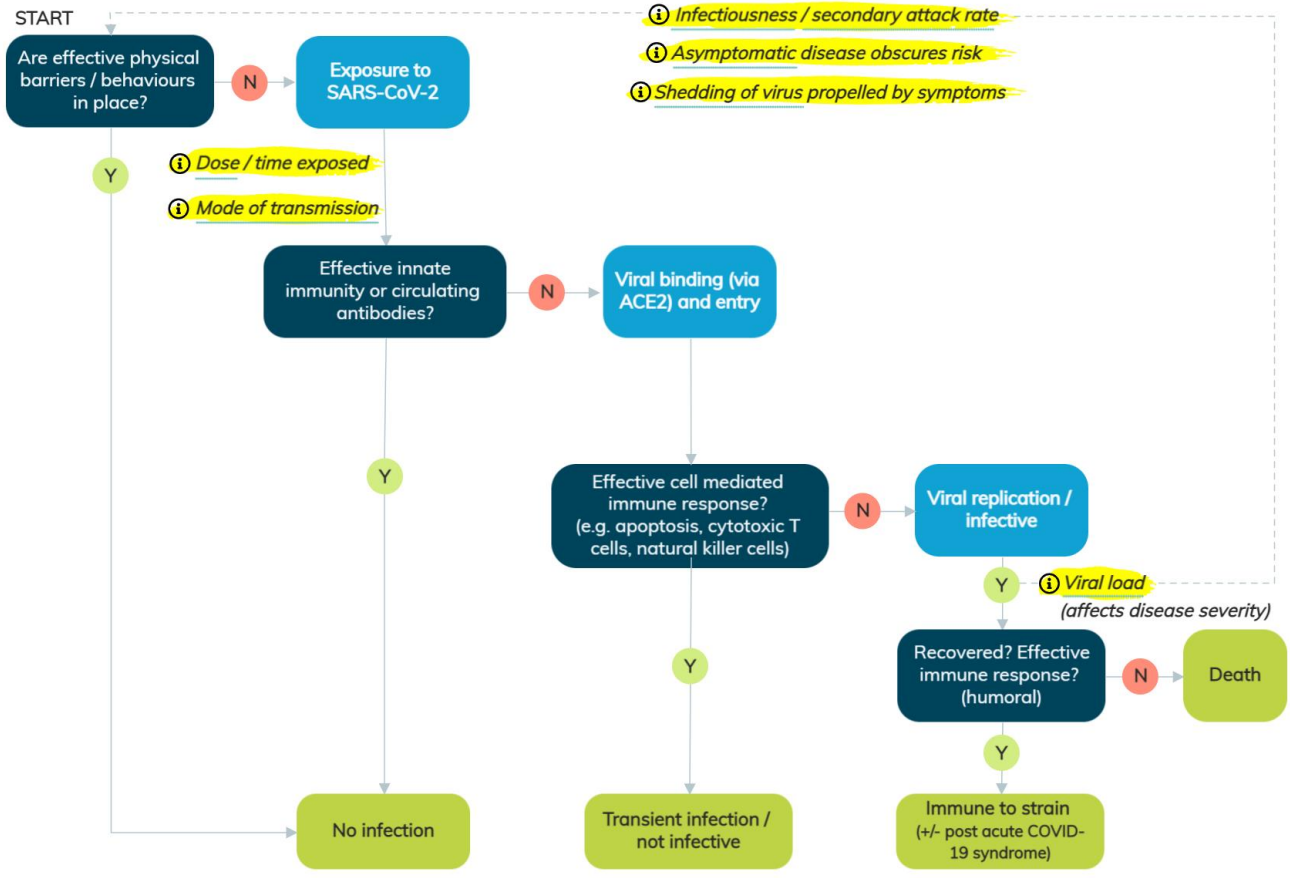
Evidence table

COVID-19 transmission

12 August 2022

This is the final version of the living evidence table on COVID-19 transmission. This evidence table was last updated in July 2022. The information in this table is no longer monitored on a regular basis.

Transmission concepts and current knowledge



Exposure to COVID-19 flow chart

The flowchart depicts factors that influence the transmission of and immunological response to SARS-CoV-2, the virus that causes COVID-19.

It starts with a question: are effective physical barriers in place? If yes, there is no infection. If no, and there is exposure to SARS-CoV-2, a range of factors affect risk of infection and developing disease.

