SCIENCE-BASED FACTS & KNOWLEDGE ABOUT WILD ANIMALS, ZOOS AND SARS-COV-2 VIRUS

This Q&A was produced by the EAZWV Infectious Diseases Working Group

Preliminary note: the scientific content of this factsheet was collected from reliable sources such as OIE, European National references laboratories, WHO, and pre-CoVid-19 scientific literature about coronavirus.

A massive amount of new science is available daily [2297 and counting at this date] but be aware to check the source [e.g. pre-print server vs. peer-reviewed].

Here you can find a good resource for daily publications: Lit Cov (see online references)

Moreover, the real information we need about the susceptibility and possible involvement of various animals is not yet available and won’t be for months or years.

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Context

The CoVid-19 is a viral infectious disease (last “d”=disease) transmitted between humans, first described in Wuhan China on the 31st of December 2019. Up to now, the virus spread globally with more than 950,000 human cases in 180 countries at the date of writing this text. The virus name is SARS-COV-2, and belongs to Coronavirus family. This name was given because of real genetic proximity of this virus with the SARS virus of 2002-2003 outbreak. On the 11th of March 2020, the WHO officially declared it as pandemic.

Questions / Answers

These are selected questions that either visitors or directors or stakeholders may ask regarding CoVid-19 risk assessment related to zoo animals.

Coronaviruses in general

Are coronavirus usual in wild species / Zoo animals?

- Yes, coronaviruses are very common in Mammals and Birds. They are not always associated to disease and there are a lot of non-symptomatic carriers often occur in many domestic and wild species.
- This RNA virus family is comprised between 4 main groups: (2)
  - Alphacoronavirus : mainly found in bats , but this group also contains
    - The Feline Coronavirus FeCov with its two forms (FeCV and FIP) (16)

CoVid19/SARS-COV-2 FAQ v4 – last updated 2nd April 2020
Authors: Alexis Lecu, Mads Bertelsen and Chris Walzer
The canine coronavirus
- Human viruses like HCoV 229-E, often a component of the common cold
  - Betacoronavirus: most represented in mammals, from carnivores to hoofstock (11) (15), from hedgehogs to bats. It also contains the 3 more recent emerging coronaviral diseases:
    - MERS CoV
    - SARS CoV
    - SARS Cov
    - Additionally: HCoV-OC43, one of the more prevalent infectious agents of the common cold in humans
  - Gammacoronavirus: viruses from cetaceans (beluga, dolphins), and a dozen of purely avian viruses
  - Deltacoronavirus: (35) mostly avian species specific coronaviruses, and some porcine one., recently recovered from leopard cats
- Chiropterans are well known to be host of many viruses, including various coronavirus at the same time (30). These include also some very specific coronaviruses that are specific to one species or only one genus of bats.
- After their first year of life, more than 80% of domestic species including dogs, cats, cattle, and pigs, are seropositive for at least one coronavirus, without expressing clinical signs.

What kind of disease does coronavirus provoke?
- Coronaviruses are able to infect several categories of somatic cells, but they often invade epithelial cells, especially those of the digestive mucosa and/or respiratory tract. Because of this tropism, the resulting diseases mainly fall into two groups:
  - Diarrhea and intestinal disorders (example seen in bovine calves, sometimes in association with rotavirus)
  - Respiratory syndromes, either from upper tract (like common cold) or deeper like bronchopneumonia.
- SARS-CoV-2 seems to have a neuroinvasive potential as well, e.g., leading to the signs of anosmia and dysgeusia in humans.

