Sax Institute

Evidence Snapshot

Update: 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.
October 2020.

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October 2020.

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Disclaimer:

Introduction

This Evidence Snapshot was commissioned by the Australian Commission on Safety and Quality in Health Care and prepared by the Sax Institute. It combines the findings from an earlier version (August 2020) and now includes literature to 8 October 2020.

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in favour of medical masks for non-aerosol generating procedures may be based in part on evidence that is no longer current.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).

Searches were conducted on 8 October 2020 and limited to 10 August 2020 to the end of 2020 (to allow for preprint articles dated for their planned date of publication).

A total of 504 papers were identified through the searches. After title and abstract review, 18 papers were included in addition to the 19 papers included in the original report. A summary of the key findings is presented in the next section, with full results reported in Appendix 4 and 5.

Summary of findings

Summary statement

A total of 37 papers were included in this updated Evidence Snapshot (18 new studies). Of these, 33 studies were considered evidence from research (reviews, experimental, and observational studies), and four were commentaries.

Overall, the evidence regarding the extent to which aerosol transmission of SARS-CoV-2 is increasing. New evidence from studies of outbreaks and of environmental sampling of air and air vents shows aerosol transmission is likely, particularly in indoor environments, air conditioned spaces and where there is close proximity.

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 greater than 2 metres (and up to 8 metres in one study) has been concluded by three different studies. In addition, several studies of hospital transmission have found SARS-CoV-2 at distances of up to 4.8 metres from patients in the absence of aerosol generating procedures.

Given that aerosolization of SARS-CoV-2 is possible, with horizontal transmission feasibly 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

- In summary, the evidence considered in this update includes:
  - Environmental sampling studies (n=13) collected in hospital wards or other facilities (nursing home, ferry, quarantine facilities) (1-13)
  - Experimental studies (n=4) (14-17)
  - Epidemiological studies (n=10): nine outbreak investigations (18-26) and one contact investigation (27)
  - Evidence reviews (n=6) (28-33)
  - Commentaries/editorials (n=4) (34-37)
- Airborne transmission of SARS-CoV-2 is possible. Five evidence reviews state the virus may spread as an aerosol (29-33), with droplets smaller than 5μm becoming airborne (29). Tang et al (2020) identified several studies that support aerosol transmission of SARS-CoV-2, and the authors assigned a plausibility score of 8 out of 9 (being the weight of the combined evidence) (33).

  Of the included studies of environmental sampling:

- nine studies identified virus on air vents (1-4, 6, 8-10, 13)
- nine studies found viral RNA in the air (1-4, 6, 8, 10, 12, 13)
- two studies identified viable virus in air samples (4, 10)

- In experimental studies conducted in laboratories, aerosolisation has been demonstrated, with persistence of the virus demonstrated for 90 minutes (15), 3 hours (16), up to 16 hours (14).
- This update included an additional eight epidemiological studies (total n=10), nine of which were investigations of outbreaks (18-26) and one investigated close contacts of a case in a general hospital ward (27).

  Of these, only two concluded that airborne transmission did not occur (18, 27). The remaining eight studies showed transmission occurred without close direct contact (19-26). Shared indoor space, closed air recirculation and singing were identified as possible factors associated with increased risk of transmission.

  Of the two studies that concluded that airborne transmission did not occur, one study found no evidence of nosocomial infection (27), in the other only close contacts who were at the patient's bedside without contact and droplet PPE were infected (18).
- In a real-world setting, factors such as virus viability, contact time, minimum infectious dose (which is not known), and superspreading appear to be important mediators of transmission (29, 32) 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, the systematic review by Bahl et al. (2020) concluded that droplets may travel distances greater than 2 meters, and in some cases up to 8 meters (28). Santarpia and Lednicky also confirm horizontal transmission up to 2 metres and 8 metres respectively (4, 10). Environmental factors such as airflow, humidity and use of air conditioners and air mixing fans may also influence the horizontal travel of droplets (30).

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 (34-36), although variability in infectious aerosol production is likely, which may explain the epidemiology of super spreading (36). Morawska cites multiple studies where airborne transmission likely occurred, particularly in crowded, poorly ventilated environments (35).
- Conversely, Conly 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 (R0) (37). The low R0 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 R0 of greater than 10. However it is important to note that R0 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. Tuberculosis, which is accepted as airborne, has a R0 <1, which also shows the R0 cannot be used to prove mode of transmission.

Jurisdiction and country responses

The position of several European countries is that COVID-19 is primarily spread through respiratory droplets, such as those generated through coughing and sneezing (Ireland, Sweden, Denmark, The Netherlands and Norway) https://www2.hse.ie/conditions/coronavirus/how-coronavirus-is-spread.html https://www.folkhalsomyndigheten.se/the-public-health-agency-of-sweden/communicable-disease-control/covid-19/ https://www.sst.dk/en/English/Corona-eng/COVID-19-and-novel-coronavirus/How-novel-coronavirus-spreads https://www.rivm.nl/en/novel-coronavirus-covid-19/coronavirus-disease-covid-19 https://www.fhi.no/en/op/novel-coronavirus-facts-advice/facts-and-knowledge-about-covid-19/facts-about-novel-coronavirus/?term=&h=1

