COVID-19 INFORMATION

# Transmission of SARS-Cov-2

## Transmission of SARS-CoV-2

1. The dominant mode of transmission of COVID-19 is via respiratory droplets during close unprotected contact.

2. Transmission of COVID-19 primarily occurs from people with symptoms, and can also occur just before they develop symptoms, when individuals are in close proximity to others for prolonged periods of time. While someone who never develops symptoms can also pass the virus to others, it is still not clear to what extent this occurs.

3. Evidence is growing that virus dispersion in clusters, i.e. crowded events/settings, is a significant factor of total transmission of SARS-CoV-2. Particular attention should be given to preventing these types of events.

## Modes of transmission

SARS-CoV-2, the virus responsible for COVID-19, is highly transmissible with the average number of new infections generated by an infectious person, or ($R_0$), ranging from 1.95 to 3.28 people. (Liu et al.) Whether an individual comes down with Covid-19 depends on several factors: dosage (how many viral particles are inhaled) and duration (for how long one inhales particles), setting of the exposure and individual health characteristics. In an analysis of 75,465 COVID-19 cases in China, 78-85% of clusters occurred within household settings, suggesting that transmission occurs during close and prolonged contact. (WHO) Data from different countries suggests that transmission rates among household members range between 10% and 40%. (Cheng et al., Rosenberg et al., Chen et al., Wei et al., Qian et al.) Close but less sustained contact such as sharing a meal is associated with a secondary attack rate (or risk of transmission from an index case to an exposed contact) of about 7%, whereas passing interactions among people shopping is associated with a secondary attack rate of 0.6%.

SARS-CoV-2 virus transmission may take place along a spectrum; it is difficult to completely rule out possibilities of how individuals become infected. It is possible for the virus to spread widely and rapidly among tightly packed groups within closed environments via multiple mechanisms. There are several potential modes of transmission explained below from most to least dominant.

**Contact and Droplet**

There is extensive published evidence from across the globe that demonstrates the overwhelming majority of transmission of SARS-CoV-2 is via large respiratory droplets and contact with infected individuals. The primary and most dominant mode of transmission of SARS-CoV-2 is through direct, indirect, or close contact with:

- Infected people through infected secretions such as saliva and respiratory secretions or their respiratory droplets, which are expelled when an infected person coughs, sneezes, talks or sings. (e.g., Burke et al., Chan et al., Pung et al.)
- Presymptomatic people in the incubation period, the time from exposure to symptom onset, who are later confirmed to have COVID-19. (Huang R et al., Tong et al., Yu P et al.)

When interactions occur within one-metre distance, respiratory droplets that include virus can reach the mouth, nose or eyes of a susceptible person and can result in infection. (WHO) Respiratory droplets have been shown to be propelled up to 2 m and were found on the floor 4 m away from the patient. (Guo et al.) A systematic review of studies assessing the horizontal distance travelled by respiratory droplets found that droplets can travel more than 2 m and up to 8 m. (Bahl et al.)

More time spent with symptomatic individuals increases the risk of exposure to the virus. Many examples of SARS-CoV-2 clusters are linked to a wide range of mostly indoor settings. (Leclec et al., Lu et al.,Jang et al.) Being outdoors presents a lower risk for coronavirus transmission than being indoors, as the risk of inhaling respiratory droplets is lower. A study from China of 318 outbreaks found that transmission occurred outdoors in only one of them. (Qiang et al) In Japan, a study found that the odds of Covid-19 transmission in a closed environment was 18.7 times greater compared to an open-air environment. (Nishiura et al.) Environmental exposures, such as sunlight, may have significant effects on viability of SARS-CoV2. Results of a laboratory experiment applying simulated sunlight (UVA/UVB) to aerosolized virus indicate 90% inactivation of virus within 20 minutes, supporting outdoor environments as lower risk for transmission. (Schuit et al.)