Could the coronaviruses be transmitted from Animal to Human?
- Generally, coronaviruses are rather species-adapted, and transmission from one species to another is rare. Only a few described species of coronaviruses have shown a broad host species range:
  - SARS-CoV (Human, civet cats, racoon dogs, horseshoe bat, swine)
  - MERS-CoV (Human, bats, hedgehogs, camels)
  - Bov-CoV (Cattle, wild ruminants, camelids, dogs, occasionally humans) (1)
- Transmission does not necessarily mean disease. Most of the time, when transmission to another species occurs, there’s only subclinical disease in the new hosts (unlike CoVid-19 in humans)
- Viruses in general lack the regulation mechanisms avoiding / fixing copy errors of the genome in animal cells. Hence, mutation rates are of larger magnitude which explains why they can adapt to new host with (relatively little) time. However, it has recently been shown that some coronaviruses are capable of some replication regulation under certain environmental circumstances, which make them more complex adaptors.
- Coronavirus mutation rates are is not greater than in most other viral families. However,
  - RNA viruses are more susceptible to mutation than DNA viruses.
  - Coronavirus RNA is longer than that of other RNA viruses, increasing the likelihood of copy incidents compared to viruses with shorter nucleic acids.
- Recombination ability is also an important feature of coronaviruses, well studied under the SARS outbreak in 2002. Coupled with mutation, this allows adaptation to occur (e.g., receptor binding ability, temperature adaptation enzymes) in a shorter time period, than for other viruses.

SARS-CoV-2

To which animal species is this SARS-CoV-2 associated?
- SARS-CoV2 is showing 96.3% genomic identity with Bat-CoV-RaTG13 that was previously detected in the intermediate horseshoe bat (*Rhinolophus affinis*) from southwest China’s Yunnan Province.
• However, there is a difference within the Receptor Binding Domain RBD of the spike (S) protein between the two viruses: the SARS-CoV-2 RBD is adapted to receptors the ACE2 which allows it to enter human cells, while Bat-CoV-RaTG13 is not.

• Pangolin coronaviruses have been described from Malayan pangolins confiscated in 2017 and 2018. Regarding the short RBD region, the Pangolin-CoV is more similar to SARS-CoV-2 region than the Bat-CoV-RaTG13. The Pangolin-CoV shares all five key amino acids in invading human cells with SARS-CoV-2 whereas Bat-CoV-RaTG13 genome only shares one out of five. However, it is important to note that pangolins or any other species have not been identified as intermediatory or amplification host in this SARS-CoV-2 outbreak. On a whole genome basis the CoV from pangolins are very dissimilar to the SARS-CoV-2.

• As horseshoe bats were hibernating at the time when CoVid-19 appeared in China, there is general consensus that the SARS-CoV-2 is of ancestral Bat-CoV-RaTG13 origin, but that an intermediate / amplification host with reassortments in the RBD region was necessary to invade human cells. Obviously, all this is speculative at this stage.

**Why did CoVid-19 break through the species barrier? Can it happen in the Zoo?**

• For a virus to make this kind of leap, a number of factors have to line up: Infected animal, infectious secretions, very close contact possibly repetition in time.

• Wildlife markets are therefore a unique occasion for interspecific transmission:
  - Poor hygiene – slaughter
  - Stressed animals likely to shed a lot of virus
  - Continuous close and crowded contact between multiple species unlikely in the wild+
  - Close proximity to livestock, poultry and domestic animals
  - Wildlife used as small household pets or slaughtered on-site and subsequently eaten, sometimes raw, promoting intimate contact between virus and host’s intestinal tract.

• Conditions within zoo settings are very different:
  - Good hygiene practice
  - Welfare of animals minimizing stress
  - Monitoring and active surveillance of animal health, veterinary observation, screenings.
  - Typically, captive bred animals
  - No human consumption of wildlife

• Time is also very important factor: several genetic retrospective and phylogenetic studies agree that SARS and MERS emergence are linked to several decades of continuous proximity, allowing several mutation and recombination event to occur consecutively.

