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EVIDENCE SEARCH REPORT

RESEARCH QUESTION: What role do ventilation systems play in the prevention and spread of COVID-19 and other respiratory diseases in non-clinical buildings?	**UNIQUE IDENTIFIER:** EOC082501-01 ESR

RESOURCES USED:

- BC Centre for Disease Control
- Center for Evidence Based Medicine
- Centers for Disease Control (CDC)
- ECRI
- Embase
- Google Advanced Search
- Google Scholar
- Medline
- medRxiv
- National Collaborating Centre for Methods and Tools
- NICE
- Norwegian Institute of Public Health
- Veteran Affairs Database
- U.S. Food & Drug Administration (FDA)
- WHO COVID-19 Global Literature Database
- WHO Website
- Citation searching of some resources

LIMITS/EXCLUSIONS/INCLUSIONS: English, Last 5 years	**REFERENCE INTERVIEW COMPLETED:** August 24, 2020
DATE: August 26, 2020	
LIBRARIAN: Michelle Dalidowicz & Catherine Young	**REQUESTOR:** Bruce Reeder
TEAM: EOC	
SEARCH ALERTS CREATED: bi-weekly	

CITE AS: Dalidowicz, M; Young, C. What role do ventilation systems play in the prevention and spread of COVID-19 and other respiratory diseases in non-clinical buildings? 2020 Aug 26; Document no.: EOC082501-01 ESR. In: COVID-19 Rapid Evidence Reviews [Internet]. SK: SK COVID Evidence Support Team, c2020. 24 p. (CEST evidence search report)

LIBRARIAN NOTES/COMMENTS

We set up a bi-weekly search alert in Embase and Medline for Bruce, Nazeem and Andreea.

We limited the search to 2015-current as the wider search parameters yielded a fair number of search results.

Let us know if the results don't meet your needs or if you'd like to try another search approach.

Kind regards,
Michelle Dalidowicz & Catherine Young

SEARCH RESULTS

To obtain the full-text articles or to request offsite access, email library@saskhealthauthority.ca.

SUMMARIES, GUIDELINES & OTHER RESOURCES

PRIMARY DOCUMENTS & GUIDANCE

American Society of Heating, Refrigerating and Air-Conditioning Engineers.

- Position Document on Infectious Aerosols. [14 April 2020]. https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf
- Guidance for re-opening of schools [20 August 2020] https://www.ashrae.org/file%20library/technical%20resources/covid-19/guidance-for-the-re-opening-of-schools.pdf

CIBSE (Chartered Institution of Building Services Engineers). Coronavirus COVID-19 and HVAC Systems. Coronavirus (COVID-19) Advice. [2020] https://www.cibse.org/coronavirus-covid-19/coronavirus-covid-19-and-hvac-systems

US Center for Disease Control.

- Operating schools during COVID-19: CDC's Considerations. CDC. [21 August 2020]. https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/schools.html
- COVID-19 Employer information for office buildings [9 July 2020] https://www.cdc.gov/coronavirus/2019-ncov/community/office-buildings.html

European Center for Disease Prevention and Control. Heating, ventilation and air-conditioning systems in the context of COVID-19. [22 June 2020]. https://www.ecdc.europa.eu/sites/default/files/documents/Ventilation-in-the-context-of-COVID-19.pdf

Federation of European Heating, Ventilation and Air Conditioning (REHVA):

- Webpage: https://www.rehva.eu/activities/covid-19-guidance
- COVID-19 guidance document [3 August 2020] https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf

Global Heat Health Information Network. Guidance: Do air conditioning and ventilation systems increase the risk of virus transmission? If so, how can this be managed? [22 May 2020] http://www.ghhin.org/heat-and-covid-19/ac-and-ventilation

Government of British Colombia. Provincial COVID-19 Health & Safety Guidelines for K-12 Settings. [17 August 2020]. https://www2.gov.bc.ca/assets/gov/education/administration/kindergarten-to-grade-12/safe-caring-orderly/k-12-covid-19-health-safety-guidlines.pdf

Public Health Agency of Canada. COVID-19 Summary of Heating, Ventilation, Air Conditioning (HVAC) Systems and Transmission of SARS-CoV-2.. [14 August 2020]. [full-text requested and attached]

State of Connecticut Department of Public Health. Guidance for School Systems for the Operation of Central and non-Central Ventilation Systems during the COVID-19 Pandemic. https://portal.ct.gov/-

/media/Coronavirus/20200622-DPH-Guidance-for-School-Systems-for-the-Operation-of-Central-and-nonCentral-Ventilation-Sys.pdf

United States Environmental Protection Agency.

- Ventilation and Coronavirus.https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19
- Indoor Air and Coronavirus. https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19
- Indoor Air Quality Tools. https://www.epa.gov/iaq-schools/epa-supports-healthy-indoor-environments-schools-during-covid-19-pandemic

World Health Organization (WHO). Q&A: Ventilation and air conditioning and COVID-19. [29 July 2020]. https://www.who.int/news-room/q-a-detail/q-a-ventilation-and-air-conditioning-and-covid-19

<u>SUMMARIES, ARTICLES AND OTHER</u>

Alberta Health Services. Has there been documented transmission of SARS-CoV-2 virus (or similar viruses) through Heating, Ventilation, and Air Conditioning (HVAC) systems in hospitals or nonhospital settings? [5. June 2020]. https://www.albertahealthservices.ca/assets/info/ppih/if-ppih-covid-19-sag-risk-transmission-hvac-systems-rapid-review.pdf

Collaborative for High Performance Schools. School Ventilation for COVID-19 Whitepaper. [June 2020]. https://chps.net/sites/default/files/file_attach/CHPS_COVID-19_Whitepaper_June2020.pdf