To limit community spread via contact or droplet transmission, WHO recommends that individuals:

- Limit close contact with infectious people. Ensure a physical distancing from others. In areas where COVID-19 is circulating and physical distance cannot be guaranteed, wear a mask.
- Clean hands and consistently cover coughs and sneezes with a tissue or bent elbow.
- Avoid crowded places, close-contact settings and confined or enclosed spaces with poor ventilation.

It is impossible to conclude that transmission always occurs via close contact or droplet; it is possible that in poorly




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ventilated, crowded indoor settings, aerosols play a role in transmission. (Klompas et al.)

**Aerosol**

Current evidence indicates that aerosol transmission is not the dominant or common mode of SARS-CoV-2 transmission. (Public Health Ontario Review), but research on the extent and scale of aerosol transmission is on-going. It can happen through the dissemination of droplet nuclei (aerosols) that remain infectious when suspended in air over distances (over 2 m) and time. Latest CDC guidance suggests that transmission of SARS-CoV-2 via aerosols can occur under special circumstances:

- Enclosed spaces within which an infectious person and exposed susceptible people are present at the same time or to which susceptible people were exposed shortly after the infectious person had left the space.
- Prolonged exposure to respiratory particles, often generated with expiratory exertion (e.g., shouting, singing, exercising) that increased the concentration of suspended respiratory droplets in the air space.
- Inadequate ventilation or air handling that allowed a build-up of suspended small respiratory droplets and particles.

This mode could also occur in close contact healthcare settings (hospitals and dental offices) during medical procedures that generate aerosols. (Tran et al., WHO). A susceptible person could inhale aerosols, and become infected if the aerosols contain the virus in sufficient quantity to cause infection within the recipient. (Gralton et al.) However, the role of aerosols is not clear when looking at quantity of aerosols and infectious dose of SARS-CoV-2 required for infection to occur. At distances greater than 2 metres viable SARS-CoV-2 has not been detected during air sampling. (Zhou et al.)

The support for this mode of transmission comes mostly from experimental or modelling studies. (Chen W et al.) These experiments estimate the half-lives of SARS-CoV-2 in aerosols to be 1.1-1.2 hours. (van Doremalen et al., Fears et al., Asadi et al., Mittal et al.) One modelling study of the outbreak linked to a choir practice in the United States describes a probable situation in which transmission by inhaling respiratory aerosols that were released during singing caused a large COVID-19 outbreak in an indoor environment. (Miller et al.) Other studies, examining the same choir practice, suggest that transmission via droplet or contaminated surfaces cannot be ruled out. (Hamner et al.) Another investigation of an outbreak in a restaurant in Guangzhou, China, of three families sitting in close proximity for more than one hour concluded that the air conditioning ventilation likely contributed to droplet or aerosol transmission. (Lu J et al.) Given the rarity of cases linked to potential aerosol transmission, more research is needed given the possible implications of this transmission route.

Reports of outbreaks in crowded settings with poor ventilation suggest that infectious aerosols were suspended in the air and that people inhaled the virus. (Public Health Agency of Canada) Aerosol and droplet transmission raise a possibility of the virus being spread through heating, ventilation, and air conditioning (HVAC) systems. This has not been demonstrated, however, studies have not been able to consider and evaluate all HVAC configurations and their potential to affect transmission of infection due to lack of data on viable virus in air samples, and the wide variety of HVAC systems. So following practical recommendations (samples listed below) can limit potential spread via HVAC systems (Alberta Scientific Advisory Group Rapid Review):

- Increase air supply and exhaust ventilation for extended operation times;
- Keep exhaust ventilation systems of toilets on continuously;
- Supply as much outside air as reasonably possible (except in toilet rooms/washrooms);
- Avoid central recirculation.

