Sax Institute

Evidence Snapshot

What is known about aerosol transmission of SARS-CoV-2?

An Evidence Snapshot brokered by the Sax Institute for the Australian Commission on Safety and Quality in Health Care.
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This updated report was prepared by: Dawson G, Moore G, Du Toit A, Gordon R, Jameson B. August 2020.
 Content expertise and peer review was provided by Professor Raina MacIntyre.

Enquiries regarding this report may be directed to the:

Manager
Knowledge Exchange Program
Sax Institute
www.saxinstitute.org.au
knowledge.exchange@saxinstitute.org.au
Phone: +61 2 9188 9500

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This Evidence Snapshot was produced using the Evidence Snapshot methodology in response to specific questions from the commissioning agency.

It is not necessarily a comprehensive review of all literature relating to the topic area. It was current at the time of production (but not necessarily at the time of publication). It is reproduced for general information and third parties rely upon it at their own risk.

Introduction

This Evidence Snapshot was commissioned by the Australian Commission on Safety and Quality in Health Care and prepared by the Sax Institute. Note that it was completed within 3 days, so while a rigorous process for searching was followed it is possible that some peer reviewed or grey literature may have been missed.

As the COVID-19 pandemic in Australia continues, and an increasing number of healthcare workers test positive for COVID-19, actions to manage a longer-term response are under consideration. In particular, the Commission is interested in the evidence on the comparative efficacy of N95 and medical masks for health care workers in hospitals and for health and other care workers in residential aged care settings. Current recommendations in Australian jurisdictions and internationally are conflicting.

Recommendations in favour of medical masks for non-aerosol generating procedures may be based in part on evidence that is no longer current. The Commission is therefore also interested in the latest evidence on aerosol transmission and whether this should change the advice on the type of masks worn by health care workers. This Evidence Snapshot reviews the most recent literature on aerosol transmission and the findings should be considered with the second Evidence Snapshot on the efficacy of respirators and medical masks in reducing transmission of COVID-19.

Review question

What is known about aerosol transmission of COVID 19?

Methods

We searched PubMed and collections of COVID-19 related research (Oxford University Centre for Evidence Based Medicine, CDC, Cochrane, ScienceDirect, Lancet, BMJ). The searches were undertaken on 10 August 2020. A total of 223 papers were identified through the searches. After title and abstract review, 19 papers were included in this report. A summary of the key findings is presented in the next section, with full results reported in Appendix 2 and 3.

Summary of findings

Summary statement

We identified 19 papers for inclusion in this Evidence Ssnapshot. Of these,15 studies were considered evidence from research (reviews, experimenta, and observational studies), and four were commentaries.

Overall, the evidence regarding the extent to which aerosol transmission of SARS-CoV-2 occurs is limited and remains inconclusive. From the evidence that is available, it appears that transmission of SARS-CoV-2 is likely to occur on a spectrum between droplet and airborne transmission, where a number of patient, disease and environmental factors mediate the risk of infection. Furthermore, horizontal transmission of droplets to distances up to 8 meters has been concluded by one systematic review.

Given that aerosolization of SARS-CoV-2 is possible, with horizontal transmission feasibily occurring at distances up to 8 metres, adherence to precautionary principles may be warranted so as to adequately protect health care workers.

Key Messages

Peer reviewed literature

- A total of 19 articles were considered to answer this question. There was: one systematic review(1); seven observational studies(2-8); three experimental studies(9-11). Four reviews, of which two were structured searches with specified search terms(12, 13) and two had no methods described(14, 15); and four commentaries(16-19).
- Airborne transmission of SARS-CoV-2 is possible. Reviews by de Gabory, Islam and Jayaweera all state the virus may spread as an aerosol, with droplets smaller than 5µm becoming airborne(12).
- Aerosolisation has been demonstrated in the laboratory with persistence of the virus demonstrated for 3 hours(11) up to 16 hours(9). Although de Gabory notes even when aerosolization does occur, viral RNA is not always present, and presence of the virus does not always generate an infection.
- Although there were only two epidemiological studies included in this snapshot, both studies(2, 8) concluded that airborne transmission did not occur. In one study there was no evidence of nosocomial infection(8), in the other only close contacts who were at the patient’s bedside without contact and droplet PPE were infected(2). Both studies recorded aerosol generating procedures occurred with the index patient. A wider search of literature examining infections in healthcare workers and the role of personal protective equipment may be needed to more fully understand this. Some studies have shown high infection rates among healthcare workers.

