National Collaborating Centre for Environmental Health
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An introduction to SARS-CoV-2

The emergence of a novel coronavirus in late 2019, now identified as SARS-CoV-2, has resulted in a global pandemic with an unprecedented public health response. This brief review of the properties of SARS-CoV-2 and how it is transmitted outlines some of the evidence that currently forms the basis of our evolving public health response to COVID-19. The evolving evidence on the dominant routes of transmission, and potential importance of pre-symptomatic and asymptomatic transmission indicate that preventing the spread of the SARS-CoV-2 virus requires a suite of precautionary measures. As new evidence and new interpretations evolve, this document will be updated.

What is COVID-19?

Coronavirus disease (COVID-19) is an illness caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a recently discovered novel coronavirus. Coronaviruses are genetically distinct from viruses that cause influenza. They are enveloped, single-stranded RNA viruses whose surface is covered by a halo of protein spikes, or "corona." Other coronaviruses that have caused significant and lethal outbreaks in the past 20 years include SARS-CoV-1 and MERS-CoV that caused SARS and Middle East respiratory syndrome (MERS), respectively. Like the SARS-CoV-2 virus, these viruses are thought to originate in bats, but may have had an intermediate mammalian host prior to transfer to humans.

SARS-CoV-2 genetics

Phylogenetic (evolutionary) analysis has helped to establish that SARS-CoV-2 emerged in the human population in November 2019. Since then, continued observation of the genome has identified small mutations that can be used to track the evolution of the virus. The rate of mutation observed for SARS-CoV-2 is significantly lower than influenza, suggesting it is evolving more slowly in response to selective pressure.[1,2] Further observation is needed to understand how mutations affect the function of the virus. At the beginning of the pandemic, one variant of the SARS-CoV-2 virus was the most prevalent (D614). In February 2020, a new variant, G614, emerged in Europe and has since replaced D614 as the most dominant form.[3] Infection with the G614 variant potentially results in higher viral loads, which has been suggested could influence transmissibility[3]; however, this has yet to be fully evaluated. It does not appear that the G614 variant result in greater disease severity.[4] Continued study of the genome and relating genomic variants to health and epidemiological data is important to evaluating how the evolution of the virus may impact on the public health response, vaccine development and the design of therapies.[1,4]

What are the symptoms?

COVID-19 can result in a broad range of symptoms that can vary from person to person. These can include cough, fever, shortness of breath, tiredness, sore throat, body aches, chills, headache and in some cases result in lethal pneumonia. Some people may also experience loss of smell or taste, nausea, vomiting or diarrhea. Among children, abdominal symptoms and skin changes or rash may be more commonly reported.[5]

The severity of disease can also vary from person to person. Not everyone with COVID-19 will display symptoms, and many cases will only experience mild symptoms.[6] About 15% of those experiencing symptoms will require hospitalization, of which about one-third may require admission to intensive care.[6] The elderly, the obese, smokers, and immunosuppressed persons and those with pre-existing conditions including diabetes, hypertension, heart disease or cancer are at the greatest risk of requiring hospitalization or dying from COVID-19.[7-9]

The case fatality rate for COVID-19 differs around the world and across Canada and relates in part to case identification and to local epidemiology.[10,11] The case fatality rate for Canada as of July 12, 2020 was reported as 8.2%, with the highest case fatality rates recorded in Quebec (10%), Ontario (7.5%), B.C. (6.2%) and Nova Scotia (5.9%) and no deaths recorded in P.E.I. or the Territories.[10] COVID-19 is less prevalent in children as compared to adults, making up only about 1-10% of cases, and children infected with SARS-CoV-2 experience less severe symptoms.[12-16] Children under one year of age and with underlying conditions may experience more severe illness than other children, but case mortality rate for children is much lower than for adults.[15] Some children with suspected or confirmed COVID-19 have been reported to experience symptoms similar to Kawasaki disease, although this is rare and typically non-life-threatening.[17-20]

Rate of Transmission

The basic reproduction number for a contagious disease, or the R_0 value, estimated at the beginning of an outbreak, indicates the number of secondary cases that can be infected by a primary case in a population with no underlying immunity, vaccine or preventive measures. Where R_0 is greater than 1, the number of infected persons is likely to increase. Over time, the effective reproductive number (R_t) changes as more people are infected and public health measures are implemented to contain the spread. The goal of public health interventions is to bring the R_t below 1, which would indicate that the outbreak is reducing and will eventually die out.[21] Monitoring the change in Rt can help to evaluate the effectiveness of public health measures.

