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Australia must act to prevent airborne transmission of SARS-CoV-2

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Abstract

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the cause of the coronavirus disease 2019 (COVID-19) pandemic, is believed by many to be transmitted via respiratory droplets and fomites, with occasional airborne transmission observed in the setting of aerosol generating procedures. However, research shows viable SARS-CoV-2 can be detected in the air in the absence of such procedures, at distances greater than those specified in physical distancing guidelines. Additionally, numerous outbreaks have occurred which can only be explained by airborne transmission. There is an urgent need to update Australia's infection prevention and control guidelines to reflect the airborne transmission route.

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Introline

Overlooking the potential for airborne transmission of SARS-CoV-2 leaves Australia vulnerable to outbreaks

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Main text

"Those who cannot remember the past are condemned to repeat it"

George Santayana

In late 2002 in southern China, a previously unknown coronavirus crossed the species barrier to humans, igniting the severe acute respiratory syndrome (SARS) pandemic that would claim over 900 lives before it was finally contained. When SARS reached Canada, healthcare workers were among its most frequent victims. In the epidemic's aftermath, an independent inquiry highlighted failures in infection control, particularly with regard to the risk of airborne transmission, and recommended the precautionary principle underpin the development of future policies and practices.[1]

Today, the world is faced with a second, unprecedented pandemic. Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has overwhelmed nations across the world, resulting in an inability to deliver normal standards of healthcare. Elective surgeries have been cancelled, field hospitals established, and more grimly, care has sometimes been rationed to those most likely to survive. Additionally, nosocomial infection has been frequent in some regions, for both healthcare workers and patients.

Since the earliest days of the pandemic, respiratory droplets and fomites were assumed to be the major transmission routes, with airborne transmission only accepted within the limited confines of certain "aerosol-generating procedures".[2] In fact, this is a misnomer, because volitional coughing produces more aerosols than both invasive and non-invasive respiratory therapies.[3,4] The experience of SARS and Middle East respiratory syndrome (MERS) should

also have alerted us to the likelihood that SARS-CoV-2 could also be transmitted via the airborne route. It did alert some. China, South Korea, and Vietnam adopted airborne precautions in early 2020.

SARS-CoV-2 is more readily aerosolised than SARS and MERS, and can retain infectivity for at least 16 hours in the air under laboratory conditions.[5] Speech is sufficient to produce aerosols which can remain suspended for tens of minutes.[6] Importantly, SARS-CoV-2 RNA is readily detected in breath samples,[7] and the virus has been cultured from air samples collected at a distance of up to 4.8 metres from COVID-19 patients, in the absence of "aerosol-generating procedures".[8] SARS-CoV-2 RNA has been detected at even greater distances in ventilation systems.[9] This evidence, which is more comprehensive than that available for other accepted airborne pathogens, clearly demonstrates the potential for airborne transmission. This is borne out by numerous documented examples.

One of the most compelling was an outbreak in apartment complex in South Korea, in which only residents living in apartments connected by a common ventilation shaft were infected. All 7 affected apartments (out of a total of 200) were located along the vertical line of the shaft, suggesting a stack effect carried virus-laden aerosols into residents' bathrooms.[10] A similar outbreak occurred in an apartment building in China, in which the virus appeared to spread from persons on the 15th floor to persons in vertically-aligned flats on the 25th and 27th floors, by means of dried-out floor or bath drains.[11] An environmental sample in an unoccupied flat on the 16th floor was also positive. Faecal aerosols produced by toilet flushing were thought to be responsible,[11] reminiscent of the Amoy Gardens SARS outbreak in Hong Kong in 2003. There have also been several documented outbreaks in healthcare settings which were not only highly suggestive of airborne transmission, but also

demonstrated that physical distancing and the use of surgical masks is not always sufficient to prevent infection.[12-15] In contrast, a study of healthcare workers from Finland found that none using FFP2/3 respirators became infected.[15]

