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《AEROSAL BASIS》

Final Report

TOPIC: SARS-CoV-2 transmission via airborne aerosol particles

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ABSTRACT

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the aetiological agent of coronavirus disease 2019 (COVID-19), has led to a global pandemic defying the geographical borders and putting the lives of billions at risk. Throughout the world, mitigation strategies have lingered on the adoption of social distancing, face masks, hand hygiene and environmental disinfection. However, containment and understanding of the modes of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission is of utmost importance for policy making. To this end, this paper focuses on the evidence of aerosol transmission of SARS-CoV-2. Several studies support that aerosol transmission of SARS-CoV-2 is plausible, and the plausibility score (weight of combined evidence) is 8 out of 9. Precautionary control strategies should consider aerosol transmission for effective mitigation of SARS-CoV-2.

INTRODUCTION

An unprecedented pandemic of coronavirus disease 2019 (COVID- 19), caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), has created a global public health threat. The origin of SARS-CoV-2 infection was first reported in people exposed to the Huanan Seafood Wholesale Market, a seafood market in Jianghan District, Wuhan City, Hubei Province, China in December 2019. It has been suggested that the infection is likely to be of zoonotic origin and transmitted to humans through a not-yet-known intermediary. As of November 8, 2020, the cumulative number of confirmed cases of COVID-19 has exceeded 50 million, with over 1.2 million deaths worldwide (WHO, 2020). SARS-CoV- 2, which causes COVID-19, is the seventh coronavirus documented to infect humans. The guidance of different countries and organizations about modes of transmission of SARS-CoV-2 mostly stipulate the droplet, contact or fomite routes (MOH, 2020; CDC, 2020; MHLW, 2020; ECDC, 2020; WHO, 2020). However, there are growing evidences that in addition to contact and droplet spread, the transmission of SARS-CoV-2 via aerosols are plausible under favorable conditions, particularly in relatively confined settings with poor ventilation and long duration exposure to high concentrations of aerosols, causing the World Health Organization (WHO) and other agencies to review their guidance. Recently WHO acknowledged aerosol transmission of SARS-CoV-2, especially in closed indoor settings, and that aerosol transmission could not be ruled out from some reported outbreaks (WHO, 2020). The aim of this review was to synthesize the evidence for aerosol transmission of COVID-19 and highlight the localities and vulnerable populations where SARS-CoV-2 aerosols may be particularly pertinent to COVID-19 transmission. Based on the synthesis of evidence, we summarized precautions and infection control strategies to mitigate the possible aerosol transmission of SARS-CoV-2, so as to inform scientific countermeasures for combatting COVID-19 globally.

RESULTS AND DISCUSSION

Articles evaluated indicating the possible aerosol transmission of SARS-CoV-2 - types, places, dates, main findings, and countries where the transmission occurred are compiled in Table 1.

TABLE 1

Empirical and laboratory studies indicating the possible aerosol transmission of SARS-CoV-2 to as July 30th, 2020

Type	Place	Date	Main Finding(s)	Country	Reference(s)
Environmental samples	Apartment	2020/Feb/14	SARS-CoV-2 was detected in surface samples (e.g. sink, faucet, and shower handle) of the restroom in a long-term vacant apartment at 16-floor, which is right above the restroom of an apartment with five persons with COVID-19 (confirmed between Jan 26 and 30) at 15-floor in Guangzhou. The possibility of aerosol diffusion through sewage pipe after flushing the toilet at the 15-floor	China	Unpublished data of China CDC