Communicable Diseases Policy Research Group, London School of Hygiene and Tropical Medicine. Rapid synthesis of evidence on settings which have been associated with SARS-CoV-2 transmission clusters. (1 July 2020). https://superspreadingdatabase.github.io/Evidence_on_clusters_final.pdf

Public Policy Institute of California. Improving K-12 School Facilities in California. [August 2020]. https://www.ppic.org/wp-content/uploads/improving-k-12-school-facilities-in-california-august-2020.pdf

University of California Davis. The Path to COVID-19 Recovery: How to improve indoor air quality when reopening K-12 schools. https://ucdavis.app.box.com/s/xouzsdn6jgqx71ulbzou1g8lhqggdi3i

Kumar, Sangeetha. A simulation framework to characterize the effect of ventilation control on airborne infectious disease transmission in schools. [2019] https://repositories.lib.utexas.edu/handle/2152/78365

Harris JE. The Subways Seeded the Massive Coronavirus Epidemic in New York City. National Bureau of Economic Research Working Paper No. 27021. [April 19, 2020] https://web.mit.edu/jeffrey/harris/HarrisJE_WP2_COVID19_NYC_24-Apr-2020.pdf

Miller, Shelly. How to use ventilation and air filtration to prevent the spread of coronavirus indoors. The Conversation. (10 August 2020) https://theconversation.com/how-to-use-ventilation-and-air-filtration-to-prevent-the-spread-of-coronavirus-indoors-143732

ARTICLES

Note: References are sorted by year (newest to oldest)

1. Allen JG, Marr LC. Recognizing and controlling airborne transmission of SARS-CoV-2 in indoor environments. Indoor Air. 2020;30(4):557-8. DOI: 10.1111/ina.12697

URL: https://www.ncbi.nlm.nih.gov/pubmed/32557915
DOI: 10.1111/ina.12697

2. Allen SAA, Ayodeji S-AM, Deborah S-AE. The Environment and COVID-19 Transmission: A Perspective. International Journal of Research Studies in Medical and Health Sciences 2020;5(7):12-9. [POTENTIAL PREDATORY PUBLISHER].
ABSTRACT: Coronavirus disease 2019 (COVID-19) has become a severe public health threat worldwide. Despite the global spread, there is an observed aberration and skewness in the geographic/regional distribution of the disease, with a high preponderance of cases and mortality occurring in the temperate regions compared to the tropics. A plausible explanation for this discrepancy could be linked to variability in environmental factors. Hence, this review discusses succinctly the possible influences of geographic location, temperature/sunlight, relative humidity and building design on the rate of transmission of COVID-19. We postulate that elevated melatonin production in a hot climate, high temperature, adequate vitamin D synthesis from sunlight exposure, high relative humidity and efficient ventilation due to housing design confers innate immunity and adaptive advantage to COVID-19 transmission for populations in the tropics over those in the temperate regions. Hence, we recommend that control studies taking into congnizance the relationship between environment and disease be prioritized. Such studies are important for predicting viral disease spread, in particular if this leads to pandemics like in the case of COVID-19, to aid decisions in public health policies at the global level.
URL: http://www.ijrsmhs.com/pdf/v5-i7/4.pdf

3. Almilaji O, Thomas P. Air recirculation role in the infection with COVID-19, lessons learned from Diamond Princess cruise ship. medRxiv. 2020:2020.07.08.20148775. DOI: 10.1101/2020.07.08.20148775
ABSTRACT: Objectives: The Diamond Princess cruise ship is a unique case because it is the place at which testing capacity has reached its highest rate in the world during the COVID-19 pandemic. By analysing data that are collected about the current COVID-19 outbreak onboard, and by considering the design of the air conditioning system of the ship and virus transmission modes on cruise ships, this study aims to raise the hypothesis regarding the role of poor ventilation systems in the spread of COVID-19. Design: This is an analysis of count data that has been collected by the onboard clinic up to the 20th February 2020. Symptomatic infection rates during the quarantine period in cabins with previous confirmed cases are compared to these in cabins without previous confirmed cases. Results: Symptomatic infection rate during the quarantine period in cabins with previously confirmed cases is not significantly higher than that in cabins without previously confirmed cases. Age does not appear to be a cofounder. Conclusions: Airborne transmission of COVID-19 through the ventilation system onboard could explain the virus spread into cabins during the quarantine period.
URL: http://medrxiv.org/content/early/2020/07/09/2020.07.08.20148775.abstract
DOI: 10.1101/2020.07.08.20148775

4. Amoatey P, Omidvarborna H, Baawain MS, et al. Impact of building ventilation systems and habitual indoor incense burning on SARS-CoV-2 virus transmissions in Middle Eastern countries. Sci Total Environ. 2020;733(139356):139356. DOI: 10.1016/j.scitotenv.2020.139356
ABSTRACT: Majority of countries across the globe have employed improving building ventilation, quarantine, social distancing, and disinfections as a general measure of preventing SARS-CoV-2 virus transmissions. However, arid Middle Eastern countries with hot climate (elevated outdoor temperature and humidity levels) are experiencing a different situation. Unfortunately, these harsh ambient climatic conditions in Middle Eastern countries make it impossible for most buildings to utilize natural/mechanical ventilation systems. Besides, indoor air temperatures of most buildings are very low due to overconsumption of air conditioning, thereby, it can be a potential factor of virus spread in most residential homes and public buildings. Most importantly, habitual indoor burning of incense which is the major source of coarse (PM10; aerodynamic diameter <10 mum) and fine (PM2.5; aerodynamic diameter <2.5 mum) particulate matters (PM) could facilitate the transmission of SARS-CoV-2 virus droplets and particles in indoor environments. In fact, it increases the spread of the virus via

inhalation in these countries, especially where the wearing of masks is not regulated in public, commercial and residential buildings. It is therefore highly recommended for the relevant public health agencies to critically assess the role of poor indoor environmental conditions including the burning of incense on virus transmissions, which may help to develop control measures for the future viral outbreak effectively.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32416534
DOI: 10.1016/j.scitotenv.2020.139356