What is the viral dose or time that a person is exposed to virus? What is the mode of transmission – is it through contact, droplets, aerosols or fomites?

A key question is whether there is effective innate immunity or circulating antibodies? If the answer to that question is yes, then there is no infection. If the answer is no, the virus is able to bind to host cells via the ACE2 receptor and enter.

The next question is whether there is an effective cell mediated immune response – do host cytotoxic T-cells and natural killer cells act to remove the infected cells? If yes, then the infection was only transient with no symptoms and the host would not have been infective. If no, then the virus replicates in the host cells and the host becomes infective – able to spread the virus. The extent of spread is shaped by the viral load, shedding, symptoms, and the secondary attack rate. Viral load also affects disease severity in the host.

The next question is whether the host recovers – mounting an effective humoral response with antibody production. If yes, then the host will be immune to the infecting strain, but may be affected by post-acute COVID-19 syndrome. If no, then the host dies.

Table 1. Transmission concepts and current knowledge

Topic	Definition	Current understanding for SARS-CoV-2 and COVID-19
Mode of transmission	The route or method of transfer by which infectious microorganisms (viruses, bacteria, parasites, etc) move or are carried from one place to another to reach a new host.	SARS-CoV-2 is primarily transmitted between people through respiratory droplets and contact routes. Short-range aerosol transmission can occur within poorly ventilated and crowded indoor spaces and can travel more than 1 metre (long-range). One study found that airborne infectivity of SARS-CoV-2 decreases over the first 20 minutes following aerosolisation to 10% of the initial value, with the majority of SARS-CoV-2 inactivated within 10 minutes. No strong, consistent evidence for: fomite transmission, direct transmission through urine or faeces, intrauterine transmission, transmission through breast milk and ocular transmission.
Setting-specific transmission **(See also secondary attack rate)**	Patterns of disease spread associated with a particular context or situation Studies usually compare secondary attack rates in different settings.	Information relating to transmissibility of the Omicron variant is provided in the Living Evidence table - SARS-CoV-2 variants. The World Health Organization states that based on current evidence, Omicron variant has a clear growth advantage over Delta variant due to immune evasion and potential intrinsic increased transmissibility. The impact of geo-environmental factors on transmission shows distinct spatiotemporal heterogeneity.

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		Household • Households have the highest transmission rates (SAR 21.1%) with significantly higher transmission for household exposures exceeding 5 days. • Mixed findings for transmission risk for adults compared to children: one systematic review found no difference in transmission from children compared with adults; whilst others found evidence for reduced transmission potential from and to individuals under 20 years of age. • Omicron infection attack rates similar across age groups for household contacts, including those aged 0-4 years. **Other** • Most frequent and heavily contaminated areas in hospital settings were air outlets and hospital floors. • Close to 40% of hospital outbreaks did not report a clear primary case and most primary cases (82.9%) did not have prior contact with people who have tested positive for COVID-19. • Risk of outdoor transmission is low compared to indoor settings. • For indoor settings, one or more factors plausibly increased the likelihood of long-distance airborne transmission, particularly insufficient air replacement (very low certainty), directional air-flow (very low certainty), and activities associated with increased emission of aerosols, such as singing or speaking loudly (very low certainty).
Minimal infectious dose (MID)	Smallest amount of a pathogen that is required to establish an infection	There is limited evidence that the minimum infective dose of COVID-19 in humans is higher than 100 particles. In a 'Human Challenge Study' in the UK, of 34 healthy volunteers aged 18-34 inoculated with 10 $TCID_{50}$ of a wild-type virus, approximately half became infected.
Dose response	The relationship between the infecting dose (the quantity of viable virus) and disease severity	Some observations support a dose response, but this is not established. Observational studies of three clusters of individuals exposed to diverse inoculum, developed divergent clinical forms of disease. In clusters where physical distancing and wearing masks were not followed, a larger proportion of individuals developed severe disease.
Viral load	The amount of measurable virus inside an individual (often	**Viral load (VL) dynamics**