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			restroom was further confirmed by an onsite tracer simulation experiment showing aerosols were found in the restroom of apartments at 25-floor (two cases confirmed on Feb 1) and 27-floor (two cases confirmed on Feb 6 and 13)		
	Lab	2020/Mar/17	SARS-CoV-2 remained viable in aerosols throughout the duration of experiment (3 h)	USA	NEJM (van Doremalen et al., 2020)
	Lab	2020/Apr/13	SARS-CoV-2 maintained infectivity in aerosols for up to 16 h	USA	Emerg Infect Dis (Fears et al., 2020)
	Hospital	2020/Feb/25	SARS-CoV-2 was detected on the surfaces of the nurse	China	MedRxiv (Jiang et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			station in the isolation area with suspected patients and in the air of the isolation ward with an intensive care patient at the First Hospital of Jilin University		
	Hospital	2020/Mar/4	Samples with 13 (87%) of 15 room sites (including air outlet fans) and 3 (60%) of 5 toilet sites (toilet bowl, sink, and door handle) were positive by using RT-PCR at the dedicated SARS-CoV-2 outbreak center in Singapore	Singapore	JAMA (Ong et al., 2020)
	Hospital	2020/Mar/8	Deposition samples inside ICU and air sample in Makeshift Hospital patient toilet were positive for SARS-CoV-2.	China	Nature (Liu et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			SARS-CoV-2 was also found in the air in outdoor areas at the hospital entrance and in front of a department store		
	Hospital	2020/Mar/8	Of the 163 surface and aerosol samples collected in the University of Nebraska Medical Center (UNMC), 126 (77.3%) had a positive result for SARS-CoV-2 with the highest concentration from an air handling grate. In room air samples were 63.2% positive with mean concentration 2.86 copies/L of air. Viable SARS-CoV-2 has been detected in the air in hospital wards using cell culture method	USA	Sci Rep (Santarpia et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
	Hospital	2020/Apr/3	Of 107 surface samples, 4 samples were positive (2 ward door door-handles, 1 bathroom toilet toilet-seat cover and 1 bathroom door door-handle). Three were weakly positive from a bathroom toilet seat, 1 bathroom washbasin tap lever and 1 bathroom ceiling exhaust louvre. One of the 46 corridor air samples was weakly positive, and virus was also found on the surface of the exhaust grilles in the bathroom	China	medRxiv (Ding et al., 2020)
	Hospital	2020/Apr/7	Air sampling is performed in three of the 27 AIIRs in the general ward, and detects SARS-CoV-2 positive	Singapore	Nat Commun (Chia et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			particles of sizes > 4 µm and 1–4 µm in two rooms, despite these rooms having 12 air changes per hour		
	Hospital	2020/Apr/10	A study in Huoshenshan Hospital in Wuhan found contamination was greater in ICU than general wards. Virus was widely distributed on surface samples of floors, computer mice, trash cans, and sickbed handrails and was detected in air samples ≈4 m from patients	China	Emerg Infect Dis (Guo et al., 2020)
	Outdoor air	2020/Apr/15	SARS-CoV-2 RNA was detected on outdoor particulate matter (PM) for the first time, suggesting that, in conditions of atmospheric stability	Italy	Environ Res (Setti et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			and high concentrations of PM, SARS-CoV-2 could create clusters with outdoor PM and, by reducing their diffusion coefficient, enhance the persistence of the virus in the atmosphere		
Cases	Public transportation	2020/Mar/4	24 of 68 people were infected at a bus in Ningbo City, Zhejiang Province. Compared to individuals in the non-exposed bus (Bus #1), those in the exposed bus (Bus #2) were 41.5 (95% CI, 2.6–669.5) times more likely to be infected with COVID-19	China	ResearchGate (Shen et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
	Public transportation	2020/Feb/11	Two died and at least 103 people were infected among 1,111 crew and 2,460 passengers in Grand Princess cruise ship	USA	US CDC (Moriarty et al., 2020)
	Apartment	2020/Feb/3	In Inner Mongolia, a case of COVID-19 reported positive when a person has passed the door of a symptomatic patient several times	China	Ir J Med Sci (Wang and Du, 2020)
	Shopping Mall	2020/Jan/21	40 people were infected at a shopping mall in Tianjin	China	Chinese Journal of Epidemiology (Wu et al., 2020)
	Shopping Mall	2020/Jan/21	Indirect Virus Transmission (e.g. virus aerosolization in a confined public space such as restrooms or elevators) in Cluster	China	Emerg Infect Dis (Cai et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			of COVID-19 Cases in Wenzhou		
	Restaurant	2020/Jan/26	Air-conditioned ventilation explained the aerosol transmission of an outbreak in a restaurant in Guangzhou, China. The distances between patient zero and others in this outbreak were all >1 m	China	Emerg Infect Dis (Lu et al., 2020)
	Choir	2020/Mar/10	A superspreading events occurred in a 2.5 h choir rehearsal at Skagit Valley Chorale (SVC) of Mount Vernon, WA of USA where 53 out of 61 attendees were infected and two were dead, even though adequate caution measures for fomite and droplet transmission being	USA	MedRxiv (Read, 2020; Miller et al., 2020)

Type	Place	Date	Main Finding(s)	Country	Reference(s)
			taken and none presented symptoms.		