5. Anonymous. Air conditioning as virus spreader?: Risk of coronavirus spread by means of cooling and ventilation systems. Deutsche Apotheker Zeitung. 2020.
URL: https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/resource/en/covidwho-677855

6. Arav Y, Klausner Z, Fattal E. Understanding the indoor pre-symptomatic transmission mechanism of COVID-19. medRxiv. 2020:2020.05.12.20099085. DOI: 10.1101/2020.05.12.20099085
ABSTRACT: Discovering the mechanism that enables pre-symptomatic individuals to transmit the SARS-CoV-2 virus has a significant impact on the possibility of controlling COVID-19 pandemic. To this end, we have developed an evidence based quantitative mechanistic mathematical model. The model explicitly tracks the dynamics of contact and airborne transmission between individuals indoors, and was validated against the observed fundamental attributes of the epidemic, the secondary attack rate (SAR) and serial interval distribution. Using the model we identified the dominant driver of pre-symptomatic transmission, which was found to be contact route, while the contribution of the airborne route is negligible. We provide evidence that a combination of rather easy to implement measures of frequent hand washing, cleaning fomites and avoiding physical contact decreases the risk of infection by an order of magnitude, similarly to wearing masks and gloves.
URL: http://medrxiv.org/content/early/2020/05/17/2020.05.12.20099085.abstract
DOI: 10.1101/2020.05.12.20099085

7. Azimi P, Keshavarz Z, Cedeno Laurent JG, et al. Mechanistic Transmission Modeling of COVID-19 on the Diamond Princess Cruise Ship Demonstrates the Importance of Aerosol Transmission. medRxiv. 2020:2020.07.13.20153049. DOI: 10.1101/2020.07.13.20153049
ABSTRACT: Background The current prevailing position is that coronavirus disease 2019 (COVID-19) is transmitted primarily through large respiratory droplets within close proximity (i.e., 1-2 m) of infected individuals. However, quantitative information on the relative importance of specific transmission pathways of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (i.e., droplets, aerosols, and fomites across short- and long-range distances) remains limited. Methods To evaluate the relative importance of multiple transmission routes for SARS-CoV-2, we leveraged detailed information available from the Diamond Princess Cruise Ship outbreak that occurred in early 2020. We developed a framework that combines stochastic Markov chain and negative exponential dose-response modeling with available empirical data on mechanisms of SARS-CoV-2 dynamics and human behaviors, which informs a modified version of the Reed-Frost epidemic model to predict daily and cumulative daily case counts on the ship. We modeled 21,600 scenarios to generate a matrix of solutions across a full range of assumptions for eight unknown or uncertain epidemic and mechanistic transmission factors, including the magnitude of droplet and aerosol emissions from infected individuals, the infectious dose for deposition of droplets and aerosols to the upper and lower respiratory tracts, and others. Findings A total of 132 model iterations met acceptability criteria (R2 > 0.95 for modeled vs. reported cumulative daily cases and R2 > 0 for daily cases). Analyzing only these successful model iterations yields insights into the likely values for uncertain parameters and quantifies the likely contributions of each defined mode of transmission. Mean estimates of the contributions of short-range, long-range, and fomite transmission modes to infected cases aboard the ship across the entire simulation time period were 35%, 35%, and 30%, respectively. Mean estimates of the contributions of large respiratory droplets and small respiratory aerosols were 41% and 59%. Short-range transmission was the dominant mode after passenger quarantine began, albeit

due primarily to aerosol transmission, not droplets. Interpretation Our results demonstrate that aerosol inhalation was likely the dominant contributor to COVID-19 transmission among passengers aboard the Diamond Princess Cruise Ship. Moreover, close-range and long-range transmission likely contributed similarly to disease progression aboard the ship, with fomite transmission playing a smaller role. The passenger quarantine also affected the importance of each mode, demonstrating the impacts of the interventions. Although cruise ships represent unique built environments with high ventilation rates and no air recirculation, these findings underscore the importance of implementing public health measures that target the control of inhalation of aerosols in addition to ongoing measures targeting control of large droplet and fomite transmission, not only aboard cruise ships but in other indoor environments as well.
URL: https://www.medrxiv.org/content/medrxiv/early/2020/07/15/2020.07.13.20153049.full.pdf
DOI: 10.1101/2020.07.13.20153049

8. Azimuddin A, Thakurdas S, Hameed A, et al. Shifting Approach to Environmentally Mediated Pathways for Mitigating COVID-19: A Review of Literature on Airborne Transmission of SARS-CoV-2. Preprints 2020. 2020. DOI: 10.20944/preprints202007.0194.v1
ABSTRACT: Coronavirus disease 2019 (COVID-19), caused by the novel coronavirus SARS-CoV-2, has been confirmed in over 10,000,000 individuals worldwide and has resulted in more than 500,000 deaths in a few months since it first surfaced. With such a rapid spread it is no surprise that there has been a massive effort around the world to collectively elucidate the mechanism by which the virus is transmitted. Despite this, there is still no definitive consensus regarding droplet versus airborne transmission of SARS-CoV-2. Public health officials around the world have introduced guidelines within the scope of droplet transmission. However, increasing evidence and comparative analysis with similar coronaviruses, such as severe acute respiratory syndrome (SARS-CoV-1) and middle eastern respiratory syndrome (MERS), suggest that airborne transmission of SARS-CoV-2 cannot be effectively ruled out. As the data supporting COVID-19 airborne transmission grows, there needs to be an increased effort in terms of technical and policy measures to mitigate the spread of viral aerosols. These measures can be in the form of broader social distancing and facial covering guidelines, exploration of thermal inactivation in clinical settings, low-dose UV-C light implementation, and greater attention to ventilation and airflow control systems. This review summarizes the current evidence available about airborne transmission of SARS-CoV-2, available literature about airborne transmission of similar viruses, and finally the methods that are already available or can be easily adapted to deal with a virus capable of airborne transmission.
URL: https://www.preprints.org/manuscript/202007.0194/v1
DOI: 10.20944/preprints202007.0194.v1