Similar outbreaks, some of which may have been aided by the dehumidifying effect of air conditioning (which might desiccate respiratory droplets), have been reported globally, with indoor transmission being the common factor. Indoor transmission appears many times more likely than outdoor transmission,[16] and outbreak settings have included restaurants,[17] public transport,[18] abattoirs,[19] cruise ships,[20] aeroplanes,[21] nursing homes,[22] places of worship,[23] and choir groups.[24] Notably, in one bus cluster, one of the secondary cases boarded the bus 30 minutes after the index case had left.[18] Such super-spreading events will continue to fuel the pandemic if measures to prevent airborne transmission are not implemented.

Countries which acknowledged the danger of airborne transmission have not only been able to control COVID-19 in the community, but where cases have occurred, they have been able to safeguard healthcare workers from getting infected. Countries which have not, including Australia, the United Kingdom, the United States, and many European nations, have not only seen widespread community transmission, but staggering numbers of healthcare worker infections. In Melbourne, 4,170 clinical and non-clinical healthcare workers were infected with SARS-CoV-2, most of them in the workplace.[25]

Despite this evidence of occupationally-acquired infection amongst healthcare workers, infection prevention and control guidelines – including those published as recently as January 2021 – continue to specify droplet and contact precautions for known and suspected COVID-19 patients.[26] It has seemed at times as if any reason, other than airborne transmission, is

being sought to explain occupationally-acquired healthcare worker infections. Healthcare workers have been accused of "doing the wrong thing in the tearoom", "mostly getting it outside work", "not doffing correctly", "car pooling", and "having unauthorised dinner parties".

Outbreaks are also occurring in hotel quarantine with increasing frequency. From November to mid-January, it is estimated approximately 1 in 200 hotel quarantine cases led to infections outside the system.[27] Genomic sequencing revealed multiple guests occupying one floor of a Brisbane hotel contracted the disease from another person in quarantine.[28] A similar outbreak occurred in Sydney.[29] Recent infections in hotel quarantine staff have triggered intensified public health measures in Melbourne, and lockdowns in Adelaide, Brisbane, and Perth. Brisbane went into a second lockdown this year after healthcare worker infections led to a resumption in community transmission.[30] A report into the hotel quarantine breach in Perth concluded the staff member was likely infected via the airborne route.[31] A probable case of airborne transmission in New Zealand's hotel quarantine system has also since been reported.[32]

The occurrence of airborne transmission of SARS-CoV-2 has far-reaching implications, particularly for the ventilation of indoor spaces including public buildings and public transport, infection control in healthcare, and provision of personal protective equipment (PPE). Australia is in an enviable position, having effectively achieved elimination of COVID-19. However, the country will remain vulnerable until the vaccination programme is complete. We should not jeopardise our prosperity by risking future, preventable outbreaks, with the attendant health, social, and economic costs that invariably follow. Recently, a group of healthcare workers and scientists wrote an open letter to the Australian Health Protection

Principal Committee (AHPPC) and other groups tasked with disease control, in addition to the Prime Minister, state and territory leaders, and Chief Health Officers of Australia, calling for national action on aerosol transmission.[33] The letter is supported by over 350 national and international signatories, and makes several specific recommendations which are summarised in Box 1. Unfortunately, the Department of Health replied that they understood there to be "little clinical or epidemiological evidence of regular airborne transmission of SARS-COV-2" based on advice received.