- England's position statement as at 21 October 2020 is that transmission of SARS-CoV-2 is primarily through respiratory (droplet and aerosol) routes. Public Health England states that airborne transmission can occur in health settings where aerosol generating procedures are performed, and may occur in poorly ventilated indoor spaces https://www.gov.uk/government/publications/wuhan-novel-coronavirus-background-information/wuhan-novel-coronavirus-epidemiology-virology-and-clinical-features#transmission
- The Canadian government states that the main mode of transmission for SARS-CoV-2 is respiratory droplets generated through coughing, sneezing, talking or breathing https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals.html#a2
- The Center for Disease Control's (CDC) current advice (5 October 2020) is that respiratory droplets generated during exhalation (e.g. breathing, speaking, singing, coughing or sneezing) are the primary mode of transmission of SARS-CoV-2. Droplet transmission is most likely to occur when someone is close to the infectious person, generally within six feet. CDC posted information on its website on 18 September 2020 which stated for the first time that SARS-CoV-2 could be spread through airborne particles that could remain suspended in the air and travel distances beyond six feet. The CDC later retracted this information and said that a draft version of proposed changes had been posted in error https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html https://www.bmj.com/content/370/bmj.m3739
- The New Zealand government's position statement is that transmission is most likely through respiratory droplets, with current evidence not supporting airborne transmission, except during aerosol generating procedures https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-information-health-professionals/covid-19-advice-all-health-professionals
- The World Health Organisation (WHO) states in their July update that WHO and the scientific community are actively discussing whether COVID-19 can spread through aerosols in the absence of aerosol generating procedures. WHO states that short-range aerosol transmission, particularly in poorly ventilated and crowded indoor spaces, cannot be ruled out https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

- The European Centre for Disease Prevention and Control (ECDC) position at 30 June 2020 is that primary transmission of COVID-19 is through respiratory droplets, and that the role of aerosols is still unclear
  https://www.ecdc.europa.eu/en/covid-19/latest-evidence/transmission

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: Search results

A Database	B Results	C Remove duplicates	D Excluded after title & abstract screening	E Full text review	F Excluded after full text review	G FINAL INCLUDED
	n=	n=	n=	n=	n=	n=
1 PubMed	58					
2 Oxford CEBM	18					
3 Cochrane	10					
4 ScienceDirect	236					
5 Lancet *	0					
6 BMJ	139					
7 Google Scholar	43					
TOTAL	504	471	412	59	22	37

The table above aggregates search results from the original report and the searches undertaken for this updated report.

Appendix 3: Summaries of included studies

Table 1—Studies that tested air and air vents

Study	Study type/location	Virus on air vents	Viral RNA in air	Viable virus in the air	Persistence in aerosol time/distance	Comments
Ben-Shmuel	Quarantine facility	Y	Y	N		No viable virus was cultured from any of the 97 surface and air samples taken
Binder	Hospital	Y	Y	N	Y	The prevalence of molecular positivity among fomites and aerosols was low along with a lack of viable SARS-CoV-2 virus in fomites and air samples implied low nosocomial risk of SARS-CoV-2 transmission through inanimate objects or aerosols
Chia	Hospital	Y	Y	N/A	Highest in early illness	COVID positive particles were detected in sizes >4um and 1-4um in two rooms despite these rooms having 12 air changes per hour. No attempt to culture the virus
Fears	Experimental	N/A	Y	Y	16 hours	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)
Guo	Hospital	Y	Y	N		SARS-CoV-2 was found to be widely distributed in the air and on object surfaces in both the ICU and general wards. Aerosol distribution characteristics in the ICU indicate that transmission distance might be 4m
Lednicky	Hospital	-Y	Y	Y	4.8m from patient	Viable SARS-CoV-2 was isolated from air samples collected 2 to 4.8 m away from the patients

Table 1—Studies that tested air and air vents

Study	Study type/location	Virus on air vents	Viral RNA in air	Viable virus in the air	Persistence in aerosol time/distance	Comments
Leung	experimental	N/A	N/A	N/A	N/A	Results indicate aerosol transmission is a potential mode of transmission for coronaviruses
Li	Hospital	N	N	N	N	SARS-CoV-2-RNA was not detected in any of the 135 aerosol samples. Results suggest lower risk of transmission in open, well-ventilated areas
Liu	Hospital	Y	Y	Not stated	N/A	The concentration of SARS-CoV-2 RNA in aerosols detected in isolation wards and ventilated patient rooms was very low, but it was higher in the toilet areas used by the patients. Levels of airborne SARS-CoV-2 RNA in the most public areas was undetectable, except in 2 areas prone to crowding; possibly due to infected individuals in the crowd
Masounbeigi	Hospital	N	N	N	N/A	
Mouchtouri	Ferry, hospital and nursing home	Y	Y			Respiratory droplets/nuclei from infected persons can be displaced by the air flow and deposited on surfaces
Ong	Hospital	Y	N	N		Viral culture was not done so viability of virus samples is unknown
Santarpia	Hospital	Y	Y	Y	>2m from patient	

Table 1—Studies that tested air and air vents

Study	Study type/location	Virus on air vents	Viral RNA in air	Viable virus in the air	Persistence in aerosol time/distance	Comments
Smither	Experimental	N/A	Y	Y	90 minutes	Results suggest small particle aerosols may remain viable for at least 90mins
Song	Hospital	N	N	N	N	No virus was found in air samples
Van Doremalen	Experimental	N/A	Y	Y	3 hours	SARS-CoV-2 remained viable in aerosols throughout the duration of the experiment (3 hours)
Zhou	Hospital	N/A	Y	N	N/A	All surface and air samples from the hospital environment had a Ct value >30, which indicates the virus is not culturable