9. Beggs CB, Avital EJ. Upper-room ultraviolet air disinfection might help to reduce COVID-19 transmission in buildings. medRxiv. 2020:2020.06.12.20129254. DOI: 10.1101/2020.06.12.20129254
ABSTRACT: As the world economies get out of the lockdown imposed by the COVID-19 pandemic, there is an urgent need to assess the suitability of known technologies to mitigate COVID-19 transmission in confined spaces such as buildings. This feasibility study looks at the method of upper-room ultraviolet (UV) air disinfection that has already proven its efficacy in preventing the transmission of airborne diseases such as measles and tuberculosis. Using published data from various sources it is shown that the SARS-CoV-2 virus, which causes COVID-19, is highly likely to be susceptible to UV damage while suspended in air irradiated by UV-C at levels that are acceptable and safe for upper-room applications. This is while humans are present in the room. Both the expected and worst-case scenarios are investigated to show the efficacy of the upper-room UV-C approach to reduce COVID-19 air transmission in a confined space with moderate but sufficient height. Discussion is given on the methods of analysis and the differences between virus susceptibility to UV-C when aerosolised or in liquid or on a surface.
URL: http://medrxiv.org/content/early/2020/06/14/2020.06.12.20129254.abstract
DOI: 10.1101/2020.06.12.20129254

10. Birnir B, Angheluta L. The Build-Up of Droplet/Aerosols Carrying the SARS-CoV-2 Coronavirus, in Confined Spaces. medRxiv. 2020:2020.08.11.20173195. DOI: 10.1101/2020.08.11.20173195
ABSTRACT: A model of the distribution of respiratory droplets and aerosols by Lagrangian turbulent air-flow is developed and used to show how the SARS-CoV-2 Coronavirus can be dispersed by the breathing of an infected person. It is shown that the concentration of viruses in the exhaled cloud can increase to infectious levels with time, in a confined space where the air re-circulates. The model is used to analyze the air-flow and SARS-CoV-2 Coronavirus build-up in a restaurant in Guangzhou, China [16, 17]. It is concluded that the outbreak of Covid-19 in the restaurant in January 2020, is due to the build-up of the airborne droplets and aerosols carrying the SARS-CoV-2 Coronavirus and could not have been prevented by standard air-conditioning.
URL: http://medrxiv.org/content/early/2020/08/12/2020.08.11.20173195.abstract
DOI: 10.1101/2020.08.11.20173195

11. Brlek A, Vidovic S, Vuzem S, et al. Possible indirect transmission of COVID-19 at a squash court, Slovenia, March 2020: case report. Epidemiol Infect. 2020;148:e120. DOI: 10.1017/S0950268820001326
ABSTRACT: Since the beginning of the COVID-19 epidemic, there is an ongoing debate and research regarding the possible ways of virus transmission. We conducted an epidemiological investigation which revealed a cluster of five COVID-19 cases, linked to playing squash at a sports venue in Maribor, Slovenia. Acquired data raises possibility that the transmission occurred indirectly through contaminated objects in changing room or squash hall or via aerosolisation in squash hall.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32600479
DOI: 10.1017/S0950268820001326

12. Chirico FS, A.; Bragazzi, N.L.; Magnavita, N. Can Air-Conditioning Systems Contribute to the Spread of SARS/MERS/COVID-19 Infection? Insights from a Rapid Review of the Literature. [POTENTIAL PREDATORY PUBLISHER]. Int J Environ Res Public Health. 2020;17(17):6052.
ABSTRACT: The airborne transmission of SARS-CoV-2 is still debated. The aim of this rapid review is to evaluate the COVID-19 risk associated with the presence of air-conditioning systems. Original studies (both observational and experimental researches) written in English and with no limit on time, on the airborne transmission of SARS-CoV, MERS-CoV, and SARS-CoV-2 coronaviruses that were associated with outbreaks, were included. Searches were made on PubMed/MEDLINE, PubMed Central (PMC), Google Scholar databases, and medRxiv. A snowball strategy was adopted to extend the search. Fourteen studies reporting outbreaks of coronavirus infection associated with the air-conditioning systems were included. All studies were carried out in the Far East. In six out the seven studies on SARS, the role of Heating, Ventilation, and Air Conditioning (HVAC) in the outbreak was indirectly proven by the spatial and temporal pattern of cases, or by airflow-dynamics models. In one report on MERS, the contamination of HVAC by viral particles was demonstrated. In four out of the six studies on SARS-CoV-2, the diffusion of viral particles through HVAC was suspected or supported by computer simulation. In conclusion, there is sufficient evidence of the airborne transmission of coronaviruses in previous Asian outbreaks, and this has been taken into account in the guidelines released by organizations and international agencies for controlling the spread of SARS-CoV-2 in indoor environments. However, the technological differences in HVAC systems prevent the generalization of the results on a worldwide basis. The few COVID-19 investigations available do not provide sufficient evidence that the SARS-CoV-2 virus can be transmitted by HVAC systems.
URL: https://www.mdpi.com/1660-4601/17/17/6052