- Environmental sampling undertaken in three studies found virus RNA in air samples(3, 4, 7) however only one study(7) measured viral replication in cell culture suggestive of infectious potential. The other two studies did not attempt to establish the viability of the virus in the samples taken.
- In a real world setting, factors such as virus viability, contact time and minimum infectious dose (which is not known) appear to be important mediators of transmission(12, 15) which may go some way to explaining the results of epidemiological investigations where transmission has been observed to be limited or non-existent.
- With respect to horizontal transmission and the assumption that large droplets only travel 2m, the systematic review by Bahl concludes that droplets may travel distances greater than 2 meters, and in some cases up to 8 meters. Environmental factors such as airflow, humidity and use of air conditioners and air mixing fans may also influence the horizontal travel of droplets(13).

Peer reviewed commentaries

- Three commentaries argue that the weight of existing evidence supports airborne transmission of SARS-CoV-2 via both small and large particle aerosols(17-19), although variability in infectious aerosol production is likely, which may explain the epidemiology of super spreading(17). Morawska cites multiple studies where airborne transmission likely occurred, particularly in crowded, poorly ventilated environments.
- Conversely, Conly(16) argues that SARS-CoV-2 does not spread through the airborne route to any significant extent citing the low secondary attack rate in family clusters and the relatively low reproductive rate (R_0), which is compatible with other respiratory viruses typical for droplet/contact modes of transmission as opposed to classical airborne viruses (e.g. measles) which are estimated to have an R_0 of greater than 10. However it is important to note that R_0 has never been a criterion for defining the mode of transmission, rather it is a function of the interaction between the pathogen, host and environment and varies according to factors such as population density and environment.

Appendices

Appendix 1: Search strategy

Key concepts

Concept 1	Concept 2	Concept 3	Concept 4
Aerosol	hospital	transmission	COVID*
airborne		infection	CoV
viral shedding			SARS CoV 2

Timeframe

- Last 12 months

Inclusion criteria

We **included** combinations of the following key words: aerosol*, airborne, viral shedding, transmission, infection, COVID*, CoV, SARS CoV 2, coronavirus. NO grey literature or jurisdictional searches were conducted due to time constraints.

We did not critically appraise the included studies and note that some studies may have been published before peer review was completed.

Appendix 2: Summary of included studies

	First author	Study type	Study reports on				
			Droplets	Aerosols	Transmission >2m	Air samples	Surface samples
1	Bahl	Systematic review	x		x		
2	Bays	Observational	x				
3	Chia	Observational		x		x	x
4	de Gabory	Review	x	x			
5	Fears	Experimental		x			
6	Guo	Observational		x		x	x
7	Islam	Review	x	x	x	x	x
8	Jayaweera	Review	x	x			
9	Leung	Experimental	x	x			
10	Li	Observational	x	x			x
11	Liu	Observational		x		x	x
12	Ong	Review	x	x			
13	Santarpia	Observational	x	x		x	x
14	Wong	Observational					
15	Van Doremalen	Experimental		x			
16	Conly	Commentary	x	x			
17	Fennelly	Commentary	x	x			
18	Morawska	Commentary		x			
19	Setti	Editorial	x	x			

Appendix 3: Data extraction tables

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
1	Bahl, 2020	systematic review	to review the evidence supporting the rule for 1-meter spatial separation for droplet precautions	n=10 studies included - not COVID specific. 7/10 were modelling studies; 2/10 used analogous water tank experiments to validate mathematical modelling. 5/10 studies were experiments using human subjects, in 2 studies this was used to validate the modelling. 4 studies generated natural sneezes/coughs.	8/10 studies showed droplets travelled >2m, and in some cases up to 8m	n/a	collectively, the studies support horizontal transmission of droplets to a distance greater than 2 meters and up to a max of 8m. This warrants a review of current recommendations for spatial separation of 1m, which is not based on current evidence.	consider in conjunction with other COVID specific studies of transmission. i.e. transmission is likely to be similar to SARS (spread by contact, droplet and airborne routes). Presence of COVID viral loads in both upper and lower respiratory tracts as well as the persistence of the virus in the air 3 hours post aerosolisation in lab settings, suggests airborne transmission is possible
2	Bays, 2020	observational	to describe patterns of transmission of COVID during 2 nosocomial	contact investigation with active case finding		ward, ICU	8 of 421 contacts were infected with COVID. Transmission was observed to occur exclusively among staff who were at the patient's bedside without contact and droplet PPE. there was no transmission to staff or patients elsewhere on the	dose response may be an important mediator of transmission. While the infectious dose required for

