view, may be unfortunate for both the owner's and the pet's health, as it is creating ample opportunities for transmission of the virus in either direction. Additionally, as the virus seems to be present in the saliva of infected animals, which lick their paws and fur, every surface in contact with the animal in an affected household should be considered potentially contaminated with SARS-CoV-2 [36]. It is likely, in the case of the very few positively tested companion animals, that the pets contracted the virus from their owners in an infected household (and not vice versa). Actually, there is no evidence for a single case of pet to human transmission to date.

Cats very often stay within the house of their owners so their risk for contracting the infectious virus from outside is much lower than in dogs, which are taken out multiple times per day while coming into contact with other dogs and humans, sniffing on and touching the ground in parks, open space, or even public transport where previously another human or animal might have infected the area with SARS-CoV-2. Nothing is known yet about the zoonotic potential of SARS-CoV-2 in seniors or elderly patients who own companion animals. In none of the positively tested cats and dogs was a reference made to the age of the owners or the age of the human commonly caring for the pet.

Prior to the news of the Bronx Zoo big cat cases, there have not been any reports of pets or other animals in the USA contracting COVID-19, according to the websites of the US Department of Agriculture and the Centers for Disease Control and Prevention (CDC) [25, 36]. Since the discovery of the cats infected with SARS-CoV-2 in New York, the website of the American Veterinary Association carefully documents each new case [22]. The guidelines of the CDC currently indicate that there is no evidence available that companion animals, including pets, can spread COVID-19 [36]. Yet, it has to be emphasized that animals have not been routinely tested in the USA and according to the website of the CDC and the American Veterinary Medical Association (AVMA) [37] as of April 23, routine testing of animals is not recommended by the AVMA, CDC, US

Department of Agriculture (USDA), American Association of Veterinary Laboratory Diagnosticians (AAVLD), National Association of State Public Health Veterinarians (NASPHV), or the National Assembly of State Animal Health Officials [37]. The CDC currently advises that public and animal health officials may decide to test animals that are showing signs of COVID-19 and that are known to have been exposed to the virus [38]. Veterinarians considering a possible COVID-19 infection in the presented patients and performing a test may thus contribute very usefully to the understanding of the zoonotic potential of SARS-CoV-2.

It is now clear that many people infected with SARS-CoV-2 remain asymptomatic while spreading the disease. If the same holds true also for animals, it cannot be ruled out that asymptomatic household pets and domesticated animals also can shed the virus and infect people without exhibiting actual symptoms of the disease. However, according to Shi and coworkers, their viral loads are much lower compared with humans [15]. The reported Hong Kong case of a SARS-CoV-2 infected dog also did not have any clinical signs of the disease. Furthermore, the SARS coronavirus (SARS-CoV; which is also an animal virus identified in 2003 that causes a zoonotic disease in humans) infects mice, macaques, and marmosets, but does not cause a respiratory disease in them similar to the one it causes in people. Middle East respiratory syndrome (MERS) similarly is a respiratory illness caused by the coronavirus MERS-CoV first reported in Saudi Arabia in 2012. MERS-CoV can infect primates and hoofed animals, including camels and alpacas. Importantly, infected alpacas appear to be asymptomatic, yet they spread the virus. Of note is that several coronavirus-mediated diseases exist both in companion animals (including canine respiratory coronavirus, enteric coronaviruses, feline infectious peritonitis) and in livestock (infectious bronchitis virus, alpha coronaviruses causing mild gastrointestinal or respiratory disease, swine enteric coronaviruses, bovine coronaviruses), although most are species-specific and do not affect humans. In the current SARS-CoV-2 pandemic, the situation is rapidly evolving and in the light of the recent evidence, we should be aware of the possibility that humans can be potentially infected with COVID-19 by animals, including by pet cats, dogs, or other domesticated species.

The CDC recently issued an interim guidance for public health professionals managing the home care

and isolation of people with COVID-19 who have pets or other animals (including service or working animals) in the same home [36]. According to these CDC guidelines, state public health veterinarians should be contacted by public health professionals, animal health professionals, or veterinarians that have discovered a household animal with a new, concerning illness and that reside with a person with COVID-19 [36]. Due to concerns of potential human-to-animal transmission of SARS-CoV-2, the CDC recommends that people with COVID-19 and in-home isolation should limit their interaction with household animals, but rather increase hygiene measures and hand washing after close contact with the pet [36]. It is recommended that while a person infected with COVID-19 is symptomatic, they should maintain separation from household animals as they would with other household members, practicing social distancing [36].

Dogs are frequently used in veterinary and cardiovascular research as large animal models of heart failure and other chronic diseases [39]. Many researchers who are working with dogs on a daily basis in universities and the pharmaceutical industry belong to vulnerable age groups. In the laboratory setting, there is an increased probability for contact with bodily fluids of potential virus carrier animals, especially during procedures that involve invasive surgery [40]. Research teams should get adequate safety training to prevent transmission of SARS-CoV-2 and closely follow laboratory guidelines for handling biological specimens, waste, and hazardous materials.

Perspectives

Pet health companies are working on developing laboratory tests for companion animals that may be affected by SARS-CoV-2. As the pandemic is progressing and testing of companion animals by veterinarians will be more often performed, our understanding of SARS-CoV-2 and its animal-to-animal and animal-to-human transmission will rapidly evolve. As of April 17, two commercial laboratories in the USA reported they had tested using RT-PCR thousands of specimens from dogs and cats for SARS-CoV-2 and had obtained no positive results [22]. These specimens were submitted from the USA, South Korea, Canada, and Europe for PCR analysis of common pathogens causing respiratory illness in dogs and cats [22]. There is no or only limited

information available as to whether these animals had close contact with human COVID-19 patients before the testing. The World Organization for Animal Health (OIE) considers SARS-CoV-2 an emerging disease, and therefore the US Department of Agriculture regularly reports confirmed US animal infections to the OIE. For up-to-date information, we advise the reader to consult the online reference sources provided at the end of this paper, including the websites of the AVMA [22], CDC [36], USDA [41], and OIE [42].

Further and broader veterinary studies are needed to determine which other companion animal species and pets can be infected by SARS-CoV-2 and elucidate, whether they demonstrate the clinical signs (e.g., upper respiratory infection, lung injury), and whether they develop an immune response. It is crucial to determine where the virus is shed in each species, whether it's in urine, tears, saliva, blood, or feces. It will be also essential to identify the species potentially serving as a reservoir for the virus. Future research opportunities include widescale serosurveys of pet animals in contact with confirmed COVID-19 patients. It may reveal the extension of this transmission route between various pet animals and humans.

Taken together, animal-to-human transmission is likely only a minor route of transmission for SARS-CoV-2. Available research suggests that companion animals may theoretically play a role by either establishing a reservoir for SARS-CoV-2, or even potentially being able to spread COVID-19 to other people in the household or people being in close contact with the animals. People should thus be advised to always follow standard handwashing practices before and after interacting with their pets.

In view of the large number of fatalities in the older generation, seniors should be advised to adopt an even improved hygiene practice with their pets similar to the “social distancing” recommendations between humans. As per CDC recommendations, elderly people in particular are instructed not to let their pets interact with other people or other pets from outside the household. Domestic cats should be kept indoors to prevent them from interacting with other animals or people. Dogs should be walked on a leash, maintaining at least 2 m from other people and animals. Dog parks or public places as well as public

transport, where a large number of people and dogs usually gather, should be avoided.

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