Table 2—Studies of outbreaks and case investigations

Study	Outbreak/Investigation	Comments
Bays	Nosocomial outbreak in two US medical centres	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. Dose response may be an important mediator of transmission
Hamner	Superspreader event in a choir	Following a 2.5 hour choir practice attended by 61 people, including an asymptomatic index patient, 32 confirmed and 20 probable secondary COVID-19 cases occurred (attack rate=53.3–86.7%). Transmission likely facilitated by close proximity (within 6ft) and augmented by singing

Table 2—Studies of outbreaks and case investigations

Study	Outbreak/Investigation	Comments
James	Outbreak at a rural Arkansas church	35/92 attendees developed lab confirmed COVID. Activities included children participating in competitions to collect offerings by hand from adults, singing and food served via a buffet
Kang	Outbreak in high rise apartment building in Guangzhou	The observed infections and locations of positive environmental samples are consistent with the vertical spread of virus-laden aerosols via stacks and vents. Transmission may have resulted from faecal aerosol transmission
Lu	Air conditioned restaurant in Guangzhou	10/91 people in the restaurant (8 staff, 83 customers) became ill with COVID-19. The most likely cause of the outbreak was droplet transmission propagated by strong airflow from the air conditioner
Payne	US Navy aircraft carrier USS Theodore Roosevelt.	Overall, 228 (60%) participants had a positive ELISA result, one fifth of infected participants reported no symptoms. Prevalence was found to be higher when cases reported previous COVID- contact. Prevalence was also higher among cases who shared the same sleeping berth with a crewmember who had positive test results. Preventative measure such as mask wearing, avoiding common areas and observing social distancing were associated with lower risk of infection
Qian	318 outbreaks involving 1,245 infected individuals in 120 cities in China (excluding Hubei province)	All identified outbreaks of three or more cases occurred in an indoor environment, indicating that sharing indoor space is a major SARS-CoV-2 infection risk
Shen	2 buses in Zhejiang province, China.	Attack rates on the exposed (Bus 2) and unexposed buses (Bus 1) were distinct (34.3% vs 0%) indicating that environments with closed air recirculation (recycled air) were associated with increased risk of CoV-2 infection
Szablewski	Outbreak at Georgia Overnight Camp	260/597 tested positive. Attack rates increased with increasing length of time spent at the camp, as staff members having the highest attack rate (56%)

Table 2—Studies of outbreaks and case investigations

Study	Outbreak/Investigation	Comments
Wong	Contact investigation in a general ward in Hong Kong	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 was not transmitted via the airborne route

Table 3— Reviews

Study	Method	Comments
Bahl	Systematic review	8/10 studies showed droplets travelled >2m, and in some cases up to 8m
De Gabory	Review	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
Islam	Review	the review suggests SARS-CoV-2 may spread as a droplet, aerosol and through the oral-faecal 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)
Jayaweera	Review	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, especially confined spaces is yet to be fully understood
Ong	Review	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
Tang	Evidence review	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

Table 4—Editorials and commentaries

Study	Study type	Comments
Conly	Commentary	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
Fennelly	Commentary	Data is accumulating that SARS-CoV-2 can be transmitted via both small and large particle aerosols. the variability of infectious aerosol production might explain the epidemiology of super spreading
Marowska	Commentary	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
Setti	Editorial	Research has 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

Appendix 4: Data extraction tables

Table 5—Peer reviewed studies from initial report

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	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

Table 5—Peer reviewed studies from initial report

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
				generated natural sneezes/coughs				
2.	Bays 2020	Observational	To describe patterns of transmission of COVID during 2 Nosocomial outbreaks with regards to possibility of airborne transmission	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 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	Dose response may be an important mediator of transmission. While the infectious dose required for 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

Table 5—Peer reviewed studies from initial report

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
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

Table 5—Peer reviewed studies from initial report

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)			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	SARS CoV-2 has greater propensity for aerosolisation than SARS or MERS (both of which are accepted as having airborne potential)

Table 5—Peer reviewed studies from initial report

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 efficiencies were compared with the efficiency of SARS-CoV and MERS-CoV. Experiments were conducted in 4 independent laboratories			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 be more important exposure transmission pathway than previously considered	and that viable virus can be detected in the air 16 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	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	

Table 5—Peer reviewed studies from initial report

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
					distance might be 4m		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 spread 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	No methods described			Both droplets and aerosols generated from non-violent and violent expirations of SARS CoV-2 infected persons may be responsible for	

Table 5—Peer reviewed studies from initial report

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
			aerosols in different environmental settings				airborne transmission of the virus. The behaviour of the virus in 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	n=246, 111 infected with human (seasonal) coronavirus, influenza virus or rhinovirus. Testing of exhaled breath samples for respiratory viruses. Randomised (50/50) to wearing and not wearing a face mask during breath			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 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	Those with coronavirus coughed more frequently than those with other respiratory viruses

Table 5—Peer reviewed studies from initial report

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
			efficacy of surgical face masks to prevent respiratory virus transmission	collection. Compared respiratory droplet samples and aerosol samples between samples collected with and without a face mask			and viral copies in large respiratory droplets and aerosols suggesting surgical masks could be used to reduce 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.		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	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

Table 5—Peer reviewed studies from initial report

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
				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		medical waste, conference rooms and the public area		

Table 5—Peer reviewed studies from initial report

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, Coleman, Chia et al. 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	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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							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	
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	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

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							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	environmental contamination and body temp reaffirms the fact that shedding of viral RNA is not necessarily linked to clinical signs of illness
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

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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
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	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

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							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	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.	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.