More specific guidance and advice for households is available from the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

**Fomite or Contaminated Surfaces**

Fomite transmission is considered a likely mode of transmission for SARS-CoV-2, given consistent findings about environmental contamination in the vicinity of infected cases and the fact that other coronaviruses and respiratory viruses can transmit this way. (WHO) Respiratory secretions or droplets expelled by infected individuals can contaminate surfaces and objects, creating fomites (contaminated surfaces). It may be possible that a person can get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose, or possibly their eyes. Transmission risk then depends on several factors, including the concentration of viable virus deposited and its viability on a specific surface for a given time period. It should be noted that people who come into contact with potentially infectious surfaces often also have close contact with the infectious person, making the distinction between respiratory droplet and fomite transmission difficult to discern.

Currently, the evidence for fomite transmission of COVID-19 is not strong. One observational study from South Africa supports the possibility. (Lessells et al.) However, viral RNA

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has been detected on surfaces in the environment of patients who have tested positive for COVID-19 (Chia et al., Guo et al., Wu et al., Jiang et al., Ong et al., Ye et al.) Viable virus can be found on contaminated surfaces for periods ranging from hours to days, depending on the environment (including temperature and humidity) and the type of surface. In experimental studies, at 40% relative humidity and 21-23°C, SARS-CoV-2 was detectable for:

- Up to four hours on copper;
- Up to 24 hours on cardboard;
- Up to two to three days on plastic and stainless steel.

Other experiments suggest that increasing temperature and relative humidity accelerates virus inactivation on surfaces. Increasing temperature to 35°C reduces the virus' half-life on non-porous surfaces to 1.0 to 8.9 hours from 6.3 to 18.6 hours at 24°C. (Biryukov et al) While SARS-CoV-2 can be very stable in favourable environments of lower temperatures (4°C) and humidity, it is highly susceptible to standard disinfection methods.(Chin et al.). For guidance on household cleaning and disinfection please refer to the resources below:

- Government of Canada, Public Health Advice
- BC Centre for Disease Control
- National Collaborating Centre for Environmental Health (Canada)
- Centres for Disease Control and Prevention (USA)

**Ocular or Eye Surface**

Transmission through the ocular surface is considered a possible route of transmission for COVID-19 based on recent case reports and evidence of virus detection in the eyes among patient cases with conjunctivitis. (Dockery et al.) To date, one study by Colavita et al. was able to isolate live virus from conjunctival swabs. A recent meta-analysis by Chu et al. confirms that eye protection can prevent coronavirus infections. This is a meta-analysis also confirms that policies on:

- Physical distancing are associated with large reductions in infection, in particular that further distances are more effective, even beyond 2 metres.
- Face masks and eye protection are effective interventions to reduce the risk of COVID-19 in both healthcare, and non-healthcare, settings.

**Fecal-oral Transmission**

The role of fecal-oral transmission remains uncertain. A person could potentially be exposed by interacting with water contaminated with untreated fecal matter or by handling contaminated stools directly. One study that collected air samples throughout a busy hospital environment, reported the highest virus levels were found in the air in a "mobile toilet". (Liu et al.) This was attributed to people coughing or sneezing in an enclosed space, as well as the potential for aerosolization of the virus from flushing fecal matter.

It has been reported that a relatively small proportion of patients experience diarrhea and vomiting during COVID-19 infection (e.g., Chen N et al., Wang et al., Tang et al.), with some case reports of gastrointestinal symptoms in the absence of respiratory symptoms. (Hosoda et al., Song Y et al.) While some stool samples tested positive for COVID-19, there have been no published reports of transmission of through feces.

**Vertical Transmission from Pregnant Mothers to Newborns**

The reported case series suggest that this mode is not a common occurrence and the case reports indicate that it may only occur under certain conditions. There is very limited evidence of intrauterine transmission of SARS-CoV-2 from infected pregnant women to their fetuses. (e.g. Kasraeian et al., Huntley et al., Yun et al.) Some studies report probable transmissions. However, the results cannot be considered definitive due to studies' limitations, such as lack of viral analyses performed on the umbilical cord blood, placenta or vaginal secretions or lack of description of infection prevention and control practice after birth.