**What about the positive domestic carnivores? What about sensitivity to other species?**

• There are 4 case reports of “positive” pets. They’re all sharing the fact that they were kept and cared for by positive and shedding owners
  - First dog in Hong Kong (Pomeranian, 17 year old), living with CoVid-positive and sick owner, had weakly positive PCR results on nasal and oral swabs (repeated 5 times), while fecal samples remained negative. At first serology was negative, but a second one was reported as positive by the Hong Kong Health Dept (https://www.news.gov.hk/eng/2020/03/20200326/20200326_210657_932.htm). The dog died from geriatric renal and cardiac failure that was reported as unrelated to SARS-CoV-2, but the owner denied necropsy.
  - Second dog (German shepherd, 2 years old), living with CoVid-19 positive and sick owner. Only one test in which nasal and oral swabs were PCR positive. No symptoms. This animal was placed in quarantine with another 4-year old dog, that remained negative. No further information on serology.
  - Cat in Belgium: After one week living with in infected owner (who had returned from Italy), the cat showed signs of illness compatible with coronavirus signs: anorexia diarrhea, vomiting and cough. RT PCR was positive for SARS-CoV-2 on gastric lavage and feces, with rather high viral RNA copies. Nine days after onset of clinical signs, the cat’s health started to improve, until the condition resolved.
  - Cat in Hong Kong: a domestic short-haired cat, when owner was confirmed with COVID-19, the cat was sent for quarantine at a state animal-keeping facility. Oral, nasal, and rectal samples tested positive for the virus. The cat has not shown any signs of disease. (source: https://www.news.gov.hk/eng/2020/03/20200331/20200331_220128_110.html?type=ticker)
More than 4000 dogs, cats and horses were screened in infected areas in South Korea and the United States by RT PCR. None were found positive (https://www.idexx.com/en/veterinary/reference-laboratories/idexx-sars-cov-2-CoVid-19-realpcr-test/).

At this stage, it remains very hard to differentiate between a passive carriage from pets acting like fomites, and a real epidemiological role of dogs and cats from these 4 reported cases. Viral loads were always found transiently, resuming to zero with days/weeks, and they were found in anatomical location compatible with passive contamination (animals with nose near owner, licking and swallowing virus from sick owner skin or environment).

The ability of SARS-CoV-2 to infect other species has mainly been assessed by in vitro by infection trial on various mammalian cells, or by computer simulated prediction according to RBD / ACE2 receptors binding abilities (2, 23). Combination of these two approaches in 4 different studies provide the report in Table A below.

Additionally, as labs rush to test SARS-CoV-2 in animal models the first results are emerging: teams in China have reported initial findings from infecting Rhesus macaques (https://www.researchsquare.com/article/rs-15756/v1) and transgenic mice (https://www.biorxiv.org/content/10.1101/2020.02.07.939389v3) that have the human ACE2 gene. Labs working on ferrets say they should also have initial results soon: a team led by virologist S. S. Vasan at the Australian Animal Health Laboratory in Geelong has found that the animals are susceptible to SARS-CoV-2 (https://www.nature.com/articles/d41586-020-00698-x#ref-CR1)

Table A: Extant knowledge about species sensitivity to SARS_CoV-2 from (16), (25), (36)