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							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 aerosol production might explain the epidemiology of super spreading	

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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
19.	Setti 2020	Editorial		N/a	Recently published studies support the hypothesis of virus transmission over a		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	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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					distance of 2m – possible diffusion in indoor environments up to 10m		possibility of airborne transmission due to its persistence into aerosol droplets in a viable infectious form	

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1.	Ben-Shmuel 2020	SARS-CoV-2 virus stability and infectivity on non-porous surfaces was tested under controlled laboratory conditions. Surface and air sampling were conducted at two COVID-19 isolation units and in a quarantine hotel	To assess the infectivity of severe acute respiratory syndrome coronavirus 2 (SARSCoV-2) contaminating surfaces and objects in two hospital isolation units and a quarantine hotel	Surface and air sampling were conducted Viral RNA was detected by RT-PCR infectivity was assessed by VERO E6 CPE test	Yes Surface and Air	Yes Eight of these samples were air samples, of which three (37.5%) were positive by PCR	No Despite the presence of viral RNA in these samples, no viable virus was cultured from any of the 97 surface and air samples taken	No Not part of the study as it was directed to study surfaces	In laboratory-controlled conditions, SARS-CoV-2 gradually lost its infectivity completely by day 4 at ambient temperature, and the decay rate of viral viability on surfaces directly correlated with increase in temperature. Viral RNA was detected in 29/55 surface samples (52.7%) and 16/42 surface samples (38%) from the surroundings of symptomatic COVID-19 patients in isolation units of two hospitals and in a quarantine hotel for	Despite prolonged viability of SARS-CoV-2 under laboratory-controlled conditions, uncultivable viral contamination of inanimate surfaces might suggest low feasibility for indirect fomite transmission

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									asymptomatic and very mild COVID-19 patients. None of the surface and air samples from the three sites (0/97) contained infectious titres of SARS-Cov-2 on tissue culture assay	
2.	Binder 2020	20 patients hospitalised with coronavirus disease 2019 (COVID-19), their hospital rooms (fomites and aerosols), and their	To find molecular evidence of virus in sample types	Collection of a nasopharyngeal (NP) swab, complete a brief questionnaire, and provide a saliva sample and a self-collected rectal swab sample. The	Y prevalence of molecular positivity among fomites and aerosol	Y Among the aerosol samples collected in 20 patient rooms during enrolment	Y	Y 1. Patient number 9 was 10 DPSO (cough, difficulty breathing, fatigue, loss of smell, and gastrointestinal symptoms)	Among >400 samples, molecular evidence of virus in most sample types was found, especially the nasopharyngeal (NP), saliva, and faecal samples, but the prevalence of molecular positivity among fomites and aerosols was low.	The low molecular prevalence and lack of viable SARS-CoV-2 virus in fomites and air samples implied low nosocomial risk of SARS-CoV-2 transmission through

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		close contacts for molecular and culture evidence		same biological samples and a brief symptom questionnaire were again collected 14 and 28 days post enrolment from COVID-19 patients, and 21 days Post enrolment from their close contacts. Environmental swabs and aerosol samples were collected in COVID-19 patient rooms	s was low	, 3 patients (15.0%) had 1 positive aerosol sample		when SARS-CoV-2 RNA was detected in aerosols particle size <4 µm at approximately 2.2 meters from the head of her bed 2. Patient number 16 was 6 DPSO (cough, difficulty breathing, fatigue) when SARS-CoV-2 RNA was detected in aerosols with particle size >4	The agreement between NP swab and saliva positivity was high (89.5%; κ=0.79). Two NP swabs collected from patients on days 1 and 7 post–symptom onset had evidence of infectious virus (2 passages over 14 days in Vero E6 cells)	inanimate objects or aerosols.

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								µm at approximately 2.2 meters from the head of her bed		
3.	Hamner 2020	CDC Morbidity and Mortality Weekly Report Report on a superspreader event in a choir		Telephone interviews with choir members (n=122) to determine attendance at choir	N/A	N/A	N/A	N/A	Following a 2.5 hour choir practice attended by 61 people, including an asymptomatic index patient, 32 confirmed and 20 probable secondary COVID-19 cases occurred (attack rate=53.3–86.7%)	
4.	James 2020	CDC Morbidity and Mortality Weekly Report.	To investigate source of the outbreak		N/A	N/A	N/A	N/A	35/92 attendees at a rural Arkansas church during March 6–11 developed lab confirmed COVID-19.	

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		Church events							Highest attack rates were in people 19-64yrs (59%) and >/65yrs (50%). An additional 26 cases linked to the church occurred in the community. Estimated attack rate ranged from 38–78%	
5.	Kang 2020	Epidemiological survey High-rise apartment building	To investigate the temporal and spatial distributions of 3 infected families in a high-rise apartment building	Epidemiological survey, PCR testing of throat swabs, surface and air samples, tracer gas released into bathrooms as surrogate for virus-laden aerosols in the drainage system	Not stated	Not stated	Not stated		Both the observed infections and the locations of positive environmental samples are consistent with the vertical spread of virus-laden aerosols via stacks and vents. Substantial tracer gas concentrations were detected in all the	

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			and examine the associated environment variables to verify the role of fecal aerosols						monitored flats	