Despite clear evidence of the airborne route, progress continues to be dogged by debate around the specifics of aerosol transmission. In a recent review, Tang and colleagues dismantle the myths preventing recognition of airborne transmission of SARS-CoV-2.[34] They note there is no clear dichotomy between respiratory droplets and aerosols, and that particles produced by breathing, talking, coughing, and sneezing span a continuum of sizes from <1 μm to >100 μm. Respiratory droplets (defined by the World Health Organisation as being >5-10 μm in size[2]) do not always fall within 1-2 metres of their source, as is often claimed, and are affected by ambient airflow. While short-range transmission may be more common, this does not rule out the airborne route, because aerosols are more concentrated at their source. Finally, Tang et al. note the lower basic reproduction number (the number of secondary cases an infection is expected to give rise to; R_0) of SARS-CoV-2 compared to measles is not evidence for droplet-only spread. R_0 has no relation to the mechanism of transmission, and there are airborne pathogens with a lower R_0 than SARS-CoV-2, such as tuberculosis.[34] Interestingly, measles was once thought to be transmitted via large respiratory droplets, requiring close contact with an infected person.[35] This view was revised following a number of "unusual" outbreaks in paediatric practice that could only be explained by airborne transmission.[35,36]

In summary, there is clear and compelling evidence for airborne transmission of SARS-CoV-2. The evidence is sufficiently strong to warrant the immediate strengthening of Australia's infection prevention and control guidelines. We must apply the precautionary principle, and urgently improve biosecurity measures at ports, airports, and quarantine facilities in particular, lest outbreaks continue to spill over into the community. The emergence of more transmissible variants heightens this urgency. Healthcare workers must also be afforded the highest level of protection, commensurate with their high risk of exposure, and to comply with workplace health and safety laws, which require every reasonably practicable method to prevent worker harm to be adopted. Australia must learn from history, not repeat the mistakes of the past.

References

1 Campbell A. The SARS Commission final report: spring of fear. Toronto: Government of Ontario, 2006. http://www.archives.gov.on.ca/en/e_records/sars/report/ (viewed 18 April 2021).

2 World Health Organisation. Transmission of SARS-CoV-2: implications for infection prevention precautions [website]. https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions (viewed 1 February 2021; last updated 9 July 2020).

3 Wilson NM, Marks GB, Eckhardt A et al. The effect of respiratory activity, non-invasive respiratory support and facemasks on aerosol generation and its relevance to COVID-19. *Anaesthesia* 2021. https://doi.org/10.1111/anae.15475

4 Brown J, Gregson FKA, Shrimpton A et al. A quantitative evaluation of aerosol generation during tracheal intubation and extubation. *Anaesthesia* 2021; 76: 174-181.

5 Fears AC, Klimstra WB, Duprex P et al. Persistence of severe acute respiratory syndrome coronavirus 2 in aerosol suspensions. *Emerg Infect Dis* 2020; 26: 2168-2171.

6 Stadnytskyi V, Bax CE, Bax A et al. The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission. *Proc Natl Acad Sci U S A* 2020; 117: 11875-11877.

7 Ma J, Qi X, Chen H et al. COVID-19 patients in earlier stages exhaled millions of SARS-CoV-2 per hour. *Clin Infect Dis* 2020. https://doi.org/10.1093/cid/ciaa1283

8 Lednicky JA, Lauzardo M, Fan ZH et al. Viable SARS-CoV-2 in the air of a hospital room with COVID-19 patients. *Int J Infect Dis* 2020; 100: 476-482.

9 Nissen K, Krambrich J, Akaberi D et al. Long-distance airborne dispersal of SARS-CoV-2 in COVID-19 wards. *Sci Rep* 2020; 10: 19589.

10 Hwang S, Chang J, Oh B et al. Possible aerosol transmission of COVID-19 associated with an outbreak in an apartment in Seoul, South Korea, 2020. *Int J Infect Dis* 2020; 104: 73-76.

11 Kang M, Wei J, Yuan J et al. Probable evidence of fecal aerosol transmission of SARS-CoV-2 in a high-rise building. *Ann Intern Med* 2020; 173: 974-980.