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
			outbreaks with regards to possibility of airborne transmission				units include an oncology ward housing a number of immunocompromised patients. these findings are consistent with transmission by respiratory droplets rather than airborne transmission. There was no evidence of airborne transmission despite multiple aerosol- generating procedures.	transmission of COVID remains unknown it is likely that the failure of airborne particles transmit infection over long distances may be attributable to an insufficient number of inhaled virions
3	Chia, 2020	observational	to identify potential patient level risk factors for environmental contamination by COVID by sampling air and surfaces surrounding hospitalised COVID patients at different stages of illness.	environmental sampling (surface and air)		3 airborne infection isolation rooms (AIIRS) in the ICU and 27 AIIRS in the general ward	245 samples were collected. 56.7% of rooms had at least one environmental surface contaminated. High touch surface contamination was shown in 10 (66.7%) out of 15 patients in the first week of illness and 3 (20%) beyond the first week of illness. Air sampling was performed in 3 of the 27 AIIRs in the general ward and detected COVID positive particles in sizes >4um and 1-4um in two rooms despite these rooms having 12 air changes per hour.	presence of COVID in the air is possibly highest in week 1 of illness

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
4	de Gabory, 2020	review	to clarify the mechanisms of production and penetration of droplets of secretions emitted during all expiratory phenomena likely to transport these viruses (SARS COV-2 and Influenza) and come into contact with the respiratory mucosa	structured search of literature: number of included studies not specified		n/a	Aerosol droplets < 5um are the most problematic because they remain airborne - however they do not all contain viral RNA. furthermore, detection of viral RNA does not imply contagiousness. Other factors such as viability and minimum infectious dose are also critical. if droplets are inhaled, the minimal infectious dose must be reached (unknown at this point) - and it is likely that contact time is also another mediating factor.	airborne particles likely to originate from the lung where the viral load is likely to be higher
5	Fears, 2020	experimental	to determine the dynamic aerosol efficiency of SARS CoV-2	to determine the aerosol stability of SARS-CoV-2 the dynamic (short term) aerosol efficiencies were compared with the efficiency of SARS-CoV and MERS-CoV. Experiment were			the comparison of short-term aerosol efficiencies of the 3 coronaviruses showed that SARS-CoV-2 approximates or exceeds the efficiency estimates of SARS-CoV and MERS-CoV. Aerosol suspension results suggests that SARS-CoV-2 persists longer than would be expected when generated at this size particle (2um mass median aerodynamic diameter). the data suggest that SARS-CoV-2 maintains infectivity at a respirable particle size over short distances > aerosol transmission may	SARS CoV-2 has greater propensity for aerosolisation than SARS or MERS (both of which are accepted as having airborne potential) and that viable virus can be detected in the air 16

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
				conducted in 4 independent laboratories			be more important exposure transmission pathway than previously considered.	hours after aerosolisation
6	Guo, 2020	observational	to determine distribution of SARS-CoV-2 in 2 hospital wards in Wuhan China by testing air and surface samples	environmental sampling (surface and air)	aerosol distribution characteristics in the ICU indicate that transmission distance might be 4m.	ICU, general ward	SARS-CoV-2 was found to be widely distributed in the air and on object surfaces in both the ICU and general wards. Environmental contamination was found to be greater in the ICU than in the general ward. Aerosol distribution characteristics in the ICU indicate that transmission distance might be 4m.	
7	Islam, 2020	review	review of current evidence on transmission dynamics and on pathogenic and clinical features of SARS-CoV-2	review of global COVID guidelines and search of publications	droplets may travel > 4m		the review suggests SARS-CoV-2 may soread as a droplet, aerosol and through the oral-fecal route. A recent study has demonstrated that droplets may travel >4m. Furthermore, environmental factors such as airflow, humidity and use of air conditioners and air mixing fans may also influence the horizontal travel of droplets (an outbreak of COVID linked to air conditioning has been reported in China).	
8	Jayaweera, 2020	review	to outline the literature on transmission of virus laden droplets and aerosols in	no methods described			both droplets and aerosols generated from non-violent and violent expirations of SARS CoV-2 infected persons may be responsible for airborne transmission of the virus. The behaviour of the virus in different environmental settings,	