13. Correia G, Rodrigues L, Gameiro da Silva M, et al. Airborne route and bad use of ventilation systems as non-negligible factors in SARS-CoV-2 transmission. Med Hypotheses. 2020;141:109781. DOI: 10.1016/j.mehy.2020.109781
ABSTRACT: The world is facing a pandemic of unseen proportions caused by a corona virus named SARS-CoV-2 with unprecedent worldwide measures being taken to tackle its contagion. Person-to-person transmission is

accepted but WHO only considers aerosol transmission when procedures or support treatments that produce aerosol are performed. Transmission mechanisms are not fully understood and there is evidence for an airborne route to be considered, as the virus remains viable in aerosols for at least 3 h and that mask usage was the best intervention to prevent infection. Heating, Ventilation and Air Conditioning Systems (HVAC) are used as a primary infection disease control measure. However, if not correctly used, they may contribute to the transmission/spreading of airborne diseases as proposed in the past for SARS. The authors believe that airborne transmission is possible and that HVAC systems when not adequately used may contribute to the transmission of the virus, as suggested by descriptions from Japan, Germany, and the Diamond Princess Cruise Ship. Previous SARS outbreaks reported at Amoy Gardens, Emergency Rooms and Hotels, also suggested an airborne transmission. Further studies are warranted to confirm our hypotheses but the assumption of such way of transmission would cause a major shift in measures recommended to prevent infection such as the disseminated use of masks and structural changes to hospital and other facilities with HVAC systems.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32361528
DOI: 10.1016/j.mehy.2020.109781

14. Dai H, Zhao B. Association of infected probability of COVID-19 with ventilation rates in confined spaces: a Wells-Riley equation based investigation. medRxiv. 2020:2020.04.21.20072397. DOI: 10.1101/2020.04.21.20072397
ABSTRACT: Background: A growing number of epidemiological cases are proving the possibility of airborne transmission of coronavirus disease 2019 (COVID-19). Ensuring adequate ventilation rate is essential to reduce the risk of infection in confined spaces. Methods: We obtained the quantum generation rate by a COVID-19 infector with a reproductive number based fitting approach, and then estimated the association between infected probability and ventilation rate with the Wells-Riley equation. Results: The estimated quantum generation rate of COVID-19 is 14-48 /h. To ensure infected probabolity less than 1%, ventilation rate lareger than common values (100-350 m3/h and 1200-4000 m3/h for 15 minutes and 3 hours exposure, respectively) is required. If both the infector and susceptibles wear masks, the ventilation rate ensuring less than 1% infected probability is reduced to 50-180 m3/h and 600-2000 m3/h correspondingly, which is easier to be achieved by normal ventilation mode applied in some typical scenarios, including offices, classrooms, buses and aircraft cabins. Interpretation: The risk of potential airborne transmission in confined spaces cannot be ignored. Strict preventive measures that have been widely adopted should be effective in reducing the risk of airborne transmitted infection.Competing Interest StatementThe authors have declared no competing interest.Funding StatementBZ has received funding from the National Natural Science Foundation of China (52041602).Author DeclarationsAll relevant ethical guidelines have been followed; any necessary IRB and/or ethics committee approvals have been obtained and details of the IRB/oversight body are included in the manuscript.YesAll necessary patient/participant consent has been obtained and the appropriate institutional forms have been archived.YesI understand that all clinical trials and any other prospective interventional studies must be registered with an ICMJE-approved registry, such as ClinicalTrials.gov. I confirm that any such study reported in the manuscript has been registered and the trial registration ID is provided (note: if posting a prospective study registered retrospectively, please provide a statement in the trial ID field explaining why the study was not registered in advance).Yes I have followed all appropriate research reporting guidelines and uploaded the relevant EQUATOR Network research reporting checklist(s) and other pertinent material as supplementary files, if applicable.YesAll data could be provided by the authors if requested.
URL: http://medrxiv.org/content/early/2020/04/24/2020.04.21.20072397.abstract
DOI: 10.1101/2020.04.21.20072397

15. Dietz L, Horve PF, Coil DA, et al. 2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations To Reduce Transmission. mSystems. 2020;5(2):e00245-20. DOI: 10.1128/mSystems.00245-20
ABSTRACT: With the rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that results in coronavirus disease 2019 (COVID-19), corporate entities, federal, state, county, and city governments,

universities, school districts, places of worship, prisons, health care facilities, assisted living organizations, daycares, homeowners, and other building owners and occupants have an opportunity to reduce the potential for transmission through built environment (BE)-mediated pathways. Over the last decade, substantial research into the presence, abundance, diversity, function, and transmission of microbes in the BE has taken place and revealed common pathogen exchange pathways and mechanisms. In this paper, we synthesize this microbiology of the BE research and the known information about SARS-CoV-2 to provide actionable and achievable guidance to BE decision makers, building operators, and all indoor occupants attempting to minimize infectious disease transmission through environmentally mediated pathways. We believe this information is useful to corporate and public administrators and individuals responsible for building operations and environmental services in their decision-making process about the degree and duration of social-distancing measures during viral epidemics and pandemics.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32265315
DOI: 10.1128/mSystems.00245-20