Currently, there is also no evidence to support mother-to-child transmission of COVID-19 through breast milk. However, during breastfeeding, an infected mother can transmit COVID-19 to the child through respiratory droplets and close-contact transmission. (e.g., Chen H et al.)

## Role of asymptomatic and pre-symptomatic individuals

SARS-CoV-2 RNA has been detected in patients 1-3 days before symptom onset, and viral load in the upper respiratory tract peaks within the first week of infection, followed by a gradual decline over time. Individuals are most infectious during the initial days of infection or 48 to 72 hours before starting to experience symptoms. (Howard et al., WHO) Three studies of patients with undisclosed or variable degree of illness showed an inability to culture virus after days 7-9 of symptom onset. (Bullard et al., CDC) For most persons with COVID-19 illness, isolation and precautions can generally be discontinued 10 days after symptom onset. While infection with SARS-CoV-2 can cause respiratory illness ranging from mild disease to severe disease and death in some people, others infected with the virus never develop symptoms.




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While most transmission of COVID19 occurs from symptomatic people to others in close contact, there is growing evidence that a significant portion of people who have COVID-19 do not show symptoms while infectious. These individuals can be:

- Asymptomatic (15-20% of infected individuals), meaning they are infected with COVID-19, but do not develop any symptoms; or
- Pre-symptomatic (6-12% of infected individuals), meaning they are infected, but have not developed symptoms yet. (Alberta Scientific Advisory Group Rapid Response Review)

Most people who become infected with SARS-CoV-2 will not remain asymptomatic throughout the course of the infection. (Buitrago-Garcia et al.) It is still unclear to what extent individuals without symptoms spread the virus. The proportion of individuals without symptoms likely varies with age due to the increasing prevalence of underlying conditions in older age groups (and thus increasing risk of developing severe disease with increasing age).

**Transmission in Children**

Children of all ages can become infected, with the coronavirus and spread it to others. Teenagers aged 12–17 years) are about twice as likely to become infected with the coronavirus as younger children (5-11 years old). (Leeb et al., Viner et al.) Available evidence indicates that children probably contract COVID-19 in their households or through contact with infected family members, particularly when schools are closed. (Posfay-Barbe et al., Qui et al., Peng et al.) Infected people also tend to spread the virus to those of similar ages. The latest observational study from India also identifies high prevalence of infection among children who were contacts of cases around their own age, suggesting social interactions among children may be conducive to transmission. (Laxminarayan et al.) Overall, child to adult transmission appears to occur at a lower rate than adult to child or child to child transmission, based on epidemiologic observations from multiple countries. This finding appears more robust in children < 10 years old. (Alberta Scientific Advisory Group Rapid Review, National Collaborating Centre for Methods and Tools Review)

A growing number of studies are evaluating the transmission potential of children. The reported secondary attack rate estimates for children vary by age group and across the studies. Age-stratified analysis, based on cases in China, showed that the secondary attack rate in symptomatic children was 4.7% compared with 17.1% in adults (≥ 20 years of age) (Li et al.) , and that the probability of infection in children was 0.26 times lower than in elderly people (≥ 60 years of age). (Jing et al.) A study from Italy, estimates the attack rate among contacts of 0-14 year old cases was 22.4%, which is higher than that of working-age adults (approximately 13.1%). (Fateh-Moghadam et al.) In South Korea, the attack rate among household contacts of index cases aged 0-9 years and 10-19 years was 5.3% and 18.6%, respectively, indicating transmission potential in both children and adolescents, and possibly more effective transmission in adolescents than in adults. (Park et al.) A report from US provides additional evidence of the role of children and adolescents in transmission. The study reported an overall attack rate of 44% among attendees (i.e. children, adolescents and adults) of an overnight camp where a teenage staff was the index case. The age-stratified attack rates were 51% among those aged 6-10 years; 44% among those aged 11-17 years and 33% among those aged 18-21 years. (Szablewski et al.) Overall, a systematic review of similar studies suggest that children under 10 years of age are unlikely to drive outbreaks of COVID-19 in daycares and schools. (National Collaborating Centre for Methods and Tools Review) Older teenagers, in high school and college and adults are more likely to be infected and more likely to transmit the coronavirus than are children under age 10 than younger children. More research is needed in the area.

