SARS-CoV-2 Transmission and the Risk of Aerosol-Generating Procedures

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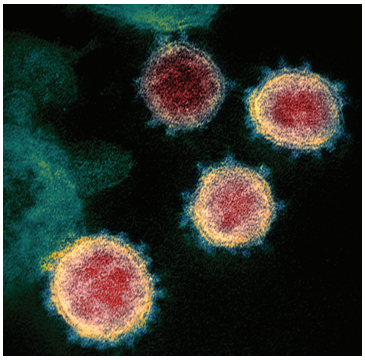
The novel coronavirus SARS-CoV-2 was identified in China in December 2019. With evidence of global spread, it has become a pandemic. At the time of writing, COVID-19, the clinical syndrome caused by SARS-CoV-2, has claimed over 340,653 lives and stretched the capacity of healthcare systems around the world.[1] The hallmark of severe COVID-19 is hypoxemic respiratory failure. Management of this condition historically involves procedures that have the potential to generate respiratory aerosols such as non-invasive ventilation and endotracheal intubation.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Patients who are not in significant respiratory failure may also require aerosol-generating procedures (AGPs), such as chest physiotherapy or pulmonary function tests, for management of other conditions. Preventing healthcare-associated transmission of infection requires understanding both how SARS-CoV-2 is spread, as well as the specific risks associated with commonly-used respiratory procedures. This document summarizes current understanding of these issues.

Respiratory Particle Definitions

Respiratory Droplets: Particles consisting mostly of water that are large enough to settle rapidly on a surface after being produced. There is no universally-accepted size cut off, but droplets are often defined as being > 5µm in diameter. Droplets are dispersed over shorter distances and remain in the air for shorter periods of time than aerosols.

Respiratory Aerosols: Smaller particles (usually <5µm) that can remain suspended in the air for minutes to hours. This term is sometimes used interchangeably with "droplet nuclei." Aerosols can disperse over long distances and spread via ventilation systems. Aerosols can be generated by sneezing, coughing, speaking, singing, and laughing.

Mechanisms of Viral Transmission

Table 1 summarizes possible routes of respiratory virus transmission.

SARS-CoV-2 Transmission

Determining viral transmission dynamics is complex and difficult to investigate experimentally. Previous research on coronaviruses, including the viruses that cause Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS), suggest that contact and droplet transmission are very likely, and that aerosol transmission may also be possible.[2] Early research on SARS-CoV-2 has shown that the virus can remain infectious on certain surfaces for up to 72 hours and in aerosols for up to 3 hours.[3] This suggests that the virus may spread through contact,

Table 1. Routes of Respiratory Virus Transmission.[2]

Type of Transmission	Mechanism	Comments	Example
Direct contact	Infective particles are transferred directly from infected person to susceptible host.		John is infected and shakes hands with Mary, directly transferring infective particles to her hand.
Indirect contact	Infective particles are transferred from an infected person to a susceptible host via an environmental surface.	Duration of infectivity varies based on type of virus, type of surface, and environmental factors such as temperature and humidity.	John coughs on his hand and touches a door-knob. Mary opens the door and then touches her face with her now-contaminated hand.
Droplet	Infective droplets settle on the mucosa (respiratory tract or eyes) of a susceptible host.	Requires close contact with infected individual. Because of their larger size, particles generally deposited in upper respiratory tract..	John laughs while talking to Mary. She inhales infective droplets.
Aerosol	Infective aerosols settle on the mucosa (respiratory tract or eyes) of a susceptible host.	No close contact required. Because of their small size, particles can settle throughout the respiratory tract, including in the lower airways.	John coughs, generating infective aerosols that remain suspended in the air. Mary enters the room 30 minutes later and inhales the aerosols

Am J Respir Crit Care Med Vol. 202, P13-P14, 2020
This Public Health Information Series piece was originally published online ahead of print June 30, 2020

droplet, AND aerosol transmission. This potential for multimodal transmission is reflected in the current CDC recommendations requiring healthcare professionals wear N95 respirators (where available) when caring for all patients with confirmed or suspected COVID-19.[4] The World Health Organization continues to recommend respirators only for healthcare workers performing aerosol-generating procedures, as they feel airborne transmission of the virus is likely limited to this context.[5]