16. García de Abajo FJ, Hernández RJ, Kaminer I, et al. Back to Normal: An Old Physics Route to Reduce SARS-CoV-2 Transmission in Indoor Spaces. ACS Nano. 2020;14(7):7704-13.
ABSTRACT: We advocate the widespread use of UV-C light as a short-term, easily deployable, and affordable way to limit virus spread in the current SARS-CoV-2 pandemic. Radical social distancing with the associated shutdown of schools, restaurants, sport clubs, workplaces, and traveling has been shown to be effective in reducing virus spread, but its economic and social costs are unsustainable in the medium term. Simple measures like frequent handwashing, facial masks, and other physical barriers are being commonly adopted to prevent virus transmission. However, their efficacy may be limited, particularly in shared indoor spaces, where, in addition to airborne transmission, elements with small surface areas such as elevator buttons, door handles, and handrails are frequently used and can also mediate transmission. We argue that additional measures are necessary to reduce virus transmission when people resume attending schools and jobs that require proximity or some degree of physical contact. Among the available alternatives, UV-C light satisfies the requirements of rapid, widespread, and economically viable deployment. Its implementation is only limited by current production capacities, an increase of which requires swift intervention by industry and authorities.
URL: https://pubs.acs.org/doi/10.1021/acsnano.0c04596

17. Gupta A, Kunte R, Goyal N, et al. A comparative analysis of control measures on-board ship against COVID-19 and similar novel viral respiratory disease outbreak: Quarantine ship or disembark suspects? Med J Armed Forces India. 2020. DOI: 10.1016/j.mjafi.2020.06.003
ABSTRACT: Background: Management of novel viral respiratory disease outbreak on-board a ship with person-to-person transmission can be a public health challenge because of close proximity of inhabitants due to confined space and air-conditioned environment. It has a potential to be explosive, with high secondary attack rate (SAR) and cause significant morbidity and mortality. This study compares control measures instituted on-board two ships with similar outbreaks and recommends a standardized evidence-based outbreak response against them. Methods: This is a descriptive study, showing comparative analysis of control measures instituted on-board two ships, a cruise ship in case of COVID-19 and a warship in case of H1N1 influenza, with novel viral respiratory disease outbreak, at different span of time. Data of the date of onset, clinical details, laboratory results, history of travel, history of contact with positive case and control measures initiated were collected, analysed and compared. Results: Of the two ships compared, one was a cruise ship with 712 COVID-19 cases, with an attack rate (AR) of 19.2% and 13 deaths, and other a warship with 14 cases of H1N1 influenza and an AR of 4.83%. The epidemic curve for both the outbreaks was plotted to study time distribution. Conclusion: Active surveillance, early self-reporting and immediate disembarkation of the suspects, along with strict compliance of hand hygiene, cough etiquettes and disinfection enhancement, will help in early mitigation of the outbreak. Health education should be undertaken to impart evidence-based knowledge and alleviate fear of the unknown.

Vaccination may not be present but if available should only be administered after strict risk-benefit, cost-benefit and effectiveness analysis.
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ABSTRACT: Recent concerns raised by the World Health Organization over the Coronavirus raised a worldwide reaction. Governments are racing to contain and stop the Coronavirus from reaching an epidemic/pandemic status. This research presents a way in tracking such a virus or any contagious germ capable of transferring through air specifically where such a transfer can be assisted by a mechanical room ventilation system. Tracking the spread of such a virus is a complicated process, as they can exist in a variety of forms, shapes, sizes, and can change with time. However, a beginning has to be made at some point. Assumptions had to be made based on published scientific data, and standards. The tracking of airborne viruses was carried out on the following assumption (for illustrative purposes); one person with one sneeze in a period of 600 s. The presence of viruses was tracked with curves plotted indicating how long it could take to remove the sneezed viruses from the mechanically ventilated room space. Results gave an indication of what time span is required to remove airborne viruses. Thus, we propose the following: (a) utilizing CFD software as a possible tool in optimizing a mechanical ventilation system in removing contagious viruses. This will track the dispersion of viruses and their removal. The numerical solution revealed that with one typical adult human sneeze, it can take approximately 640 s to reduce an average sneeze of 20,000 droplets to a fifth; (b) upscaling the status of human comfort to a "must have" with regards to the 50% relative humidity, and the use of Ultraviolet germicidal irradiation (UVGI) air disinfection in an epidemic/pandemic condition. A recommendation can be presented to the local authorities of jurisdiction in enforcing the above proposals partially/fully as seen fit as "prevention is better than cure". This will preclude the spread of highly infectious viruses in mechanically ventilated buildings.
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ABSTRACT: Abstract Information on air-conditioning and ventilation has been continuously disseminated in response to the Japanese Government's announcement of the need for appropriate ventilation measures against the new coronavirus disease (COVID-19), and the issuing of an emergency presidential discourse by the presidents of Engineering Societies. In this paper, we add to the information the latest knowledge on the behavior of SARS-CoV-2 in air, describe its diffusion characteristics in the built environment, and summarize the effects of temperature and humidity on the virus. Then we recommend varying approaches of air-conditioning control for facility type.
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DOI: 10.1002/2475-8876.12183

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ABSTRACT: As coronavirus disease 2019 (COVID-19) is spreading worldwide, there have been arguments regarding the aerosol transmission of its causative agent, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Moreover, some re-detectable positive (RP) patients have been reported. However, little attention has been given to the follow-up of recovered patients, and there is no environmental evidence to determine whether these patients continue to shed the virus after they test negative. Therefore, with an objective to test the hypothesis of airborne transmission of SARS-CoV-2, it is necessary to 1) determine whether