PRECAUTIONARY MEASURES & CONTROL STRATEGIES

Precautionary control strategies that are important for public health protection are needed to avoid aerosol transmission of SARS-CoV-2. As long duration of viral shedding was reported in asymptomatic cases, with high infectivity relative to symptomatic cases, the virus could spread *via* aerosols during breathing and talking before awareness is triggered by symptoms. This poses risks, particularly in confined and poor ventilated environments with prolonged person to person contact. Settings with a large proportion of infected people or contaminated samples, such as hospitals, healthcare institutions and laboratories are the highest risk, especially to health care workers (HCWs), who should be provided airborne precautions. The general public and vulnerable populations should be made aware that confined, crowded and poor ventilation environments may pose a medium risk when an infected person is present. Prevention and control countermeasures are proposed to reduce the potential aerosol transmission under different occasions.

The measures that should be taken to mitigate airborne transmission risk include:

- Provide sufficient and effective ventilation (supply clean outdoor air, minimize recirculating air) particularly in public buildings, workplace environments, schools, hospitals, and aged care homes.
- Supplement general ventilation with airborne infection controls such as local exhaust, high efficiency air filtration, and germicidal ultraviolet lights.
- Avoid overcrowding, particularly in public transport and public buildings.
- Proper use and disinfection of toilet areas can effectively limit the concentration of SARS-CoV-2 RNA in aerosols. Floor drains and other outlets of sewer should have adding water frequently to ensure seals work at all time.
- Frontline HCWs who come in direct contact with potentially infected patients, such as doctors, nurses, allied health workers, phlebotomists collecting medical laboratory specimens, food service staff, cleaners and laboratory professionals in open-space laboratories should wear proper personal protective equipment (PPE), specifically waterproof gowns, N95/KN95 (and above) particle protective respirator or powered air purifying respirators, face shields or goggles, and gloves, in addition to the usual contact-transmission prevention precautions (e.g. handwashing and respiratory hygiene) to avoid potential infection**.**

SUMMARY & FUTURE

Summary

Airborne route appeared to be a major contributor for superspreading events in a 2.5 h choir rehearsal on March 10, at Skagit Valley Chorale (SVC) of Mount Vernon, WA, USA where 53 out of 61 attendees were infected and two died, even though adequate precautions for fomite and droplet transmission were taken and no-one had symptoms. It is suspected that during singing, the forceful exhalation and inhalation may have aerosolized SARS-CoV-2, leading to high levels of disease transmission. This indoor transmission risk may have been increased because of high occupancy, long duration, loud vocalization, and poor ventilation. A recent study addressed the potential long distances covered by SARS-CoV-2 through cough and sneeze and revealed that small droplets, emitted during a sneeze, could reach distances of 7–8 m. Similarly, Paules et al. recently demonstrated that the airborne transmission of SARS-CoV-2 may occur in addition to close contact transmission. On April 1, 2020, National Academy of Sciences (NAS) committee on emerging infectious diseases and 21st century health threats letter has pointed out that "While the current SARS-CoV-2 specific research is limited, the results of available studies are consistent with aerosolization of virus from normal breathing". In addition, there have been some other outbreaks, mostly involving confirmed cases in relatively confined or crowded environments (e.g. hospitals, shopping malls, public transportation vehicles, offices, and prisons) (Table 1). For example, a case study of South China Seafood Market showed that the median risk of a customer acquiring SARS-CoV-2 infection *via* the aerosol route after 1 hr exposure in the market with one infected shopkeeper was about 2.23×10^{-5}. With the assumption of one infected shopkeeper in the market, the 97.5% percentile infection risk by aerosol transmission was about 2.34×10^{-4} and could be reduced to about 10^{-4} with a ventilation rate of 1 ACH, for customers with 1 h exposure in poorly ventilated markets. The risk was about 5–10 times lower than the manageable risk (1.17×10^{-3}), but it could be increased by several times if multiple infected shopkeepers were simultaneously in the market, becoming close to the manageable risk. Poor ventilation for a relatively long time, and lack of mask use may have increased the risk of aerosolized infection. Taken together, this suggests the possibility of aerosol transmission, especially in confined settings after exposure to high concentrations of viral aerosols for a long time.