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6.	Lednicky 2020	Hospital rooms of two COVID patients One ready for discharge and other newly admitted	To know if severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) can be transmitted through aerosols	Air samples collected in the hospital room of two coronavirus disease-2019 (COVID-19) patients, one ready for discharge and the other newly admitted, were subjected to RT-qPCR and virus culture. The genomes of the SARS-CoV-2 collected from the air and isolated in cell culture were sequenced	NA	Yes	Yes	Yes 2-4.8 m	Viable SARS-CoV-2 was isolated from air samples collected 2 to 4.8 m away from the patients. The genome sequence of the SARS-CoV-2 strain isolated from the material collected by the air samplers was identical to that isolated from the newly admitted patient. Estimates of viable viral concentrations ranged from 6 to 74 TCID50 units/L of air	Patients with respiratory manifestations of COVID-19 produce aerosols in the absence of aerosol-generating procedures that contain viable SARS-CoV-2, and these aerosols may serve as a source of transmission of the virus

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7.	Lu 2020	'Research letter' Epidemiological investigation Air conditioned restaurant, no windows, distance between tables >1m	To report on COVID-19 transmission in an air conditioned restaurant	Mapping air flow from the air conditioner. Testing of throat swabs Testing of smear samples of air conditioner	No	N/A	N/A	N/A	10/91 people in the restaurant (8 staff, 83 customers) became ill with COVID-19 On Jan 24 an asymptomatic patient ate lunch with family members on table A By Feb 5: - 4 other family members on table A had become ill with COVID-19 - 3 people on table B (next to table A) had become ill with COVID-19 - 2 people on table C (on other side of table A) had become ill with COVID-19	

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8.	Masoumbeigi 2020	Referral hospital Iran	To investigate hospital indoor air quality to SARS-Cov-2 occurrence and determination on its air born potential	Air sampling was done (n=31) on selected wards including Emergency 1, Emergency 2, bedridden (4-B, 10-D), ICU 2, ICU 3, CTSCAN, and laundry	No	No	No	N/a	All of the samples were negative for SARS-Cov-2 occurrence. These results showed that SARS-Cov-2 had not airborne potential in this hospital	Although SARS-Cov-2 similar to the SARS virus but, SARS-Cov-2 is not an airborne virus

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9.	Mouchtouri 2020	Environmental sampling conducted on a ferry boat, hospital and nursing home		Environmental samples were collected from a ferryboat during a COVID-19 ongoing outbreak investigation and a nursing home and from three COVID-19 isolation hospital wards and a long-term care facility where asymptomatic COVID-19 cases were isolated. Samples were tested by real-time reverse transcriptase–polymerase chain reaction	Y	Y			SARS-CoV-2 RNA was detected on the air exhaust duct surface and screen of the ship hospital and cabins exhaust to open deck. Respiratory droplets/nuclei were displaced and deposited on the air duct and screen of the ship air exhaust that was located in the open deck, three decks above the ship hospital examination area. Air from cabins and toilets of symptomatic and asymptomatic patients were directed towards the	Respiratory droplets/nuclei from infected persons can be displaced by the air flow and deposited on surfaces. It can be assumed that in the same manner, air flow could transfer and deposit infected respiratory droplets/nuclei from infected persons to the mucous membranes of persons standing against the air flow direction

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									same air exhaust duct. SARS-CoV-2 RNA was detected on the filter of the air-conditioner device in the nursing home patient room The virus RNA was detected in one out of the 12 air samples collected. The sample was collected at a height of approximately 0.8 m and 2.5 m away from a symptomatic patient not wearing a face mask	
10.	Ong S, Tan, Chia et al. 2020	Environmental sampling in a dedicated		N=3 patients at the dedicated SARS-CoV-2 outbreak center	Y	N	UK	N/A	There was extensive environmental contamination by 1 SARS-CoV-2 patient	Significant environmental contamination by patients with

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		SARS-CoV-2 outbreak center in Singapore		in Singapore in AIIRs (12 air exchanges per hour) with anterooms and bathrooms had surface environmental samples taken at 26 sites. Air sampling was done on 2 days using SKC Universal pumps. Specific real-time reverse transcriptase–polymerase chain reaction (RT-PCR) targeting RNA-dependent RNA polymerase and Egenes was					with mild upper respiratory tract involvement. Air samples were negative despite the extent of environmental contamination. Swabs taken from the air exhaust outlets tested positive, suggesting that small virus-laden droplets may be displaced by airflows and deposited on equipment such as vents. Viral culture was not done so viability of virus samples is unknown Note: The volume of air sampled	SARS-CoV-2 through respiratory droplets and faecal shedding suggests the environment as a potential medium of transmission

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				used to detect the presence of SARS-CoV-2					represents only a small fraction of total volume, and air exchanges in the room would have diluted the presence of SARS-CoV-2 in the air	
11.	Payne 2020	Report on outbreak Sample of US Navy Service Members – USS Theodore Roosevelt, April 2020	To inform about COVID-19 information- among young, healthy US service members experiencing close contact aboard an aircraft	Outbreak investigation But study was volunteer questionnaire based, that included 382 service members on board in aircraft carrier USS Theodore Roosevelt. Each subject	N/A	N/A	N/A	N/A	Overall, 228 (60%) participants had a positive ELISA result, one fifth of infected participants reported no symptoms. Prevalence was found to be higher when cases reported previous COVID-contact with someone compared to who did not (OR 2.5; 95% CI 1.1–	