<table>
<thead>
<tr>
<th>Species</th>
<th>In Vitro Infected Cell</th>
<th>Viral Particle Enter</th>
<th>Computer prediction of receptor binding Score /5 : matched Amino acid</th>
<th>In vivo experimental infection success</th>
<th>NY=Not yet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horseshoe Bat</td>
<td>YES</td>
<td>YES</td>
<td>Likely</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Daubenton's bat</td>
<td>?</td>
<td>NO</td>
<td>?</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Vampire bat</td>
<td>?</td>
<td>?</td>
<td>Likely (4/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Cynomolgus monkey</td>
<td>?</td>
<td>YES</td>
<td>Likely (5/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Anubis baboon</td>
<td>?</td>
<td>?</td>
<td>Likely (5/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Orangutan</td>
<td>?</td>
<td>?</td>
<td>Likely (5/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>?</td>
<td>?</td>
<td>Likely (5/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Swine</td>
<td>YES</td>
<td>NO</td>
<td>Likely (5/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Cattle</td>
<td>?</td>
<td>NO</td>
<td>Likely (4/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Elephant</td>
<td>?</td>
<td>?</td>
<td>Unlikely (3/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Camel</td>
<td>?</td>
<td>?</td>
<td>NY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mouse</td>
<td>NO</td>
<td>NO</td>
<td>Unlikely (2/5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rat</td>
<td>?</td>
<td>?</td>
<td>Unlikely (3/5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Hamster</td>
<td>?</td>
<td>NO</td>
<td>Likely (4/5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guinea Pig</td>
<td></td>
<td></td>
<td>Unlikely (2/5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dog</td>
<td>?</td>
<td>YES</td>
<td>Likely (3/5)</td>
<td>No but seronconversion</td>
<td></td>
</tr>
<tr>
<td>Cat</td>
<td>?</td>
<td>?</td>
<td>Likely (3/5)</td>
<td>Yes + transmission to other cats</td>
<td></td>
</tr>
<tr>
<td>Ferret</td>
<td>YES</td>
<td>YES</td>
<td>Likely</td>
<td>Yes + transmission to other ferrets</td>
<td></td>
</tr>
<tr>
<td>Meerkat</td>
<td>?</td>
<td>?</td>
<td>Unlikely (2/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Civet cat</td>
<td>YES</td>
<td>?</td>
<td>Likely</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Raccoon</td>
<td>?</td>
<td>?</td>
<td>Unlikely (2/5)</td>
<td>NY</td>
<td></td>
</tr>
<tr>
<td>Elephant</td>
<td>?</td>
<td>?</td>
<td>Unlikely (3/5)</td>
<td>NY</td>
<td></td>
</tr>
</tbody>
</table>

Two recent papers still under review (21,32 ) show that ferrets and domestic cats are at least somewhat susceptible species as they are able to be experimentally infected, shows clinical signs from mild (cats) to more severe (ferrets), but also to excrete enough virus for efficient transmission to cage mates. In contrast, dogs seemed to allow minimal replication, while chickens, ducks and pigs were apparently not susceptible.
Great caution should be paid to all new papers and information released about animal species susceptibility to the virus:

- the objective sometimes is to assess a real role of animal species in transmission, sometimes to identify potential animal models needed for further treatment and vaccination testing.
- the methods to get to conclusions may vary a lot like the following examples:
  - only in vivo assays (where immune system effects of hosts are mostly not considered)
  - raw computer models (prediction of molecular binding abilities)
  - experimental infection using high infective dose of SARS-CoV-2 injected directly injected in nose, trachea or blood
- Hence, while all these studies provide valuable information, that may not be directly applicable to daily life (e.g. where animals are not exposed to extreme viral loads)

**What about testing in animals?**

- In human beings, testing so far relies on RT-PCR research of viral RNA, mainly from nasopharyngeal and oropharyngeal swabs, but also from feces. These tests are either qualitative (mainstream used one for quick result) or quantitative to precisely assess viral load. Aside from these direct tests, a lot of serological assays are under development, mostly using the form of “Rapid Test”.
- Regarding veterinary labs, Idexx has developed its own RT-PCR. Initial studies on dogs and cats showed:
  - that this RT-PCR test is not cross-reacting with other coronavirus (e.g. feline coronavirus), granting a good specificity
  - that the usual commercial test for feline or canine coronavirus (ELISA) are not cross-reacting with SARS-CoV-2 either.
- So far, there are no PCR or serological test available on the market for animals by veterinary labs.
- Several serological tests are about to be released, especially to support the de-confinement phase in a lot of countries. Review of techniques embedded in those test (Rapid flow ones, ELISA...) show that some of them may have further potential for other animal species such as non-human primates, but this use is not yet assessed properly and needs further studies.