Aerosol Generating Procedures and Risks of SARS-CoV-2 Transmission

Aerosol generating procedures (AGPs) are those that have the potential to generate aerosols and droplets that can spread respiratory pathogens (Table 2). However, much of the information regarding the true aerosolizing potential of various procedures, and their role in the transmission of respiratory diseases is speculative.[6] Most data regarding risks to healthcare workers has been extrapolated from epidemiologic data collected during infectious outbreaks. For example, case-control and retrospective cohort studies during the SARS outbreak show increased risk of transmission associated with endotracheal intubation, and possibly non-invasive ventilation and tracheostomy. No increased risk was seen with 20 other AGPs.[6] However, these studies are limited by sample size and study design.

Table 2: Procedures with potential to generate respiratory aerosols

- Non-invasive ventilation (examples)
  - Bi-level
  - CPAP/Autopap
  - ASV
  - Home ventilators
- Sputum induction
- Chest physiotherapy
- High flow oxygen
- Nebulizer administration
- Bronchoscopy
- Airway suctioning
- Pulmonary function testing
- Bag mask ventilation prior to intubation
- Endotracheal intubation and extubation
- High frequency oscillatory ventilation
- Tracheostomy
- Speech language pathologists' procedures (instrumental and non-instrumental) that trigger cough reflex
- E.N.T procedures that trigger cough refle
- Surgery
- Autopsy
- Cardiopulmonary resuscitation

CPAP = continuous positive airway pressure; ASV = adaptive servo ventilation.

Reducing Risks of Transmission During Aerosol Generating Procedures

Given the uncertainty around the transmission risks associated with AGPs, many institutions and professional societies recommend postponing non-urgent AGPs (e.g. pulmonary functions tests for monitoring of chronic lung disease), and optimizing the patient environment and using maximal protective equipment when AGPs are required. In addition to employing standard and droplet precautions, the following may be used:

N95 Respirators: N95s are masks that (when fitted properly) block at least 95% of 0.3 micron particles. *The CDC and the WHO recommend the use of N95 respirators during any AGP.*

N100 Respirators: N100s are masks that (when fitted properly) block at least 99.97% of 0.3 micron particles.

Powered Air Purifying Respirators (PAPR): PAPRs are half or full face masks connected to a breathing tube, battery-operated blower, and a particulate filter. Room air is blown through the filter and thus purified before being delivered to the facepiece.

Face Shields: Face shields are clear plastic barriers that cover the face and block portals of entry. They are typically worn in conjunction with face masks and may further reduce transmission of droplets and aerosols containing virus.[8]

Protective Eyewear: Transmission of the virus through ocular route has been described and therefore eyes should be shielded at all times during these procedures.[9]

Negative Pressure Rooms: Negative pressure rooms are those in which the air pressure is maintained at a lower level than that of surrounding patient care areas. As a result, air flow is directed into the negative pressure room, preventing aerosols from moving into higher pressure areas. The contaminated air is then ventilated out of patient care areas. Per CDC standards, negative pressure rooms must have a minimum of 12 air changes per hour.[10] *Performing AGPs in negative pressure rooms reduces the risk of aerosol spread to other patient care areas. It DOES NOT obviate the need for healthcare providers engaged in AGPs to wear appropriate respirators.*

Conclusion

Our understanding of SARS-CoV-2 continues to evolve. Mounting evidence suggests the virus can be transmitted via contact, droplet, and possibly aerosol routes. Management of patients with COVID-19 often requires AGPs. Healthcare workers performing AGPs should use appropriate personal protective equipment (minimum of N95 respirator as well as standard and droplet precautions). Where possible, AGPs should be performed in negative pressure rooms to minimize risk of viral transmission to other patient care areas.

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