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			carrier after US	provided serum specimens for antibody reactivity using a CDC-developed SARS-CoV-2 spike protein enzyme-linked immunosorbent assay (ELISA)					5.8). Also, prevalence was higher among cases who shared the same sleeping berth with a crewmember who had positive test results ((OR=3.3; 95% CI=1.8–6.1). Service members who reported taking preventive measures had a lower risk of infection rate when compared to those who did not report such measure. Measure such as using face coverings (55.8% versus 80.8%; OR=0.3; 95% CI=0.2–0.5); observing social	

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									distancing (54.7% versus 70.0%; OR=0.5; 95% CI=0.3–0.8) and avoiding common areas (53.8% versus 67.5%; OR=0.6; 95% CI=0.4–0.9)	

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12.	Qian 2020	Review of outbreak case reports	To identify major characteristics of the enclosed areas in which outbreaks were determined to have occurred and to find associated indoor environment issues	318 outbreaks involving 1,245 infected individuals in 120 cities in China, not including Hubei province Category is based on venue (Homes, transport, restaurants, food venues, entertainment venues, shopping venues) Municipal Health Commission website and was consulted to confirmed cases from the local of 320 prefectural	N/A	N/A	N/A	N/A	Among 126/231 outbreaks, the average time from symptom onset to the ending infectious date was 3·76 ± 4·42 days for those on and before 28 January and 0·87 ± 2·80 days for those afterward. 254/ 318 outbreaks occur in home, 108/318 in transport, 4/318 at a restaurant or other food venue, 7 at an entertainment venue, and 7 at a shopping venue. The average number of cases was 3·7 for the home outbreaks, 3·8 for transport, 4·9 for food venues, 3·6 for	All identified outbreaks of three or more cases occurred in an indoor environment, which confirms that sharing indoor space is a major SARS-CoV-2 infection risk

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				cities in mainland China, not including Hubei province					entertainment venues, 8·7 for shopping venues, and 4·4 for miscellaneous venues	

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13.	Shen 2020	Cohort study (outbreak)	To inform an evidence from of COVID-19 outbreak can be transmitted as an aerosol (i.e. air borne) and to investigate the potential transmission route.	Throat swabs were collected for all individuals involved in the outbreak and the close contact identified through follow-up contact tracing. Samples were tested by reverse transcription polymerase chain reaction or by viral genome sequencing. Demographic data was collected through standard questionnaire and additional phone or in-	N/A	N/A	N/A	N/A	The source was passenger on bus 2 and was asymptomatic during the bus rides. 24/68 person who rode in Bus 2 developed infection, and they were 42.2(95%CI,2.6–679.3) more likely to develop infection when compared to passenger in bus 1. And risk difference was 34.3% (95% CI, 23.0–45.7%). None of the 60 individuals in bus 1 were infected. Passenger sitting closer to the index patient on the	SARS-CoV-2 is a highly transmissible pathogen in closed environments with air recirculation

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				person interviews through epidemiologic investigation carried out by local Centres for Disease Control and Prevention. Community transmission through 2 buses in Zhejiang province, China. There were total 128 individuals in 2 buses on a 100-minute round trip to attend a 150-minute worship event					exposed bus did not have statistically higher risks of COVID-19 as those sitting further away. Attack rates on the exposed (Bus 2) and unexposed buses (Bus 1) were distinct (34.3% vs 0%) shows that environments with closed air recirculation (recycled air) were responsible for increased risk of CoV-2 infection	
14.	Szablewski 2020	Case report (outbreak)	Not stated To inform	Overnight Camp: Georgia, June	N/A	N/A	N/A	N/A	Out of 597 Georgia attendees, 260 tested	These findings demonstrate that

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			the evidence on SARS-CoV-2 Transmission among attendees of the Georgia Overnight Camp	2020 List of all attendees was obtained and matched to laboratory results from the State Electronic Notifiable Disease Surveillance System and data from DPH case investigations. Study reported the use of preventative measures during camping such as cloth masks to prevent an outbreak for staff members but not					positive. The attendees included trainees, staff members, and campers. Attack rates increased with increasing length of time spent at the camp, as staff members having the highest attack rate (56%). 31 cabins averaged 15 persons per cabin (range=1–26) was observed during Georgia camp occupancy, the median cabin attack rate was 50% (range=22–70%) among 28 cabins that	SARS-CoV-2 spread efficiently in a youth-centric overnight setting, resulting in high attack rates among persons in all age groups, despite efforts by camp officials to implement most recommended strategies to prevent transmission

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				required for campers					had one or more cases. Among 136 cases with available symptom data, 100 of them reported having a symptom. The commonly reported symptoms included were fever (65%), headache (61%), and sore throat (46%)	

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15.	Smither 2020	Experimental	To determine the ability of SARS-CoV-2 to survive in aerosols at different humidity levels and in artificial saliva	Virus was isolated in tissue culture media. Virus was added to artificial saliva. Virus maintained in a dynamic aerosol for 90mins at medium or high relative humidity. The titre of the virus was measured over time	N/A	Y	Y	90 minutes	Results suggest that if produced within small particle aerosols the virus may remain viable for at least 90mins	
16.	Song 2020	Environmental contamination surveillance. Shanghai Public Health	To evaluate the risk of viral transmission in AIIRs	Environmental samples were collected from floors, walls, washbasins, furniture, medical and personal	Patient room: No Corridor: N/a	Patient room: No Corridor: No	Patient room: No Corridor: No		No virus was found in air samples. It was found on various surfaces Note: The researchers found viral RNA on HCWs	*"The directional top-to-bottom airflow in AIIRs greatly reduced the transmission of respiratory droplets and the*