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	measured in a standard volume of plasma, or blood)	• VL in upper respiratory tract peaks around symptom onset (or few days after) and becomes undetectable 2 weeks after symptom onset. Some evidence of prolonged VL in stool samples. • VL peaks around 4.7 days in the throat and 6.2 days in the nose post-inoculation. Peak VL was higher in nasal samples than in throat samples. • Higher VL was found in Delta and Alpha variants (compared to earlier variants), particularly in pre- or asymptomatic cases. • Omicron infections feature lower peak viral RNA and a shorter clearance phase than Delta among both the vaccinated and unvaccinated populations. Preliminary data suggest that BA.2 infections have a higher viral load than BA.1 and Delta in the upper pharynx. • Fine aerosols (≤5μm) generated during talking and singing contain more VL than coarse aerosols (>5μm). Talking and singing emit significantly more detectable RNA in fine aerosols than breathing. **Viral load and age** • Positive association between VL and age. • Children and adolescents have lower first-positive VL than adults (aged 20-65), and the time from onset of shedding to peak VL is 4.3 days. • Infants younger than 6 months showed higher VL than any other age group (0-9 years). Children older than 7 months display lower VL compared to those found in adults. • Symptomatic and younger children (under 5 years) have higher VL than asymptomatic children. **Viral load and severity** The evidence on the correlation between VL and symptom status is mixed. • Some studies suggest no difference, with VL similar in asymptomatic vs symptomatic cases; • While others suggest pre-symptomatic and symptomatic cases tend to have a higher VL than asymptomatic cases. • Inconclusive results of the relationship between COVID-19 severity and VL have also been reported. • Regarding VL and mortality, one study found that for each additional unit of viral RNA detected, there was a 7% increase in mortality risk; while another found VL

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		on admission was not independently associated with ICU admission or death. **Viral load and infectivity** • Positive correlation between VL and infectivity. • Threshold VL for a 50% probability of transmission is approximately $10^{7.5}$ viral RNA copies/mL. Infected persons are likely to be above this threshold for about 1 day. • Larger effect of VL in household contacts vs non-household contacts, with a transmission probability of 48% when VL > 10^{10} copies per mL. • Highly infectious cases had VLs of at least 9.0 $\log_{10}$ RNA copies per swab, compared to an average of 6.39 $\log_{10}$ for all cases. • Cluster size is positively associated with the presence of individuals with a high VL in significant clusters. **Viral load and vaccines** The evidence on the correlation between VL and vaccination status is mixed. • There is evidence to suggest that vaccinated cases with breakthrough infections have a lower (especially a short time after vaccination) or similar peak VL; and a faster decline in viral RNA shedding and infectious virus shedding than unvaccinated cases. • Some studies have shown vaccine favourable effect on VL start to wane two months after two doses of mRNA vaccines and vanished at around five to six months. The effect of vaccine on reducing breakthrough infection VL was found to be restored after a booster dose.
Viral shedding	The expulsion and release of viable virus progeny following successful reproduction during a host-cell infection. It can refer to viral release from one infected cell; from one part of the body to another; and from an infected host into the environment. During COVID-19, *shedding* has also	A systematic review reported mean SARS-CoV-2 **RNA shedding** duration to be: • 17·0 days (max shedding duration 83 days) in upper respiratory tract • 14·6 days (max 59 days) in lower respiratory tract • 17·2 days (max 126 days) in stool • 16·6 days (max 60 days) in serum samples • Positively associated with age • Similar to findings reported by another systematic review The likelihood of detecting replication-competent virus after 10 days following symptom onset is very low in people with mild

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	been used to refer to the release of non-viable viral genetic material or particles into the environment	to moderate disease. For people with severe disease, 88% do not shed infectious virus beyond 10 days. Several case studies report prolonged infectious viral shedding in immunocompromised patients, ranging from 70 days to four months post symptom onset. **Asymptomatic cases** Mixed findings of viral shedding in those with persistently asymptomatic infection: • Asymptomatic cases had faster viral clearance than symptomatic cases; • Asymptomatic cases had longer duration of shedding. • Note: Studies use PCR, rather than culturing methods, which may mean shedding of live virus is overstated. **Gastrointestinal shedding** • Gastrointestinal shedding might occur in a substantial portion of children and might persist long after negative respiratory testing. The pooled prevalence of gastrointestinal SARS-CoV-2 RNA in children with COVID-19 was 86%. After respiratory specimen had become negative, 72% had persistent shedding in gastrointestinal specimens. The gastrointestinal RNA had a positive test result. • The median clearance time in stools was 22 days. After 34 days, 19.9% of patients have a persistent detection in stools.
Incubation period	The time between exposure to the virus and symptom onset,	The median incubation period for COVID-19 is 4.9 – 7 days, with a range of 1 – 14 days. Most people who are infected will develop symptoms within 14 days of infection. A systematic review reported that the weighted pooled mean incubation period is 6.5 days (95% CI: 5.9, 7.1). The incubation period of the Omicron variant is shorter than that of Delta and the other previous variants. For Omicron BA.1 sub-lineage which is S-gene target positive, the median incubation period is around 3 days.
Pre-symptomatic	Refers to the period before symptoms appear among infected individuals	Multiple studies have shown that people infect others before becoming ill. However, estimates of the proportion of secondary cases acquired from pre-symptomatic persons vary: • 44% of secondary cases were acquired from cases that were pre-symptomatic at the time of transmission.