SARS-CoV-2 particles are present in the indoor air and 2) determine whether recovered patients are still shedding virus, thus providing much-needed environmental evidence for the management of COVID-19 patients during the recovery period. In this study, surface and air samples were collected from an intensive care unit (ICU) containing one ready-for-discharge patient. All surface samples tested negative, but the air samples tested positive for SARS-CoV-2. This implies that SARS-CoV-2 particles may be shed in aerosol form for days after patients test negative. This finding may be one of the reasons for the observation of RP patients; therefore, there is a need for improved clinical and disease management guidelines for recovered COVID-19 patients.
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ABSTRACT: The coronavirus disease-2019 (COVID-19) pandemic has heightened the awareness of aerosol generation by human expiratory events and their potential role in viral respiratory disease transmission. Concerns over high severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) viral burden of mucosal surfaces has raised questions about the aerosol-generating potential and dangers of many otorhinolaryngologic procedures. However, the risks of aerosol generation and associated viral transmission by droplet or airborne routes for many otorhinolaryngology procedures are largely unknown. Indoor aerosol and droplet viral respiratory transmission risk is influenced by 4 factors: (1) aerosol or droplet properties; (2) indoor airflow; (3) virus-specific factors; and (4) host-specific factors. Herein we elaborate on known aerosol vs droplet properties, indoor airflow, and aerosol-generating events to provide context for risks of aerosol infectious transmission. We also provide simple but typically effective measures for mitigating the spread and inhalation of viral aerosols in indoor settings. Understanding principles of infectious transmission, aerosol and droplet generation, as well as concepts of indoor airflow, will assist in the integration of new data on SARS-CoV-2 transmission and activities that can generate aerosol to best inform on the need for escalation or de-escalation from current societal and institutional guidelines for protection during aerosol-generating procedures.
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ABSTRACT: Objective: To study onset of respiratory symptoms among students in China in relation to the school and the home environment. Methods: A two-year prospective cohort study among 1325 students in eight schools. Air pollution was measured at baseline in the schools. Respiratory symptoms and the home environment were assessed by a questionnaire. Results: The 2-year onset was 14.3%, 23.2%, 15.4%, 4.7% and 37.3% for wheeze, daytime attacks of breathlessness, nocturnal cough, nocturnal wheeze/breathlessness and respiratory infections, respectively. The mean concentrations of PM10, SO2, NO2, ozone and CO2 in the classrooms were 129 microg/m(3), 68.0 microg/m(3), 43.2 microg/m(3), 8.6 microg/m(3) and 1208 ppm, respectively. Environmental tobacco smoke (ETS), dampness/mold at home and ozone in the classroom were associated with onset of wheeze. Onset of daytime breathlessness was associated with redecoration and dampness/mold at home and CO2 and relative air humidity (RH) in the classrooms. Dampness/mold at home, PM10, CO2 and RH in the classrooms and outdoor PM10, SO2 and NO2 were associated with onset of nocturnal cough. Onset of nocturnal wheeze/breathlessness was associated with dampness/mold at home and RH and PM10 in the classrooms. Respiratory infections were more common at higher levels of outdoor PM10. Conclusions: Air pollution (PM10, ozone, SO2 and NO2) and inadequate ventilation flow in the classrooms (indicated by CO2 > 1000 ppm) and ETS, dampness or mold and chemical emissions from redecoration at home can increase onset of respiratory symptoms.
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ABSTRACT: Background: The role of aerosols in the transmission of SARS-CoV-2 remains debated. We analysed an outbreak involving three non-associated families in Restaurant X in Guangzhou, China, and assessed the possibility of aerosol transmission of SARS-CoV-2 and characterize the associated environmental conditions. Methods: We collected epidemiological data, obtained a video record and a patron seating-arrangement from the restaurant, and measured the dispersion of a warm tracer gas as a surrogate for exhaled droplets from the suspected index patient. Computer simulations were performed to simulate the spread of fine exhaled droplets. We compared the in-room location of subsequently infected cases and spread of the simulated virus-laden aerosol tracer. The ventilation rate was measured using the tracer decay method. Results: Three families (A, B, C), 10 members of which were subsequently found to have been infected with SARS-CoV-2 at this time, or previously, ate lunch at Restaurant X on Chinese New Year's Eve (January 24, 2020) at three neighboring tables. Subsequently, three members of family B and two members of family C became infected with SARS-CoV-2, whereas none of the waiters or 68 patrons at the remaining 15 tables became infected. During this occasion, the ventilation rate was 0.75-1.04 L/s per person. No close contact or fomite contact was observed, aside from back-to-back sitting by some patrons. Our results show that the infection distribution is consistent with a spread pattern representative of exhaled virus-laden aerosols. Conclusions: Aerosol transmission of SARS-CoV-2 due to poor ventilation may explain the community spread of COVID-19.
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ABSTRACT: During January 26-February 10, 2020, an outbreak of 2019 novel coronavirus disease in an air-conditioned restaurant in Guangzhou, China, involved 3 family clusters. The airflow direction was consistent with droplet transmission. To prevent the spread of the virus in restaurants, we recommend increasing the distance between tables and improving ventilation.
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ABSTRACT: Hand washing and maintaining social distance are the main measures recommended by the World Health Organization (WHO) to avoid contracting COVID-19. Unfortunately, these measured do not prevent infection by inhalation of small droplets exhaled by an infected person that can travel distance of meters or tens of meters in the air and carry their viral content. Science explains the mechanisms of such transport and there is evidence that this is a significant route of infection in indoor environments. Despite this, no countries or authorities consider airborne spread of COVID-19 in their regulations to prevent infections transmission indoors. It is therefore extremely important, that the national authorities acknowledge the reality that the virus spreads through air, and recommend that adequate control measures be implemented to prevent further spread of the SARS-CoV-2 virus, in particularly removal of the virus-laden droplets from indoor air by ventilation.
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ABSTRACT: During the rapid rise in COVID-19 illnesses and deaths globally, and notwithstanding recommended precautions, questions are voiced about routes of transmission for this pandemic disease. Inhaling small airborne droplets is probable as a third route of infection, in addition to more widely recognized transmission via larger respiratory droplets and direct contact with infected people or contaminated surfaces. While uncertainties remain regarding the relative contributions of the different transmission pathways, we argue that existing evidence is sufficiently strong to warrant engineering controls targeting airborne transmission as part of an overall strategy to limit infection risk indoors. Appropriate building engineering controls include sufficient and effective ventilation, possibly enhanced by particle filtration and air disinfection, avoiding air recirculation and avoiding overcrowding. Often, such measures can be easily implemented and without much cost, but if only they are recognised as significant in contributing to infection control goals. We believe that the use of engineering controls in public buildings, including hospitals, shops, offices, schools, kindergartens, libraries, restaurants, cruise ships, elevators, conference rooms or public transport, in parallel with effective application of other controls (including isolation and quarantine, social distancing and hand hygiene), would be an additional important measure globally to reduce the likelihood of transmission and thereby protect healthcare workers, patients and the general public.
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ABSTRACT: Background: By early April 2020, the COVID-19 pandemic had infected nearly one million people and had spread to nearly all countries worldwide. It is essential to understand where and how SARS-CoV-2 is transmitted. Methods: Case reports were extracted from the local Municipal Health Commissions of 320 prefectural cities (municipalities) in China, not including Hubei province, between 4 January and 11 February 2020. We identified all outbreaks involving three or more cases and reviewed the major characteristics of the enclosed spaces in which the outbreaks were reported and associated indoor environmental issues. Results: Three hundred and eighteen outbreaks with three or more cases were identified, involving 1245 confirmed cases in 120 prefectural cities. We divided the venues in which the outbreaks occurred into six categories: homes, transport, food, entertainment, shopping, and miscellaneous. Among the identified outbreaks, 53.8% involved three cases, 26.4% involved four cases, and only 1.6% involved ten or more cases. Home outbreaks were the dominant category (254 of 318 outbreaks; 79.9%), followed by transport (108; 34.0%; note that many outbreaks involved more than one venue category). Most home outbreaks involved three to five cases. We identified only a single outbreak in an outdoor environment, which involved two cases. Conclusions: 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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ABSTRACT: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a strain of coronaviruses that causes coronavirus disease 2019 (COVID-19). In these days, the spread of the SARS-CoV-2 virus through the air has become a controversial topic among scientists. Various organizations provide standard methods for monitoring biological agents in the air. Nevertheless, there has been no standard recommended method for