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
			different environmental settings.				especially confined spaces is yet to be fully understood.	
9	Leung, 2020	experimental	to explore the importance of respiratory droplet and aerosol routes of transmission with a particular focus on corona- , influenza- , and rhino- , viruses by quantifying the amount of respiratory virus in exhaled breath and determining the potential efficacy of surgical face masks to prevent	n=246, 111 infected with human (seasonal) coronavirus, influenza virus or rhinovirus. Testing of exhaled breath samples for respiratory viruses. Randomized (50/50) to wearing and not wearing a face mask during breath collection. Compared respiratory droplet samples and aerosol samples between samples collected with and without a face mask.			Coronavirus RNA was detected from respiratory droplets (30% of samples) and aerosols (40% of samples) in the not-mask-wearing group. Coronavirus was not detected in respiratory droplets or aerosols in the mask-wearing group. The difference was significant for aerosols. Results indicate aerosol transmission is a a potential mode of transmission for coronaviruses (as well as influenza- and rhino- viruses). The study demonstrated the efficacy of surgical masks to reduce coronavirus detection and viral copies in large respiratory droplets and aerosols suggesting surgical masks could be used to reduce transmission.	Those with coronavirus coughed more frequently than those with other respiratory viruses.

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			respiratory virus transmission.					
10	Li, 2020	observational	to assess the effectiveness of infection prevention and control procedures on eliminating SARS-CoV-2 contamination in a hospital setting	researchers examined the viral load of SARS-CoV-2 in aerosol samples and environmental surfaces in a hospital designated for treating severe COVID-19 patients. Samples were taken 1 hour after routine twice-daily cleaning of contact surfaces and floors and after four-time-daily air disinfection with a plasma air steriliser		Environmental surfaces inside and outside the ward were swabbed. Aerosol samples were collected from locations including: the ICU, general isolation wards, fever clinic, storage room for medical waste, conference rooms and the public area	All but two of 90 surface swabs were negative for SARS-CoV-2-RNA. The two positive samples were taken from inside a patient's mask. SARS-CoV-2-RNA was not detected in any of the 135 aerosol samples	viral cultures not performed

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
11	Liu, 2020	observational	to investigate the aerodynamic nature of SARS-CoV-2 by measuring viral RNA in aerosols in different areas of two Wuhan hospitals during the outbreak of COVID-19 in Feb and Mar 2020	Analysed the occurrence of airborne SARS-CoV-2 and its aerosol deposition at 30 sites in two hospitals and public areas in Wuhan then quantified the copy counts of SARS-CoV-2 in aerosol samples		Patient areas, ICUs, staff areas, public areas (e.g. hospital pharmacy, outpatient hall, supermarket)	concentration of SARS-CoV-2 RNA in aerosols that was detected in isolation wards and ventilated patient rooms was very low, but it was higher in the toilet areas used by the patients	Results suggest lower risk of transmission in open, well-ventilated areas. Findings also suggest virus-laden aerosol deposition may have a role in surface contamination. Infectivity of virus samples was not established.
12	Ong, 2020	review	summary of available evidence on transmission modes and environmental contamination	no methods described			COVID-19 patients can shed viable virus from both the respiratory and GI tracts resulting in transmission either directly via droplet and opportunistic aerosol generation or indirectly via contamination of the environment or fomites. Based on current evidence, the extent of airborne contamination is unclear. It is likely to lie on a continuum from droplet to airborne, with several mediating factors related to patient, disease and environment. While several studies have detected SARS-CoV-2 RNA in air samples, none have isolated viable virus in culture.	transmission likely lies on a spectrum between droplet to airborne transmission depending on a range of patient, disease and environmental factors

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13	Santarpia, 2020	observational	collected air and surface samples to examine viral shedding from isolated individuals to inform infection and control guidelines			isolation rooms being used for care of COVID-19 patients in two Nebraska hospitals	75% of room surface samples tested positive for SARS-CoV-2 4/5 ventilation grates tested positive 63% of in-room air samples tested positive Findings indicate SARS-CoV-2 may spread through both direct (droplet and person-to-person) and indirect (contaminated objects and airborne transmission) mechanisms. The observation of viral replication in cell culture for two of the samples (air and windowsill) confirms these samples may have infectious potential.	The data indicate significant environmental contamination in rooms where COVID-19 patients are cared for. Data suggests viral aerosol particles are produced by individuals with COVID-19 even in the absence of a cough. Lack of a strong relationship between environmental contamination and body temp. reaffirms the fact that shedding of viral RNA is not necessarily linked to clinical signs of illness.