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		• Pre-symptomatic transmission ranged from 45.9% to 69.1%. The mean transmission time was 2.6 days before and 1.4 days after the infector symptom onset. • One systematic review reported that the proportion of all transmission from pre-symptomatic individuals was higher than from asymptomatic individuals. Another systematic review, however, has been unable to quantify the likely fraction of transmission occurring from asymptomatic or pre-symptomatic individuals.
Asymptomatic	Without signs or symptoms of the disease	**How many COVID-19 cases are asymptomatic?** Multiple systematic reviews have found varied rates of asymptomatic infection: • 4% to 41%; • 10% to 20%; • 33.3%; • 36.9% • 40.50%. • The percentage of asymptomatic infections was found to decrease with age. Another systematic review and meta-analysis showed asymptomatic transmission among familial clusters, adults and health care workers to be 15.72%, 29.48% and 0%, respectively. **Children** • Asymptomatic transmission among children was 21.1% - 24.09%. • A report by National Centre for Immunisation Research and Surveillance (NCIRS), Australia, found 98% of infected children had asymptomatic or mild infection during the Delta outbreak in NSW. **Are asymptomatic cases infectious?** • Transmission can occur from persistently asymptomatic persons, although they seem less likely to transmit. • SAR of symptomatic index cases was higher than asymptomatic cases. **Antibody responses** • Asymptomatic SARS-CoV-2 patients have short-lived antibody responses (around 69 days), compared

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		to recovered (211 days) and persistent (257 days) cases. • Rates of non-responders (seronegative) were higher among asymptomatic infections than symptomatic infections. • A study of 69 children and adolescents with asymptomatic or mild symptomatic infection found robust antibody response at the time of acute infection, and 2 and 4 months after the acute infection.
Reinfection	A person was infected once, recovered, and then later became infected again.	• Re-infection among recovered COVID-19 patients: 3 per 1000 patients. Recurrence and hospital readmission among recovered COIVD-19 patients: 133 and 75 per 1000 respectively. • Risk of reinfection decreased by 80·5–100% among those with previous COVID-19 infections. • Reinfection in unvaccinated individuals had 90% lower odds of resulting in hospitalization or death than primary infections. • 5.4-fold increased risk of reinfection with the Omicron variant compared with the Delta variant. • Lower reinfection risk in children with the Delta variant compared to adults
Infectiousness	The capacity to spread disease by transmitting a pathogen to others.	Persons who have SARS-CoV-2 with or without symptoms can transmit. • Transmission can occur from persistently **asymptomatic** persons, although they are less likely to transmit. Viral titers normally peak within 3 days of the first positive test. • Among symptomatic patients, a report found the SAR increased with severity of the index case and specific symptoms of fever and expectoration. • Transmission potential is greatest in the first 2 days before and 1-3 days after onset of symptoms in the index patient. Infectiousness declined rapidly within a week of symptom onset. • Period of infectiousness is shorter than the duration of detectable RNA particle shedding.
Transmission dynamics	The pattern and rate of spread from infectious to susceptible hosts.	The virus has heterogeneous transmission dynamics. Most persons do not transmit virus, whereas some cause many secondary cases in transmission clusters called "superspreading events." Early studies estimate 80% of secondary infections arose from 10-20% of index cases. Subsequent modelling estimated