12 Klompas M, Baker MA, Rhee C et al. A SARS-CoV-2 cluster in an acute care hospital. *Ann Intern Med* 2021. https://doi.org/10.7326/M20-7567

13 Klompas M, Baker MA, Griesbach D et al. Transmission of SARS-CoV-2 from asymptomatic and presymptomatic individuals in healthcare settings despite medical masks and eye protection. *Clin Infect Dis* 2021. https://doi.org/10.1093/cid/ciab218

14 Goldberg L, Levinsky Y, Marcus N et al. SARS-CoV-2 infection among healthcare workers despite the use of surgical masks and physical distancing - the role of airborne transmission. *Open Forum Infect Dis* 2021. https://doi.org/10.1093/ofid/ofab036

15 Oksanen LAH, Sanmark E, Oksanen SA et al. Sources of healthcare workers' COVID-19 infections and related safety guidelines. *Int J Occup Med Environ Health* 2021. https://doi.org/10.13075/ijomeh.1896.01741

16 Bulfone TC, Malekinejad M, Rutherford GW et al. Outdoor transmission of SARS-CoV-2 and other respiratory viruses: a systematic review. *J Infect Dis* 2021; 223: 550-561.

17 Li Y, Qian H, Hang J et al. Probable airborne transmission of SARS-CoV-2 in a poorly ventilated restaurant. *Build Environ* 2021. https://doi.org/10.1016/j.buildenv.2021.107788

18 Luo K, Lei Z, Hai Z et al. Transmission of SARS-CoV-2 in public transportation vehicles: a case study in Hunan Province, China. *Open Forum Infect Dis* 2020; 7: ofaa430.

19 Günther T, Czech-Sioli M, Indenbirken D et al. SARS-CoV-2 outbreak investigation in a German meat processing plant. *EMBO Mol Med* 2020; 12: e13296.

20 Azimi P, Keshavarz Z, Cedeno Laurent JG et al. Mechanistic transmission modeling of COVID-19 on the Diamond Princess cruise ship demonstrates the importance of aerosol transmission. *Proc Natl Acad Sci U S A* 2021; 118: e2015482118.

21 Speake H, Phillips A, Chong T et al. Flight-associated transmission of severe acute respiratory syndrome coronavirus 2 corroborated by whole-genome sequencing. *Emerg Infect Dis* 2020; 26: 2872-2880.

22 de Man P, Paltansing S, Ong DSY et al. Outbreak of COVID-19 in a nursing home associated with aerosol transmission as a result of inadequate ventilation. *Clin Infect Dis* 2020. https://doi.org/10.1093/cid/ciaa1270

23 Katelaris AL, Wells J, Clark P et al. Epidemiologic evidence for airborne transmission of SARS-CoV-2 during church singing, Australia, 2020. *Emerg Infect Dis* 2021. https://doi.org/10.3201/eid2706.210465

24 Miller SL, Nazaroff WW, Jimenez JL et al. Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event. *Indoor Air* 2021; 31: 314-323.

25 Department of Health and Human Services, State Government of Victoria. Victorian healthcare worker (clinical and non-clinical) coronavirus (COVID-19) data [website]. https://www.dhhs.vic.gov.au/victorian-healthcare-worker-covid-19-data (viewed 1 February 2021; last updated 20 January 2021).

26 Department of Health, Government of Australia. Coronavirus disease 2019 (COVID-19) CDNA national guidelines for public health units. Canberra: Commonwealth of Australia, 2021. https://www1.health.gov.au/internet/main/publishing.nsf/Content/7A8654A8CB144F5FCA2584F8001F91E2/$File/COVID-19-SoNG-v4.2.pdf (viewed 1 February 2021).

27 Scott S, Lloyd M, Clark E. Experts call on Federal Government to acknowledge possible airborne transmission of COVID-19 in hotel quarantine [website]. https://www.abc.net.au/news/2021-01-16/hotel-quarantine-gap-prevent-airborne-spread-of-covid-19/13057644 (viewed 1 February 2021; last updated 16 January 2021).

28 Eaton M. Brisbane's Grand Chancellor COVID-19 cluster now extends to six people. Here's what authorities are doing about it [website]. https://www.abc.net.au/news/2021-01-13/coronavirus-queensland-uk-strain-brisbane-hotel-quarantine/13054284 (viewed 1 February 2021; last updated 13 January 2021).