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14	Wong, 2020	observational	to describe an outbreak investigation of a patient with COVID-19 who was nursed in an open cubicle of a general ward setting in Hong Kong	contacts were identified and risk stratified and respiratory samples were taken during the surveillance period.		general ward	The index patient stayed on the general ward for 35 hours including an AGP (18 hours of oxygen therapy 8L/min)71 staff and 49 patients were identified from contact tracing. 17 were identified as being close contacts. After the 28-day surveillance period all tested negative. The authors conclude that SARS-CoV-2 is not transmitted via the airborne route.	no evidence of nosocomial infection. High use of PPE by staff and some patients
15	Van Doremalen, 2020	experimental	to evaluate the stability of SARS-CoV-2 and SARS-CoV-1 in aerosols and on various surfaces and estimate their decay rates	10 experimental conditions involving the two viruses in 5 environmental conditions (aerosols, plastic, stainless steel, copper and cardboard). Decay rates estimated using Bayesian regression model			SARS-CoV-2 remained viable in aerosols throughout the duration of the experiment (3 hours). SARS-CoV-2 was more stable on plastic and stainless steel with viable virions detected up to 72 hours after application - although the infectious titre was greatly reduced. The stability of SARS-CoV-2 was similar to SARS-CoV-1 under the different experimental conditions.	differences in the epidemiological characteristics of the two viruses probably arise from other factors including high viral load in the upper respiratory tract, and the potential for SARS-CoV-2 patients to shed and transmit the virus whilst asymptomatic

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16	Conly, 2020	commentary		n/a			the vast majority (75-85%) of investigated infection clusters occurring within families, with a household secondary attack rate varying between 3-10% is not consistent with airborne transmission. The reproduction rate was estimated to be between 2.0-2.5 which is compatible with influenza and other respiratory viruses typical for droplet/contact mode of transmission as opposed to classical airborne viruses such as measles which is estimated to have a reproductive rate of greater than 10.	based on the scientific evidence to date, the authors postulate that SARS-CoV-2 does not spread via the airborne route to any significant extent and argue that the use of particulate respirators offers no advantage over medical masks for routine care of COVID-19 patients in the healthcare setting
17	Fennelly, 2020	Commentary		n/a			infectious aerosols are particles with potentially pathogenic viruses are suspended in the air, which are subject to the same physical laws as other airborne particulate matter. The biology of pathogens predicts their airborne survival. Particle size is the most important determinant of aerosol behaviour. small particles <5um are most likely to remain airborne for indefinite periods. humans produce infectious aerosols in a wide range of particle sizes, but pathogens predominate in small particles <5um that are immediately respirable by exposed individuals. data is accumulating that SARS-CoV-2 can be transmitted via both small and large particle aerosols. the variability of infectious	the author suggests that the weight of evidence supports the potential for airborne transmission and that respirators should be used for those in close contact with COVID patients.

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
							aerosol production might explain the epidemiology of super spreading.	
18	Morawska, 2020	Commentary		n/a			the authors argue that SARS-CoV-2 should be treated as having the potential to spread via the airborne route. They cite multiple studies where airborne transmission was likely to have occurred, particularly in crowded, poorly ventilated environments. The authors suggest specific exposure circumstances may be an important factor. as such effective prevention should consider all important exposure pathways.	while uncertainties remain regarding the relative contributions of the different transmission pathways, the authors argue that the existing evidence is sufficiently strong to warrant actions to mitigate airborne transmission, in this case, the use of engineering controls such as ventilation, filtration and disinfection of air.

Reference number	Author, year	Study type	Aim/objective	Notes on methods	Distance travelled including if >2m	Location (ward, ICU, ED, other, not stated	Results/findings	Notes/comments
19	Setti, 2020	editorial		n/a	recently published studies support the hypothesis of virus transmission over a distance of 2m - possible diffusion in indoor environments up to 10m.		researchers have demonstrated higher aerosol and surface stability as compared with SARS-CoV-1 and that airborne transmission can occur besides close-distance contacts. The authors suggest there is reasonable evidence to support the possibility of airborne transmission due to its persistence into aerosol droplets in a viable infectious form.	the authors argue that the available evidence supports the hypothesis of a model of airborne droplets from person to person at a distance greater than 2m

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