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		Clinical Center, Airborne Infections Isolation Rooms (AIIRs) n=115 rooms		protective equipment surfaces, as well as air samples. Sampling sites covered all three regions in the inpatient area of the hospital: the clean area, the semi-contaminated area, and the contaminated area. Collected before and after cleaning during a 4 week period					footwear, on the pedals of foot operated openers inside AIIRs, and on the floor in corridors. They suggest this could be due to the direction of the airflow forcing respiratory droplets downwards to the floor	*high air change rate prevented the accumulation of virus aerosols. Indeed, we did not detect any viral RNA from samples on the face shields or on front side of HCW's coveralls, or from the air samples collected inside the AIIRs. However, it is important to note that due to limitations in sampling and RNA detection, these results do not completely*

Table 6—Peer reviewed studies from updated report

Reference number	First author, year	Study type and location	Aim/ objective	Methods	Virus on air vents Yes/No	Viral RNA in the air Yes/No	Viable virus in the air Yes/No	Persistence in aerosols or distance (>2m and specify if known)	Results	Conclusions
										elim- inate the possibility of airborne transmission of SARS- CoV-2 inside AIIRs."
17.	Tang 2020	Evidence review	to synthesize the evidence for aerosol transmission of COVID-19 and highlight the localities and vulnerable populations where	Used Jones-Brosseau criteria.	N/A	N/A	N/A	N/A	Ranked the plausibility of aerosol transmission as 8 out of 9. Aerosol generation: 3 out of 3 Viability in the environment: 2 out of 3 Access to target tissue: 3 out of 3	*"Precautionary control strategies should consider aerosol transmission for effective mitigation of SARS-CoV-2."*

Table 6—Peer reviewed studies from updated report

Reference number	First author, year	Study type and location	Aim/ objective	Methods	Virus on air vents Yes/No	Viral RNA in the air Yes/No	Viable virus in the air Yes/No	Persistence in aerosols or distance (>2m and specify if known)	Results	Conclusions
			SARS-CoV-2 aerosols may be particularly pertinent to COVID-19 transmission							

Table 6—Peer reviewed studies from updated report

Reference number	First author, year	Study type and location	Aim/ objective	Methods	Virus on air vents Yes/No	Viral RNA in the air Yes/No	Viable virus in the air Yes/No	Persistence in aerosols or distance (>2m and specify if known)	Results	Conclusions
18.	Zhou 2020	prospective cross-sectional observational study multi-site London hospital	To evaluate SARS-CoV-2 surface and air contamination during the COVID-19 pandemic in London	Air and surface samples were collected from 7 clinical areas, occupied by patients with COVID-19, and a public area of the hospital. Three or four 1.0 m3 air samples were collected in each area using an active air sampler. Surface samples were collected by swabbing items in the immediate vicinity of each air sample. SARS-CoV-2 was detected by	N/A	Yes	*"In our study, all surface and air samples from the hospital environment had a Ct value >30."*	N/A	Viral RNA was detected on 114/218 (52.3%) of surfaces and 14/31 (38.7%) air samples but no virus was cultured. Viral RNA was detected on surfaces and in air in public areas of the hospital but was more likely to be found in areas immediately occupied by COVID-19 patients than in other areas (67/105 (63.8%) vs. 29/64 (45.3%) (OR 0.5, 95% confidence interval 0.2– 0.9, p=0.025, Chi squared test)). The high PCR Ct value for all samples (>30)	*"Extensive viral RNA contamination of surfaces and air across a range of acute healthcare settings in the absence of cultured virus underlines the potential risk from environmental contamination in managing COVID-19, and the need for effective use of PPE, physical distancing, and hand/surface hygiene."*

Table 6—Peer reviewed studies from updated report

Reference number	First author, year	Study type and location	Aim/ objective	Methods	Virus on air vents Yes/No	Viral RNA in the air Yes/No	Viable virus in the air Yes/No	Persistence in aerosols or distance (>2m and specify if known)	Results	Conclusions
				RT-qPCR and viral culture; the limit of detection for culturing SARS-CoV-2 from surfaces was determined					indicated that the virus would not be culturable	

Appendix 5: Grey literature

Country/ organisation	Source	Date of advice	Details on aerosol transmission	Notes
Ireland	HSE How COVID-19 is spread	22 October 2020	Information for the general public on the transmission of COVID-19. States that the virus spreads through close contact with someone who has the virus, through droplets from their nose or mouth, e.g. through loud talking, singing, shouting, coughing or sneezing	
England	Public Health England COVID-19: epidemiology, virology and clinical features	21 October 2020	This resource states that SARS-CoV-2 is primarily transmitted between people through respiratory (droplet and aerosol) and contact routes. Transmission risk is highest where people are in close proximity (within 2 metres). Airborne transmission can occur in health and care settings in which procedures or support treatments that generate aerosols are performed. Airborne transmission may also occur in poorly ventilated indoor spaces, particularly if individuals are in the same room together for an extended period of time	
Sweden	The Public Health Agency of Sweden FAQ about COVID-19	20 October 2020	This website for the public states that SARS-CoV-2 is mainly transmitted between people via respiratory droplets or secretions from the respiratory tract. The virus can also be transmitted via contaminated surfaces	
Scotland	National Services Scotland: Assessing the evidence base for medical	16 October 2020	The focus of this resource is on aerosol generating procedures in hospitals that increase the risk of patient to healthcare worker transmission	