For SARS-CoV-2 the preliminary World Health Organization estimate of R_0 was 1.4-2.5[22] with subsequent research estimating the mean R_0 at 3.28.[23] This suggests that every primary case at the beginning of the outbreak could potentially infect about three others. The R_t is an average and can vary depending on the location and patterns of local transmission over time.[24] Estimates of R_t can not easily account for secondary cases that are asymptomatic unless these cases have been detected in the population through widespread testing.[25] The R_t for Canada near the beginning of the pandemic in March 2020 was estimated to be > 2. Following widespread public health measures to prevent transmission, the R_t dropped to < 1 from about the end of April to late June 2020.[26] Since then, the R_t has shown a slight upward trend, reflecting localized outbreaks in some regions of the country. The Rt varies between and within provinces and territories. For example, modelling for the province of Ontario towards the end of June 2020 estimated the median R_t for the province to be 1.0. The Rt was found to vary within Ontario from 0.8 in Toronto to 2.1 in the Northern region.[27] This difference is partially explained by the large difference in the total number of cases in Toronto (12802) compared to the Northern region (330).

How is the virus transmitted?

SARS-CoV-2 is primarily transmitted via prolonged close contact with an infected person, likely due to their respiratory secretions passed in the air, which can include a range of droplet sizes, and potentially due to transmission via surfaces (fomites). The vast majority of COVID-19 outbreaks have taken place indoors and are most often associated with close contacts in the home environment, or other indoor spaces where there is a high density of people and an extended period of contact.[28-31]

Large respiratory droplets

The primary mode of human-to-human transmission of SARS-CoV-2 is considered to be via direct contact with an infected person and their respiratory droplets generated during coughing, sneezing, and other respiratory actions that produce large droplets (e.g., > 5 µm diameter).[32] Exposure potential is greatest in close proximity of an infected person. Large respiratory droplets can be contained by actions such as mask wearing, respiratory etiquette (covering one's mouth and nose when coughing or sneezing) and via physical distancing measures that help to ensure there is sufficient distance for respiratory droplets emitted from an infected person to drop to the ground before reaching others. Large droplets are thought to travel less than 1 m before dropping to the ground, leading to the 2 m physical distancing practice that has been adopted for limiting the spread in the general public.[32-35] Current evidence has shown that measures to protect against the spread of respiratory droplets, namely physical distancing and mask wearing, have led to a reduction in cases.[36]

Small respiratory droplets/respiratory aerosols

Increasingly, transmission via smaller droplets or respiratory aerosols (< 5 µm diameter) produced by speaking, singing, shouting, or heavy breathing is considered to be an important route of transmission, with some experts calling for greater awareness of airborne precautions for some activities and in some settings.[37-43] Small respiratory droplets can remain in the air longer than large droplets and could present both a risk of exposure in close contact with an infected individual, and potentially over longer distances in enclosed spaces.[42,44] Some preliminary evidence under experimental conditions suggests that SARS-CoV-2 may remain viable when airborne over short distances for several hours.[45,46] Transmission via respiratory aerosols could be occurring in settings where these particles accumulate in poorly ventilated indoor environments where there is a high density of people and extended duration of contact.[29,47] Control measures for this type of transmission may rely heavily on reducing crowding, reducing the duration of interactions in indoor spaces, and ensuring good ventilation.[48,49]

The relative importance of transmission via droplets and airborne aerosols requires further investigation and may have implications for public health recommendations for indoor versus outdoor environments.[45,50-54]

Contact with surfaces

Contact with contaminated surfaces (fomites) followed by touching of the eyes, mouth or nose is a another possible mode of SARS-CoV-2 transmission, although is not considered to be the main transmission route.[32] Fomites can become contaminated by deposition of droplets, aerosols, sputum or feces, either directly or by cross-contamination by touching an object with contaminated hands.

The risk of transmission through contact can depend on the concentration of viable virus, its viability on a specific surface over time *(see below for persistence on different surfaces)* and the quantity of virus a person is exposed to by touching of the eyes, mouth or nose. Surfaces that are frequently touched by many people, such as door handles or faucets may be more important in fomite transmission compared to objects or surfaces that are only touched incidentally and less frequently. Hand hygiene and routine cleaning and disinfection of surfaces reduces the likelihood of contact transmission.[55]

There have been few studies that have assessed the presence of viable virus on surfaces. One observations study of surfaces in clinical and public areas of a hospital treating COVID-19 patients found SARS-CoV-2 RNA on over half of the surfaces tested, especially computer keyboards, chairs and alcohol gel dispensers.[56] While no culturable virus was detected in the study, evidence of surface contamination supports recommendations for hand and surface hygiene. Washing with soap for 20 seconds followed by rinsing can help to emulsify the lipid layer of the virus, rendering it inviable and diffuse virus particles, making spread less likely.[24,57] Using hand sanitizers to inactivate the virus is an alternative to handwashing.[58] Chemical disinfectants can be used to inactivate the virus on surfaces. Both Health Canada[59] and the US EPA[60] have issued a list of disinfectants that are approved for use on hard surfaces against SARS-CoV-2. The Public Health Agency of Canada (PHAC) has also developed guidance on cleaning and disinfection of public spaces for SARS-CoV-2.[61]

Transmission via feces

There is some evidence that the SARS-CoV-2 virus is shed via feces,[62] and the virus has been detected in the toilets of COVID-19 patients.[52-54] Several studies have identified the presence of SARS-CoV-2 RNA in feces but only a few have identified infectious virus.[63] There is little evidence to suggest that the fecal-oral pathway (e.g., passing in fecal particles from one person to the mouth, or fecal contamination of food) is significant in the current pandemic.

