The evidence on COVID-19 transmission

COVID-19 is a multisystem disease that spreads easily from person to person. Current evidence suggests that SARS-CoV-2 (the virus that spreads COVID-19) is most commonly transmitted through *respiratory droplets* (which can enter the mouth, nose and eyes), while the infected person is speaking, singing, coughing, etc. in close proximity of another person (typically 1-2 meters) for a prolonged period of time.[1] Additional ways the virus can be transmitted is through *fomites* (when respiratory droplets land on surfaces and are spread through physical contact), and aerosol transmission (a smaller respiratory droplet known as a 'droplet nuclei'). Evidence has shown aerosol-generating medical procedures create a high risk of aerosol transmission in healthcare settings[2], and there is growing evidence that aerosol transmission (likely combined with respiratory droplet transmission) may play a role in the transmission of the virus in closed and crowded spaces (such as bars, restaurants, fitness class or choir practice).

Individuals with COVID-19 are most infectious around 2 days prior to showing symptoms, and into their initial symptom development of the disease (this is different than the common flu, which is most infectious while symptoms are strongest). The virus has also been shown to spread by asymptomatic people infected with SARS-CoV-2 through the same transmission patterns described above.

Explanation of terms: What are the different transmission pathways of the virus?

Respiratory droplets are defined as droplets expelled by infected people when they cough, sneeze, talk or sing and are measured as >5-10 µm in diameter, whereas droplets that are smaller (≤5µm in diameter) are referred to as *droplet nuclei* or aerosols. Respiratory droplets play an important role in the transmission of several respiratory illnesses including influenza virus, the common cold (rhinovirus) as well as corona viruses (including those that cause the common cold as well as SARS and COVID-19). Typically respiratory droplets travel an estimated 1-2 meters (or 6 feet) in the air from their point of origin (i.e. the person speaking, singing, etc.).

'Airborne' or aerosol transmission is when an infectious agent (like a virus) is carried in droplet nuclei (also known as aerosols) that are expelled from an infectious person; these aerosols containing the virus remain infectious when suspended in the air over longer distances and time than respiratory droplets.[3] An example of a respiratory disease that is known to spread easily through aerosols is measles or tuberculosis. Aerosols have been found to play a role in transmission of SARS-CoV-2 in medical facilities where aerosol-generating procedures are conducted, and in other non-medical enclosed spaces, and crowded areas with poor ventilation. Enclosed spaces where people are required to speak at higher volumes close together (such as bars or clubs) have also been linked with potential aerosol transmission of SARS-CoV-2.

Fomites are defined as the contaminated surfaces that respiratory droplets from infected individuals land on. As environmental contamination has been documented in several reports for COVID-19, it is possible that people can also be infected by touching these surfaces and touching their eyes, nose or mouth before cleaning their hands. However, this is believed to cause fewer cases than droplet or aerosol transmission.

Emerging Evidence

Continued efforts are underway to better understand and demonstrate the relative importance of different transmission routes; the role of airborne or aerosol transmission in the absence of aerosol-generating procedures; the dose of virus required for transmission to occur (i.e. whether inhaling more quantity of virus leads to more severe illness); the settings and risk factors for superspreading events (where many people are infected at the same time); and the extent of asymptomatic and pre-symptomatic transmission. [4] Key points from a review of the literature include:

- A Review in the Lancet Respiratory Medicine suggests that SARS-CoV-2 is transmitted by both small and large particle aerosols. Key messages include that increased protection is observed in healthcare settings when surgical masks are worn by patients as well as staff. This also has implications for non-medical settings, where universal mask use decreases the overall amount of respiratory droplets in the environment.[5]
- There have been several studies in hospital and lab settings that have found air samples with SARS-CoV-2 virus;[6789] however, at this time, the amount of viable virus was low or not existent (i.e. in these air samples there was not enough virus to cause infection).
- Studies of infection rates among healthcare workers are mixed, with several studies showing infection rates that mirror the surrounding population, and others showing increased risk among healthcare workers.[10] Studies showing increased risk among healthcare workers were also linked to inadequate PPE supply.[11]
- There have been increasing reports of likely transmission of SARS-CoV-2 on long flights[12], but less evidence pointing to transmission on shorter flights. Where people have (likely) been infected on long flights, they have typically been seated very near a COVID-19 case.
- Evidence of potential aerosol transmission of SARS-CoV-2 has been linked to some outbreaks in bars and restaurants, emphasizing that louder, crowded and poorly ventilated conditions are a significant risk factor for COVID-19 transmission.
- Increasing evidence suggests over-dispersion transmission of the virus, meaning that COVID-19 seems to be spread most commonly through super-spreading events.[13]

Why do questions keep emerging about airborne vs. non-airborne transmission?

