Transmission Routes of SARS-Cov-2: Literature Review as of August 14, 2020

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With COVID-19 rapidly spreading throughout the world, there is great interest in determining the main method of transmission. By knowing the main route of transmission, proper mitigation can help prevent further spread. For example, if it is found that SARS-Cov-2 spreads mainly via fomites, or materials that carry infectious virus that you touch, then frequent cleaning would be the best method to stop further spread of the virus.

Currently, transmission from droplets is recognized as the predominant route for SARS-Cov-2. But, to pinpoint a specific route takes time as transmission studies are difficult to complete, so we are reliant on using mathematical modeling, experimental studies, and contact tracing from actual outbreaks. Besides the information supporting droplet transmission, there is evidence that suggests that SARS-Cov-2 may also be spread through fomites and aerosols, but much less than the droplet route. Below is a brief summary of evidence for specific routes of transmission as they pertain to the current pandemic.

**Droplet**

Droplet transmission refers to droplets released by an infected person larger than a standard, accepted cutoff of 5\(\mu\)m. Droplets are generally created during high expulsion activities such as sneezing or coughing and are created simultaneously to aerosols described below.\(^1\), \(^2\) Transmission occurs when droplets from an infectious individual enter a new host, for example, when a healthy individual inhales after an infectious individual has sneezed in close proximity. This route of transmission has received attention as other respiratory viruses such as SARS, MERS, and influenza also transmit via droplets. Currently, this is the most plausible transmission route and both the CDC and WHO view this as the main route of transmission.\(^3\) Additionally, specific outbreak investigations give evidence for this being the main route of transmission. For example, the Skagit county choir practice in Washington could have propagated via droplets, in addition to possible aerosol spread, from the close contact of attendees during the 2.5 hour practice.\(^4\) And, early transmission has been shown to occur from close contacts since the beginning of the outbreak in China.\(^5\)

Due to the larger size of droplets, gravity will pull them down before they have the chance to travel long distances. Most droplets will be removed from the air before traveling 1-2 meters.\(^6\) Although, some studies have shown that droplets may be able to travel further distances when strong air currents are present.\(^7\) After falling, these infectious droplets can remain on surfaces which can then become a route of transmission. Studies have shown detection of viral RNA on floors, toilets, door handles, bed railings, etc.\(^8\)-\(^10\) Most nations have implemented interventions to curb this route of transmission, namely, physical distancing by 6 feet/2 meters, wearing facemasks as source control, covering eyes, and stay at home orders.
Fomite

Fomite refers to transmission via an object that is carrying infectious material. These could be door handles, light switches, sinks, etc., that have had aerosols or droplets settle on them, are touched by an individual, and then transferred to that individual via touching the eyes or mouth. This is a plausible pathway as studies have found virus on numerous surfaces and their ability to survive hours and even days in some cases. While the virus may be detectable on surfaces, the amount can rapidly decline. For example, a study being conducted on common materials of items from libraries has shown live SARS-Cov-2 virus to be undetectable after 1 day for common book paper or DVD cases. Other materials can support live virus for longer, such as up to 4 days for glossy book paper or magazine paper. Transmission via fomites is thought to have increased the number of infections during a business conference and amongst visitors at a church in Singapore, as well as contributed to transmission of COVID-19 in a Chinese shopping mall through shared touch surfaces. While live virus can be detected on some materials for extended time, evidence still suggests that droplet transmission from face-to-face contact is still the predominant route.

To combat transmission of SARS-Cov-2 by fomites, the WHO and CDC recommend frequent handwashing, cleaning of surfaces, and avoiding touching one’s face. By constantly cleaning hands and surfaces the virus will be removed or deactivated and will then be unable to infect others.

Aerosol

Aerosolization refers to small aerodynamic droplets generally accepted as being less than 5 µm in diameter. These particles are created mainly through aerosol generating actions or procedures such as intubation. Additionally, other actions such as talking, singing, heavy breathing are actions in which small particles may be released. Aerosolized viruses may lead to more severe COVID-19 diagnoses since the smaller particles are able to travel further into the lungs. The dynamics of aerosol transmission differs from droplets. Aerosolization can be especially problematic because the virus is able to suspend in the air in these small droplets. These droplets are then subject to the airflow of a given space and therefore could travel large distances beyond the accepted physical distancing of 6 feet/2 meters and survive suspended in the air.