When is the virus transmitted?

The mean incubation period (time between exposure to the virus and the appearance of symptoms) has been estimated to be around five days,[64,65] with modelling indicating a range of about two to 11 days (2.5th and 97.5th percentiles).[66,67] An infected person can transmit the virus to others both before they show any symptoms (pre-symptomatic) and when they are symptomatic. The efficiency of viral transmission during exposure can be affected by the number of infectious viral particles inhaled and the duration of exposure for a secondary case.[68] Infection may occur as a result of a short but intense dose of infectious virus, or following prolonged exposure to a smaller dose. Current evidence suggests that most transmission occurs during the symptomatic phase, but research is still needed to understand the relative importance of pre-symptomatic and asymptomatic transmission.[69]

Pre-symptomatic and asymptomatic transmission

The occurrence of pre-symptomatic transmission (during the incubation phase of an infected person) and asymptomatic transmission (transmission via an infected person who never displays symptoms) has been recorded throughout the pandemic in various locations around the world.[30,70-74] The precise incidence of pre-symptomatic and asymptomatic transmission and overall importance to the spread of the virus is still unknown. A review of studies by Heneghan et al. (2020) found that between 5% and 80% of people infected with SARS-CoV-2 may be asymptomatic, but the rate of transmission to others requires further study.[75]

Pre-symptomatic and asymptomatic cases have been found to shed virus.[76,77] It is not clear what level of infectious virus is shed during the pre-symptomatic phase, or via asymptomatic spreaders, given that a primary route of transmission (large respiratory droplets) is limited by the absence of coughing and sneezing.[72] Other routes of transmission, such as via smaller respiratory droplets released during breathing, speaking, laughing or singing, may be more important for pre-symptomatic or asymptomatic transmission.[78] He et al. (2020)[79] estimated that infected persons could be transmitting the virus 0.6-2.5 days before the onset of symptoms, although for asymptomatic spread, the period of transmission is still being investigated. Current evidence suggests that asymptomatic transmission is more likely to occur following prolonged close contact, such as in family settings where there may be exposure during shared meals, talking, and contact with shared common objects and surfaces.[30,69,74,80]

Symptomatic transmission

Once a person becomes symptomatic, they could be transmitting the virus to others for days to several weeks after symptom onset.[67] Research is ongoing to help explain the relationship between viral dose (e.g., the level of exposure to the virus via respiratory droplets, or contact with fomites), the viral load (the quantity of viral particles per unit of bodily fluid in the infected person) and severity of disease.[81] The viral dose required to cause infection by various routes remains unknown.[82] Most cases of COVID-19 are diagnosed using reverse transcription PCR (RT-PCR), which identifies whether viral RNA is present or not, and can provide some indication of the level of viral load.[83] While this type of test cannot determine if viral particles are infectious, the more viral RNA in the body may be an indication that more virus can potentially be released by coughs, sneezes, breathing or talking.

The level of viral RNA has been measured to be highest soon after symptom onset in the early stages of the disease, when level of transmission may also be highest, and decreases about one week following the peak.[84,85] The virus replicates predominantly in the tissues of the upper respiratory tract.[86] The pattern of viral shedding for SARS-CoV-2 has been found to be more similar to influenza as compared to SARS-CoV-1.[69,77] Patients with a higher viral load appear to experience more severe symptoms and shed more virus over a longer timeframe than mild cases.[87] Positive results for viral RNA do not always indicate that infectious virus is being shed but Woelfel et al. (2020) found that viable virus could be isolated at the peak of viral shedding, about four days after symptom onset.[86] Studies of viral load indicate that the amount of viable virus decreases over a much shorter period as compared to viral RNA, which can persist much longer but is not infectious.[67]

Sensitivity of SARS-CoV-2 to environmental factors

Research is ongoing to understand the persistence of SARS-CoV-2 on different surfaces and under various environmental conditions.