- Since SARS-CoV-2 is a new virus, scientists are continuing to learn about it, from how it is transmitted to how it causes illness. As new evidence emerges sometimes original assumptions must shift, making communication about COVID-19 transmission more challenging.
- The US CDC recently updated their guidance on COVID-19 to include airborne transmission. While the organization recognized the evidence for airborne transmission, it was highlighted that the most common pathway of transmission is likely still respiratory droplets via close contact, followed by airborne transmission, followed by fomites. Safety precautions and recommendations for the public remain the same (including physical distancing, avoiding crowded and poorly ventilated spaces, face coverings, hand washing and cough etiquette).
- For viruses that are *primarily* spread through airborne or aerosol transmission, we see much higher rates of transmission between people sharing accommodation. For example, in home care settings with a case of measles, there is an 85% chance of non-immune household members becoming infected; observations so far with COVID-19 are that on average 10% of household members become infected when someone in their home has COVID-19. Therefore, while aerosols may play a role in transmission, it is likely that aerosols transmission of COVID-19 in day-to-day life is not the primary spreader of this disease.[14]

What transmission patterns are responsible for most of the spread of COVID-19?

Emerging evidence points towards SARS-CoV-2 acting in **super-spreader transmission patterns**[15] with the majority of new cases are caused by a minority of infected individuals. Multiple studies have found that a small percentage (as few as 10 to 20 per cent) of infected people may be responsible for as much as 80 or 90 per cent of transmission to new people. Many infected people appear to transmit it to one or no other people.

A study in Hong Kong found that about 19 per cent of cases were responsible for 80 per cent of transmission, and 69 per cent of cases did not transmit the virus to anyone at all.[16] In recent research from India (the largest contact tracing project ever recorded), researchers found that 71 per cent of infected individuals did not infect any of their contacts, while a mere eight per cent of infected individuals accounted for 60 per cent of new infections.[17]

These "super-spreaders" may often be implicated in one or more superspreading events, where many people are infected at the same time. The risk of superspreading is higher in places where aerosol transmission is easier: in places where people spend a significant amount of time in a crowded and poorly ventilated space with someone who is infectious, whether they have symptoms or not, and where people are talking loudly, singing, or otherwise generating a lot of respiratory droplets or aerosols containing the virus.

So, what does this mean?

From a public health perspective, the **ways in which the public can protect themselves from COVID-19 remain the same**. These include **physical distancing, sneezing and cough etiquette, face coverings**[18] **and hand hygiene**. Keep **social gatherings to small groups** and spend as much time as possible in open spaces (i.e. **avoid closed, poorly ventilated, and crowded areas**) to reduce transmission of COVID-19.

The **high dispersion of COVID-19**—where transmission is primarily caused by superspreading events, rather than evenly dispersed transmission—supports continued investment in contact tracing, including backward contact tracing to identify people infected during super-spreading events, and continued support and interventions on locations and contexts where superspreading events are more likely to occur.

More on emerging evidence can be found on a weekly basis on the Health Help Desk: COVID-19 Weekly Updates.

Sources

[1] WHO: Transmission of SARS-CoV-2: implications for infection prevention precautions

[2] Joshua L Santarpia, Vicki L Herrera, Danielle N Rivera, Shanna Ratnesar-Shumate, St. Patrick Reid, Paul W Denton, Jacob W.S. Martens, Ying Fang, Nicholas Conoan, Michael

V Callahan, James V Lawler, David M Brett-Major, John J Lowe. The Infectious Nature of Patient-Generated SARS-CoV-2 Aerosol. doi**:** https://doi.org/10.1101/2020.07.13.20041632

[3] WHO: Transmission of SARS-CoV-2: implications for infection prevention precautions
[4] WHO: Transmission of SARS-CoV-2: implications for infection prevention precautions

[5] Fennelly, KP. Particle sizes of infectious aerosols: implications for infection control. The Lancet Respiratory Medicine, Published:July 24, 2020DOI:https://doi.org/10.1016/S2213-2600(20)30323-4.

[6] Chia, P.Y., Coleman, K.K., Tan, Y.K. *et al.* Detection of air and surface contamination by SARS-CoV-2 in hospital rooms of infected patients. *Nat Commun* **11,** 2800 (2020). https://doi.org/10.1038/s41467-020-16670-2

[7] Guo Z, Wang Z, Zhang S, et al. Aerosol and Surface Distribution of Severe Acute Respiratory Syndrome Coronavirus 2 in Hospital Wards, Wuhan, China, 2020. *Emerging Infectious Diseases*. 2020;26(7):1583-1591. doi:10.3201/eid2607.200885.