29 SBS News. NSW authorities investigating how COVID-19 spread between neighbouring hotel rooms [website]. https://www.sbs.com.au/news/nsw-authorities-investigating-how-covid-19-spread-between-neighbouring-hotel-rooms (viewed 17 April 2021; last updated 17 April 2021).

30 Robertson J. Inside Brisbane's COVID-19 crisis at the Princess Alexandra Hospital [website]. https://www.abc.net.au/news/2021-04-03/qld-covid-outbreak-princess-alexandra-hospital-lockdown-ppe/100045672 (viewed 18 April 2021; last updated 3 April 2021).

31 Weeramanthri T. Review of Western Australia's hotel quarantine arrangements. Final advice. Perth: Department of the Premier and Cabinet, Government of Western Australia, 2021. https://www.wa.gov.au/sites/default/files/2021-04/Review-of-Hotel-

Quarantine-Arrangements-in-Western-Australia-Final-Advice.pdf (viewed 18 April 2021).

32 Eichler N, Thornley C, Swadi T et al. Transmission of severe acute respiratory syndrome coronavirus 2 during border quarantine and air travel, New Zealand (Aotearoa). *Emerg Infect Dis* 2021. https://doi.org/10.3201/eid2705.210514

33 Berger D, Ananda-Rajah M, Miller A et al. Australia must take urgent coordinated national action on aerosol transmission of COVID-19 [website]. https://healthcareworkersaustralia.com/national-action-on-aerosol-transmission-of-covid-19/ (viewed 1 February 2021; last updated 26 January 2021).

34 Tang JW, Bahnfleth WP, Bluyssen PM et al. Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus (SARS-CoV-2). *J Hosp Infect* 2021. https://doi.org/10.1016/j.jhin.2020.12.022

35 Bloch AB, Orenstein WA, Ewing WM et al. Measles outbreak in a pediatric practice: airborne transmission in an office setting. *Pediatrics* 1985; 75: 676-683.

36 Remington PL, Hall WN, Davis IH et al. Airborne transmission of measles in a physician's office. *JAMA* 1985; 253: 1574-1577.

Tables

Box 1. Summary of recommendations to prevent airborne transmission of SARS-CoV-2

Key areas for action
• Reinforce the border through improved ventilation in quarantine facilities, vaccination of workers and the use of airborne PPE • Replace high-rise quarantine facilities with accommodation modelled on the Howard Springs facility, in which residents are separated by open air • Update all COVID-19 guidance to emphasise the risk of aerosol transmission of SARS-CoV-2 • Mandate and fund ventilation assessments and upgrades of essential public institutions, such as hospitals, schools, aged care facilities and prisons • Promote strategies to reduce transmission risk through clear public health messaging and education • Ensure the availability of fit-tested P2/FFP2/N95 respirators for anyone in contact with a potential COVID-19 patient • Replace the harmful concept of "aerosol generating procedures" as the sole risk for airborne spread with the knowledge that airborne spread is likely the norm in all situations, given SARS-CoV-2 containing aerosols are readily produced by breathing • Fast track research into indoor air quality, including the study of carbon dioxide (CO_2) monitoring as a surrogate measure of indoor air quality and airborne pathogen risk • Include recommendations on the usage of indoor air cleaners such as appropriately sized portable air filtration (HEPA) units or simple, practical and low-cost homemade devices using MERV-11/13 filters and box fans

- Develop clear national ventilation standards for indoor environments
- Broaden the diversity of people advising on infection control, by including experts from aerosol science, engineering, HVAC, occupational hygiene, occupational health and safety, and organisational psychology

Note: Recommendations are adapted from the open letter to the Australian Health Protection Principal Committee (AHPPC) and national and state and territory leaders.[33] HEPA = high-efficiency particulate air; HVAC = heating, ventilation, and air conditioning; MERV = minimum efficiency reporting value; PPE = personal protective equipment.