Temperature

Experiments have found that high temperatures are more effective for deactivating the SARS-CoV-2 virus, and the virus is more persistent at colder temperatures. Experiments using viral suspension found minimal reduction over 14 days at 4°C, but detected no viable particles after four days at 22°C, within one day at 37° C, less than 30 minutes at 56°C and less than five minutes at 70°C.[88-90] A study of persistence of SARS-CoV-2 in milk also found that pasteurization temperatures of 56°C and 63°C for 30 minutes resulted in no viable virus; however no reduction was detected after 48 hours stored at 4°C, and only a minimal reduction after 48 hours stored at -30°C.[91]

Humidity

Humidity can influence both persistence on surfaces and infectivity of the virus, by affecting spread of the virus and susceptibility of respiratory systems to viral infection.[92] There is preliminary evidence that persistence of the virus may decrease with increases in temperature and humidity and the virus may remain infectious under dry conditions.[89,92,93] Further research is needed to better characterise how humidity influences persistence and infectivity of SARS-CoV-2 in indoor and outdoor environments.

Light/Ultraviolet (UV) radiation

UV irradiation has been shown to reduce viral loads for respiratory viruses, including SARS-CoV-1 in clinical and other controlled settings,[94,95] Germicidal effects can occur between 200-320 nm, which covers the range of UV produced by natural sunlight (UV-B, 280-320 nm) and UV produced by lamps for specific applications (UV-C, below 280 nm) Solar UV-B has been shown to provide a disinfectant effect under a high UV-index over a sustained period.[96] Disinfection using UV-C is more efficient than UV-B, and UV-C has been shown to be effective for inactivation of double-stranded, enveloped RNA viruses.[97-100] UV irradiation has also been proposed as a decontamination method for personal protective equipment (PPE) contaminated by SARS-CoV-2.[101-103] Initial results suggest that UV treatment may be more effective on smooth surfaces such as steel as compared to fabrics or porous materials.[104] The use of UV-C for disinfection carries some risk, as UV-C can be harmful to human skin and eyes. Further study is needed to determine the optimum dose needed for inactivation of SARS-CoV-2, and how UV-C could be safely applied in public settings.

Persistence on surfaces

A limited number of studies have specifically examined the persistence of SARS-CoV-2 on common surfaces.[46,88,105-107] Previous study of coronaviruses (MERS, SARS-CoV-1 and other human coronavirus variants) found that they are detectable on wood, glass, metal and plastic for between four and nine days.[106] One of the first studies on SARS-CoV-2 by van Doremalen et al. (2020) found that the virus was most persistent on stainless steel and plastic surfaces and least persistent on cardboard and copper.[46] Chin et al. (2020) also found that SARS-CoV-2 was more persistent on smooth, hard surfaces (stainless steel and plastic) than porous materials (wood, cloth, paper and tissue).[88] Liu et al (2020) also found that the virus was least persistent on cloth and paper but on most other surfaces, infectious virus was detectable after seven days.[108] Studies of persistence on metals such as copper and aluminum have found the shortest level of persistence under experimental conditions.[88,107] It is important to note that the studies mentioned have been conducted under different experimental conditions, including temperature, relative humidity, and with variations in the concentrations and volumes of infectious titer that were used. The findings of these studies are presented Table 1 below, however additional research is needed to better understand how experimental conditions relate to real-world situations.

Table 1: Persistence of SARS-CoV-2 on various surfaces under experimental conditions*

SURFACE	Persistence of SARS-CoV-2 under experimental conditions
Paper Cardboard	Cardboard: up to 24 hours[46] Paper and tissue: up to three hours[88] Paper: rapid loss of infectivity after one hour; no infectious virus after five days[108]
Stainless steel	Up to three days (72 hours) although viability significantly reduced at 48 hours[46] Up to four days (96 hours)[88] > 7 days[108]
Copper	Up to four hours[46]
Aluminum	Up to four hours[107]
Plastics	Up to three days (72 hours)[46] Up to four days (96 hours)[88] > 92 hours (less than 1 log_{10} drop on polystyrene after 92 hours)[107] > 7 days[108]
Wood	Up to two days[88] > 7 days[108]
Glass	Up to four days[88] > 44 hours (3.5 log_{10} drop after 44 hours)[107] > 7 days[108]
Ceramics	> 7 days[108]
Cloth	Up to two days[88] Cotton: rapid loss of infectivity after one hour; no infectious virus after four days[108]
Latex gloves	> 7 days[108]
Surgical mask	> 7 days[108]

*Reference	Experimental temperature	Relative humidity	Concentration of infectious titer	Volume of infectious titer
van Doremalen et al.[46]	21-23 °C	40 %	10^5 $TCID_{50}$ per ml	50 µl
Chin et al.[88]	22 °C	65 %	$10^{7.8}$ $TCID_{50}$ per ml	5 µl
Pastorino et al.[107]	19-21 °C	45-55 %	10^6 $TCID_{50}$ per ml	50 µl
Liu et al.[108]	25-27 °C	35 %	10^6 $TCID_{50}$ per ml	50 µl

Additional COVID-19 related resources to support environmental health can be found on our Environmental Health Resources for the COVID-19 Pandemic topic page.

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