[8] Santarpia, J.L., Rivera, D.N., Herrera, V.L. *et al.* Aerosol and surface contamination of SARS-CoV-2 observed in quarantine and isolation care. *Sci Rep* **10,** 12732 (2020). https://doi.org/10.1038/s41598-020-69286-3

[9] Jie Zhou, Jonathan A Otter, James R Price, Cristina Cimpeanu, Danel Meno Garcia, James Kinross, Piers R Boshier, Sam Mason, Frances Bolt, Alison H Holmes, Wendy S Barclay, Investigating SARS-CoV-2 surface and air contamination in an acute healthcare setting during the peak of the COVID-19 pandemic in London, *Clinical Infectious Diseases*, , ciaa905, https://doi.org/10.1093/cid/ciaa905

[10] Long H. Nguyen, David Alden Drew, Amit D. Joshi, Chuan-Guo Guo, Wenjie Ma, Raaj S. Mehta, Daniel R. Sikavi, Chun-Han Lo, Sohee Kwon, Mingyang Song, Lorelei A. Mucci, Meir Stampfer, Walter C. Willett, A. Heather Eliassen, Jaime Hart, Jorge E. Chavarro, Janet Rich-Edwards, Richard Davies, Joan Capdevila, Karla A. Lee, Mary Ni Lochlainn, Thomas Varsavsky, Mark Graham, Carol H. Sudre, M. Jorge Cardoso, Jonathan Wolf, Sebastien Ourselin, Claire Steves, Timothy Spector, Andrew T. Chan. Risk of COVID-19 among frontline healthcare workers and the general community: a prospective cohort study. doi**:** https://doi.org/10.1101/2020.04.29.20084111 ***[pre-print]***

[11] https://doi.org/10.1101/2020.04.29.20084111 ***[pre-print]***

[12] Khanh NC, Thai PQ, Quach H-L, Thi NA-H, Dinh PC, Duong TN, et al. Transmission of severe acute respiratory syndrome coronavirus 2 during long flight. Emerg Infect Dis. 2020 Nov [*date cited*]. https://doi.org/10.3201/eid2611.203299

[13] Ramanan Laxminarayan, R, Wahl, B, Dudala, S.R. *et al.* Epidemiology and transmission dynamics of COVID-19 in two Indian states. Science (30 Sep 2020)

[14] American Public Health Association 23 September Newswire

[15] Tufekci, Zeynep. This Overlooked Variable is the Key to the Pandemic. It's not R. *The Atlantic* 1 Oct 2020 (first published 30 Sep 2020).

[16] Adam, D.C., Wu, P, Wong, J.Y. *et al*. Clustering and superspreading potential of SARS-CoV-2 infections in Hong Kong. *Nat Med* (2020). https://doi.org/10.1038/s41591-020-1092-0

[17] Ramanan Laxminarayan, R, Wahl, B, Dudala, S.R. *et al.* Epidemiology and transmission dynamics of COVID-19 in two Indian states. Science (30 Sep 2020)

[18] Hendrix MJ, Walde C, Findley K, Trotman R. Absence of Apparent Transmission of SARS-CoV-2 from Two Stylists After Exposure at a Hair Salon with a Universal Face Covering Policy — Springfield, Missouri, May 2020. MMWR Morb Mortal Wkly Rep 2020;69:930-932.
DOI: http://dx.doi.org/10.15585/mmwr.mm6928e2external icon.

Additional Resources & Scientific Evidence

Jefferson T, Foxlee R, Del Mar C, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. *BMJ*. 2008;336(7635):77-80. doi:10.1136/bmj.39393.510347.BE

Klompas M, Baker MA, Rhee C. Airborne Transmission of SARS-CoV-2: Theoretical Considerations and Available Evidence. *JAMA*. 2020;324(5):441–442. doi:10.1001/jama.2020.12458

Morawska, Lidia et Cao, Junju. Airborne transmission of SARS-CoV-2: The world should face the reality. Env International, Vol. 139, June 2020, 105730. https://doi.org/10.1016/j.envint.2020.105730

Liu, Y., Ning, Z., Chen, Y. *et al.* Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. *Nature* **582,** 557–560 (2020). https://doi.org/10.1038/s41586-020-2271-3

Renyi Zhang, View ORCID ProfileYixin Li, Annie L. Zhang, View ORCID ProfileYuan Wang, and Mario J. Molina. Identifying airborne transmission as the dominant route for the spread of COVID-19. PNAS June 30, 2020 117 (26) 14857-14863; first published June 11, 2020; https://doi.org/10.1073/pnas.2009637117.

Santarpia JL, Rivera DN, Herrera V, Morwitzer MJ, Creager H, Santarpia GW, et al. Transmission potential of SARS-CoV-2 in viral shedding observed at the University of Nebraska Medical Center (pre-print). MedRxiv. 2020 doi: 10.1101/2020.03.23.20039446. ***[pre-print]***

US CDC: How COVID-19 spreads (updated 5 October 2020)

Nick Wilson, Stephen Corbett, et Euan Tovey. Airborne transmission of covid-19. *BMJ* 2020; 370 doi: https://doi.org/10.1136/bmj.m3206 (Published 20 August 2020)Cite this as: BMJ 2020;370:m3206.

Pre-print articles *have not yet undergone stringent peer-review and are released during the pandemic for scientists and doctors to have all evidence available to them in real time. Please note that sometimes after peer review of the article methods and conclusions are deemed by the scientific community to be not reliable.*