Considering the high transmission capacity of SARS-CoV-2, prolonged viral shedding, and as the we await vaccine and systematic medication, the most important action to limit infection is to cut off the transmission chain by adhering to/following effective mitigation measures.

Future

Around the world, epidemiologists are constructing short- and long-term projections as a way to prepare for, and potentially mitigate, the spread and impact of SARS-CoV-2, the virus that causes COVID-19. Although their forecasts and timelines vary, modelers agree on two things: COVID-19 is here to stay, and the future depends on a lot of unknowns, including whether people develop lasting immunity to the virus, whether seasonality affects its spread, and — perhaps most importantly — the choices made by governments and individuals. “A lot of places are unlocking, and a lot of places aren’t. We don’t really yet know what’s going to happen,” says Rosalind Eggo, an infectious-disease modeler at the London School of Hygiene & Tropical Medicine (LSHTM).

Recommendation

Protection of general public and vulnerable populations - To curb aerosol transmission of SARS-CoV-2 government/appropriate authorities must carry out massive awareness in order to educate the general public and vulnerable populations about this transmission route (aerosol transmission). And ensure that the general public and vulnerable populations are provided with the necessary precautionary measures guidelines as per the consideration of aerosol transmission.

REFERENCES

WHO, 2020. Q&A on coronaviruses (COVID-19): **Is COVID-19 airborne?** (Accessed November 5, 2020, at https://www.who.int/news-room/q-a-detail/q-a-coronaviruses).

S. Tang, Y. Mao, R.M. Jones, Q. Tan, J.S. Ji, N. Li, J. Shen, Y. Lv, L. Pan, P.Ding, X. Wang, Y. Wang, C.R. MacIntyre, X. Shi.
Aerosol transmission of SARS-CoV-2? Evidence, prevention and control
Environ Int (2020), 10.1016/j.envint.2020.106039

L. Morawska, D.K. Milton
It is time to address airborne transmission of COVID-19
Clin Infect Dis (2020), 10.1093/cid/ciaa939

Jones and Brosseau, 2015 R.M. Jones, L.M. Brosseau
Aerosol transmission of infectious disease
J. Occup. Environ. Med., 57 (2015), pp. 501-508

Lu et al., 2020 Lu, J. Gu, K. Li, *et al.*
COVID-19 outbreak associated with air conditioning in restaurant, Guangzhou, China, 2020
Emerg. Infect. Dis., 26 (2020), pp. 1628-1631

Atkinson et al., 2009 J. Atkinson, Y. Chartier, C. Lúcia Pessoa-Silva, P. Jensen, Y.Li, W.-H. Seto
Natural Ventilation for Infection Control in Health-Care Settings
WHO, Geneva (2009)

Miller, S.L., Nazaroff, W.W., Jimenez, J.L., et al.,2020.
Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event. 2020:2020.06.15.20132027.

Liu Y, Ning Z, Chen Y, Guo M, Liu Y, Gali NK, et al.
Aerodynamic analysis of SARS-CoV-2 in two Wuhan Hospitals.
Nature 2020 Apr 27. https://doi.org/10.1038/s41586-020-2271-3.

Drossinos Y, Stilianakis NI.
What aerosol physics tells us about airborne pathogen transmission.
Aerosol Sci Tech 2020;54(6):639–43. https://doi.org/10.1080/ 02786826.2020.1751055.

Zhang X., Ji Z., Yue Y., Liu H., Wang J. Infection risk assessment of COVID-19 through aerosol transmission: a case study of South China seafood market. Environ. Sci. Technol. 2020[PMC free article] [PubMed] [Google Scholar]