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		approximately 4%-10% of cases lead to 80% of secondary transmissions. A systematic review on setting specific transmission rates estimated SAR for asymptomatic index cases was ~1/7th, and for pre-symptomatic 2/3rd of those for symptomatic index cases. **Vaccination and transmission** • Vaccination of healthcare workers is associated with a decrease in documented cases of COVID-19 among members of their households. • Risk of household transmission is lower in vaccinated cases as shown in studies from Israel and England. • Household transmission was 40 to 50% lower in households of index patients who had been vaccinated 21 days or more before testing positive. • Vaccination reduces the risk of Delta variant infection, however, fully vaccinated individuals with breakthrough cases can still transmit the virus to fully vaccinated contacts. • Emerging evidence of moderate transmission prevention provided by Comirnaty (Pfizer) and Vaxzevria (Oxford/AstraZeneca) vaccines. Data for other vaccines are scant. • Vaccine-associated reductions in transmission of the Delta variant were smaller than those with the Alpha variant, and reductions in transmission of the Delta variant after two Comirnaty vaccinations were greater than after two Vaxzevria vaccinations. • The overall risk of infection was lower for the fully vaccinated compared to that of the unvaccinated, especially for variants other than Delta.
Secondary attack rate	A measure of the frequency of new cases among the contacts of known patients	**In households** • Studies have found household SAR to be 16.6% - 19.9%. • SAR was higher in households: from symptomatic index cases (compared to asymptomatic or pre-symptomatic index cases); to adult contacts than to child contacts; to spouses than to other family contacts; among contacts of similar age; and in households with one contact than households with three or more contacts. • SAR from child index cases were lower compared to adult index cases. • Paediatric COVID-19 only comprised a minority of the household transmission. The total pooled household SAR of child index cases and contacts were 0.20 and

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		0.24. Younger children were as susceptible as the older children. • A rapid review found that children > 10 years may spread the virus more easily to family members than younger children, and may even spread it as easily as adults. • Index cases aged 65 years or older were more likely to infect their contacts than other adults or children. **Variants** • Substantially higher transmissibility is associated with Alpha, Beta, and Gamma variants of concern.^ • SAR is 1.31 times higher for variants of concern (B.1.1.7 and N501Y) than non-variants of concern. • Asymptomatic and pre-symptomatic index cases of variants of concern had even higher SAR compared to that of non-variants of concern (1.91 times and 3.41 times higher, respectively). • Household SAR estimates range from 13.6% to 31% for Omicron compared to 10.1% to 21% for Delta. • Data from England suggests a 10.6% SAR for BA.1 and 13.6% SAR for BA.2 in household settings. The SAR for non-household settings is estimated to be 4.2% and 5.3% for BA.1 and BA.2, respectively. **Other settings** • In healthcare settings, SAR was 0.7%. • Endotracheal intubation, noninvasive ventilation, and administration of nebulized medications increase the odds of healthcare workers contracting SARS-CoV-2. • Limited evidence for other settings with high SAR include: meetings (84.6%), a chalet (73.3%), at choirs (70.4%, 53.3%), eating with a case (38.8%, 28.6%) and traveling with a case (80.8%, 46.6%), religious events (14.8%). **Educational settings** • SAR at daycare and schools was found to be 2.54 cases per index case and 0.5% of close contacts positive from child index cases only. • SAR reported by the NCIRS in all schools in NSW during Term 4 2021 was 2.9% overall, and lowest in high schools (1.0%). An earlier report found the SAR from primary cases in educational settings to be 4.7%. SAR from a child or an adult primary case to a child close contact in education settings was 1.6% and 7.0%, respectively.

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		• Highest SARs reported in indoor, high-contact sports settings, staff meetings/lunches and elementary school classrooms, early childhood education and care services between staff. • SARs were lower in encounters with relatives (3.5% to 6.6%), social contacts (0.9% to 2.2%), and at workplace or school (0% to 5.3%). • Lower probability of being positive to SARS-CoV-2 in children who had school contacts or who had flu symptoms compared to children who had household contacts.

Methods

An initial PubMed search for Systematic reviews was conducted on the 17 February 2021. Supplementary topic specific searches were undertaken when evidence in systematic reviews was not sufficient and individual studies were included, but these do not represent a complete list of studies. Grey literature including publications from key organisations such as the World Health Organisation were also included.

Notes

*Preliminary data, not fully established, in some cases small numbers or short follow up; interpret with caution

^ Commentary grey literature, pre-peer review or news

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