Studies also suggest that children are less likely to show clinical symptoms compared to adults and/or have mild disease. (Davies et al.) Estimates of asymptomatic paediatric cases range from 4% to 28%. (Dong et al., Stregn et al.) A systematic review presenting data on paediatric patients with COVID-19 from China, Spain, Iran, the Republic of Korea and the United States identified 14.9% asymptomatic cases in children. (Heald-Sargent et al.) Others have reported 18% asymptomatic cases in a meta-analysis of 551 laboratory-confirmed cases in children (Zhang et al.) and 16% asymptomatic cases among a European cohort of 582 children. (Götzinger et al.) Presence of asymptomatic transmission further complicates tracking secondary attack rates from child index cases.

## Impact of infectious individuals and crowded settings

Evidence points to the phenomena that a small number of people are responsible for seeding a vast majority of new COVID-19 infections. The science of COVID-19 dispersion is not fully understood. But experts agree that some people emit more virus more others, (Asadi et al.) while others seem to develop higher amounts of the virus in their system, increasing their odds of transmitting the virus. (Jones et al.) One study estimates that about 62%of transmissions to multiple individuals happened when the index case was pre-symptomatic. (Goyal et al.) Children and adolescents can spark outbreaks within families, even when their symptoms




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are mild — and even, in some cases, where initial tests are negative. A 13-year-old girl who became infected with the coronavirus just before a three-week family gathering infected eleven other relatives. (Schwartz et al.)To date, no study has been published that identifies individual characteristics that might account for an infected person's degree of infectiousness or could otherwise help predict who may be more likely to infect multiple individuals.

Scientists use a value called the dispersion factor (*k*), which indicates the likelihood that a particular disease will spread in clusters. The lower *k* is, the more transmission comes from a small number of people. Some studies estimates that *k* for COVID-19 could range from 0.1 to 0.5, meaning 10% of cases lead to 80% of the spread. (Endo et al., Riou et al.) Given these early estimates, particular attention should be given to the prevention of possible uncommon but explosive transmission events, while the establishment of sustained transmission chains from single cases cannot be ruled out. The previous experience with SARS-CoV has shown that established practices of infection control, such as early detection and isolation, contact tracing and the use of personal protective equipment, can stop such an epidemic.

In case of COVID-19, events sparked by few individuals have caused clusters of cases in cities around the world. In Hong Kong, the study estimated that 20% of infected people were responsible for 80% of onward infections. (Dillon et al.) Another study concluded that 80% of transmissions were caused by 8-9% of cases, based on data from Shenzhen in southern China. (Qifagn et al.) The latest estimate from India supports substantial variation in individuals' likelihood of transmitting: no secondary infections were linked to 71% of cases whose contacts were traced and tested, while 5% of people accounted for 80% of the infections detected by contact tracing. (Laxminarayan et al.) The largest outbreaks, where more than 100 people were infected, involved hospitals, elder care facilities, worker dormitories (including one event with 800 infections), and ships. Outbreaks infecting 50 to 100 people were most common in indoor religious gatherings, schools, bars, sporting events, and retail stores.

In addition, the possibility of the virus spreading though aerosols may be a key element to large spreading events. An infected person could seed a poorly ventilated indoor space with virus without even getting physically close to all the people they end up infecting. Modeling studies of virus dispersion dynamics suggests that just reducing exposure opportunities, such as events with more than 20 people, could get the virus spread under control. (Goyal et al.)

Go to alberta.ca/covid19 for the most up-to-date information on restrictions to contain COVID-19.




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