Country/ organisation	Source	Date of advice	Details on aerosol transmission	Notes
	procedures which create a higher risk of respiratory infection transmission from patient to healthcare worker			
Denmark	Danish Health Authority How novel coronavirus spreads	12 October 2020	This website states that infection is spread through droplets and contact in the same way as common colds or influenza. Small droplets from coughing, sneezing or shouting can be inhaled by another person, causing infection. Risk of infection increases with indoor gatherings with poor ventilation	
The Netherlands	National Institute for Public Health and the Environment: Coronavirus disease (COVID-19	12 October 2020	This website states that the virus is spread via coughing and sneezing. When someone coughs or sneezes, the virus is released into the air in droplets. If other people inhale those droplets, or get them in their mouth, nose or eyes, for example via their hands, they may become infected with the virus	
Canada	Government of Canada, Coronavirus disease: Coronavirus disease (COVID-19): For health professionals	10 October 2020	This resource for health professionals states that the main mode of transmission for COVID-19 is person-to-person spread via respiratory droplets. The virus is contained in the droplets of an infected person. When the infected person coughs, sneezes, talks or breathes, their droplets can reach the mucous membrane of another person and infect them	

Country/ organisation	Source	Date of advice	Details on aerosol transmission	Notes
United States	Center for Disease Control: Scientific Brief: SARS-CoV-2 and Potential Airborne Transmission	5 October 2020	This scientific brief states that the principal mode by which people are infected with SARS-CoV-2 is through exposure to respiratory droplets carrying infectious virus. Respiratory droplets are produced during exhalation (e.g. breathing, speaking, singing, coughing, sneezing) and span a wide spectrum of sizes that may be divided into two basic categories based on how long they can remain suspended in the air: • **Larger droplets** some of which are visible and that fall out of the air rapidly within seconds to minutes while close to the source • Smaller droplets and particles (formed when small droplets dry very quickly in the airstream) that can remain suspended for many minutes to hours and travel far from the source on air currents. The epidemiology of SARS-CoV-2 indicates that most infections are spread through close contact, not airborne transmission. Available data indicate that SARS-CoV-2 has spread more like most other common respiratory viruses, primarily through respiratory droplet transmission within a short range (e.g., less than six feet). There is no evidence of efficient spread (i.e., routine, rapid spread) to people far away or who enter a space hours after an infectious person was there	CDC posted information on its website on Friday 18 September 2020 which stated (for the first time) that COVID-19 could be spread through *"respiratory droplets or small particles, such as those in aerosols, produced when an infected person coughs, sneezes, sings, talks or breathes…This is thought to be the main way the virus spreads…There is growing evidence that droplets and airborne particles can remain suspended in the air and be breathed in by others and travel distances beyond 6 feet (for example, during choir practice, in restaurants, or in fitness classes). In general, indoor environments without good ventilation increase this risk."* CDC later removed the information about aerosols and said that a draft version of proposed changes had been posted in error

Country/ organisation	Source	Date of advice	Details on aerosol transmission	Notes
New Zealand	NZ Ministry of Health Updated advice for health professionals: novel coronavirus	27 August 2020	This advice for health professionals states that transmission is considered to occur primarily through respiratory droplets and secretions. Transmission is likely to occur through virus contact with respiratory mucosa or conjunctivae, either by direct exposure or by transfer on hands from contaminated fomites. The current evidence does not support airborne transmission, except during aerosol generating procedures	
Norwegian Institute of Public Health	Facts about the SARS-CoV-2 virus	17 July 2020	This website for the general public states that the virus is transmitted through droplets (when someone who is contagious coughs, sneezes, or talks/sings) and through direct contact and indirect contact (e.g. surfaces)	
WHO	Transmission of SARS-CoV-2: implications for infection prevention precautions	9 July 2020	This scientific brief states that airborne transmission of SARS-CoV-2 can occur during medical procedures that generate aerosols. WHO, together with the scientific community, has been actively discussing and evaluating whether SARS-CoV-2 may also spread through aerosols in the absence of aerosol generating procedures, particularly in indoor settings with poor ventilation. WHO states that further studies are needed to determine whether it is possible to detect viable SARS-CoV-2 in air samples from settings where no procedures that generate aerosols are performed and what role aerosols might play in transmission. Outside of medical facilities, some outbreak reports related to indoor crowded spaces have	

Country/ organisation	Source	Date of advice	Details on aerosol transmission	Notes
			suggested the possibility of aerosol transmission, combined with droplet transmission, for example, during choir practice, in restaurants or in fitness classes. In these events, short-range aerosol transmission, particularly in specific indoor locations, such as crowded and inadequately ventilated spaces over a prolonged period of time with infected persons cannot be ruled out	
European CDC	Transmission of COVID-19	30 June 2020	The European CDC states that currently available evidence indicates that human coronaviruses primary transmission mode is person-to-person contact through respiratory droplets generated by breathing, sneezing, coughing, etc. as well as direct contact. Infection is understood to be mainly transmitted via large respiratory droplets containing the SARS-CoV-2 virus. The European CDC states that transmission through aerosols has also been implicated but the relative role of large droplets and aerosols is still unclear	

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* References added in this updated report are marked with an asterisk. References which are not asterisked are from the original report published in August 2020.