Aerosols are highly debated as a truly viable route of transmission for SARS-Cov-2. This route of transmission has been suggested in controlled experimental labs, where virus has been detected in air samples and surfaces well beyond the 6 foot physical distancing space of known cases in both published and pre-print studies. The most notable study showing this is by van Doremalen et al., which showed that the SARS-Cov-2 virus was still viable in aerosols for at least 3 hours, the total length of time of the experiment. Although, in one study that collected live virus, the amount was small. Additionally, when HEPA filters are in use, no
aerosols were detected in the air samples.\textsuperscript{25} Alternatively, numerous studies have taken air samples from COVID-19 positive patient rooms and have been unable to detect any virus.\textsuperscript{28, 29} These studies had patients who were wearing masks, which could have contributed to less shedding of virus into the air. Overall, when measuring for virus within the air, the literature is mixed, which is likely why this transmission route is frequently debated.

For SARS-Cov-1, the most known outbreak caused by aerosols occurred at the Amoy Gardens living complex, where residents living on floors above an infectious case also became infected through aerosol transport of the virus.\textsuperscript{30} Certain outbreaks of COVID-19, such as those described in a restaurant where infected individuals did not sit together, cannot rule out transmission via aerosols.\textsuperscript{31}

The main method of combating this route of transmission is through high ventilation rates of the space, use of HEPA or high-rated MERV filters to filter out the particles, and wearing of personal protective equipment such as ventilators. Environments with poor ventilation can be especially dangerous as these particles will “hang” in the air for extended periods of time while still remaining infectious.\textsuperscript{32}

\textit{Fecal}

A common theme through many studies of patients with COVID-19 is that viral RNA is detectable in fecal matter well beyond when a nasopharyngeal test is negative. Many studies compare the difference in time from a negative nasopharyngeal test versus a negative test in a stool sample or anal swab. This time can vary drastically, with most studies finding an average time difference of 10-20 days, with some exceptions that may exceed 40-50 days.\textsuperscript{33-38}

With viral RNA detectable in fecal matter, the concern of transmission of SARS-Cov-2 via the fecal-oral route exists. Most studies have focused on detection of viral RNA and only a few have investigated whether the fecal-oral route is possible. Based on the literature, there is confidence that fecal matter contains viral RNA.\textsuperscript{39} Although, only a few studies have claimed to have found live virus capable of infection in small samples of subjects.\textsuperscript{40, 41} Based on this information, there is no definitive answer on whether the fecal-oral route of transmission is viable, which suggests that handwashing should continue to be encouraged.

\textit{Asymptomatic/Pre-symptomatic}

One area that has garnered attention is the transmission of SARS-Cov-2 from asymptomatic and pre-symptomatic cases. It is believed that persons with COVID-19 may be able to transmit the virus days before symptoms develop.\textsuperscript{42, 43} This is possible because viral loads of asymptomatic and pre-symptomatic persons has been shown to be just as high as those with symptoms and viral shedding is at its highest levels at the time symptoms begin.\textsuperscript{44}
A few outbreak investigations have found evidence of transmission from asymptomatic patients. These investigations found spread from asymptomatic individuals amongst a group of friends, between patrons in a restaurant, and within a household where one individual was not showing symptoms at the time of transmission.\textsuperscript{31, 45, 46} There is no particular intervention that can be done to stop the spread of COVID-19 by asymptomatic cases except to encourage the same use of PPE, physical distancing, and cleaning as mentioned prior. If everyone follows these recommendations, even if a person is not showing symptoms but is infectious, the probability of transmission is reduced.

Conclusion

The literature supports droplet transmission from close face-to-face contact as being the main route of transmission for SARS-Cov-2. But, the difference between droplets and aerosols is not a dichotomy, rather, a continuum of particle sizes. Any droplet transmission more than likely involves smaller aerosols as well, suggesting that aerosols are also important to consider. While fomite transmission is also plausible, it seems more transmission comes from droplets, but that should not deter from taking the proper precautions of cleaning, washing hands, and avoiding touching one’s eyes and mouth.