**Zoo Context**

The EAZA statement on SARS-CoV-2 can be found here:


**Is there any risk of transmission from visitors / keepers to animals?**

- According to the current knowledge, SARS-CoV-2 is showing abilities to enter cells of several animal species such as bats, cats, ferrets and some primates. Therefore, close contact between these species and infected / suspect human with CoVid19 should be restricted.
- Individuals handling or caring for animals should implement the following basic hygiene measures, applying to both visitors or keepers:
  - Prevent contact with animals when ill
  - Wash hands thoroughly before and after handling animals, their food, or supplies
  - Avoid any close contact like “kissing” or petting (especially without gloves)
- Regarding great apes, there are already a number of guidance documents:
  - One from EAZA great Ape TAG Vet advisors
Reassuring Statements about risk of transmission from zoo animals to visitors / keepers?

- Zoo animals are under veterinary care, including ongoing monitoring of infectious diseases. For some particular species, screening for some coronaviruses is already part of entry requirements (e.g. FIP in some Felidae) or readily looked for when any clinical signs are noted (e.g. diarrhea in young bovids)
- The species of chiropterans that are mostly involved with coronavirus (like Asiatic horseshoe bats or other small insectivorous species) are not kept within European zoo collection, mostly focusing on flying foxes that are not known hosts of the high-profile zoonotic coronaviruses.
- The environmental, sanitary and welfare conditions of zoo settings cannot in any way be compared to conditions in wildlife markets. Zoos employ exemplary hygiene and sanitation practices, excellent holding conditions adapted to the species’ needs and daily monitoring of all animals in their care.
- One may be scared of animals being infected by keepers and of back transmission to keepers/visitors. According to the few examples of viral load excreted by domestic animals naturally infected by human begins (dogs and cats), dose of excreted virus seems very low and are likely to be lower than the minimal infective one. This zoonotic risk is considered as very low by several national health agencies (Belgium, France,..)
- Hence, risk of any incidentally infected wild captive animals shedding enough virus to infect keepers and visitors could be considered as even lower, regarding the greater distanciation compared to pets.

What about stability of virus in environment?

- Infective media: SARS-CoV-2 could be excreted through oral cavity (saliva), respiratory tract (breath / aerosol) and also intestinal tract (feces), ocular conjunctiva (tears) and blood in some stages of the human disease. In experimentally infected ferrets, virus was also found in urine until days 8, but with lower loads than nasal washes or fecal samples (21).
- SARS-CoV-2 is likely inactivated by heat above 56°C but exposure time has not been assessed yet and all presumptions are derived from knowledge about SARS-CoV-1.
- SARS-CoV-1 and SARS-CoV-2 seem to share the same propriety of stability on surface and in aerosols (30)
  - remaining viable in aerosol droplets for up to 3 hours
  - remaining detectable on metal or plastic surface for up to 3 days, but their titers reduced a lot (e.g. from $10^{3.7}$ to $10^{1.6}$ Tissue Culture Infective Dose / mL over 72h)
- The most efficient disinfectant remains alcoholic compounds, but with appropriate contact time: propanol (100% or 70%) or ethanol (70%) for a minimum of 30 sec. For other compounds such as quaternary ammonium or phenolic compounds, efficient contact time regarding coronavirus is usually 10 minutes. Other disinfectants that could be used include wine vinegar (1 minute), sodium chlorite (1-2 minutes), hydrogen peroxide (usually 2 minutes). (20)
- Caution should be paid that some references are refereeing simply to RNA or genome detection, whereas other focus on actual tissue culture infective dose. Obviously, the latter are more relevant.

Online live references:


Literature


28. Ong, Sean Wei Xiang, Yan Kim Tan, Po Ying Chia, Tau Hong Lee, Oon Tek Ng, Michelle Su Yen Wong et Kalvisar Marimuthu. 2020. "Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient." JAMA.