sampling and determination of viruses in air. This manuscript aimed at reviewing published papers for sampling and detection of corona viruses, especially SARS-Cov-2 as a global health concern. It was found that SARS-Cov 2 was present in some air samples that were collected from patient's rooms in hospitals. This result warrants its airborne transmission potential. However, due to the fact that in the most reviewed studies, sampling was performed in the patient's room, it seems difficult to discriminate whether it is airborne or is transmitted through respiratory droplets. Moreover, some other disrupting factors such as patient distance from the sampler, using protective or oxygen masks by patients, patient activities, coughing and sneezing during sampling time, air movement, air conditioning, sampler type, sampling conditions, storage and transferring conditions, can affect the results. About the sampling methods, most of the used samplers such as PTFE filters, gelatin filers and cyclones showed suitable performance for trapping SARS-Co and MERS-Cov viruses followed by PCR analysis.
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ABSTRACT: Minimizing all aspects of COVID-19 exposure is a high priority as universities prepare to reopen One of those aspects includes developing protocols for interior spaces such as academic buildings This paper applies mathematical modeling to investigate different virus exposure levels due to traffic patterns within academic buildings The assumption used are: 1) Risk of infection is a product of exposure rate and time and 2) the exposure rate decreases with distance One-way vs two-way pedestrian traffic scenarios within hallways were modeled and analyzed for various configurations The underlying assumption that a small exposure to a large number of people is similar to a large exposure to a few people is the driver to minimize exposures levels in all aspects The analysis indicates that minimizing the time spent in passing between classes is the driving factor in minimizing risk, and one-way traffic may increase the time required to pass between classes While the case presented is limited, the modeled approaches are intended to provoke future research that can be extended and applied to larger populations to help provide decision makers with more rigorous tools to shape future policies regarding traffic flow within buildings
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ABSTRACT: The HVAC systems in most non-medical buildings play only a small role in infectious disease transmission, including COVID-19.1 Knowledge is emerging about COVID-19, the virus that causes it (SARS-CoV-2), and how the disease spreads. Reasonable, but not certain, inferences about spread can be drawn from the SARS outbreak in 2003 (a virus genetically similar to SARS-CoV-2) and, to a lesser extent, from transmission of other viruses. Preliminary research has been recently released, due to the urgent need for information, but it is likely to take years to reach scientific consensus.
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ABSTRACT: In the CoViD-19 pandemic, the precautionary approach suggests that all possible measures should be established and implemented to avoid contagion, including through aerosols. For indoor spaces, the virulence of SARS-CoV-2 could be mitigated not only via air changes, but also by heating, ventilation, and air conditioning (HVAC) systems maintaining thermodynamic conditions possibly adverse to the virus. However, data available in literature on virus survival were never treated aiming to this. In fact, based on comparisons in terms of specific enthalpy, a domain of indoor comfort conditions between 50 and 60 kJ/kg is found to comply with this objective, and an easy-to-use relationship for setting viable pairs of humidity and temperature using a proper HVAC plant is proposed. If confirmed via further investigations on this research path, these findings could open interesting scenarios on the use of indoor spaces during the pandemic.
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ABSTRACT: Social distancing and ventilation were emphasized broadly to control the ongoing pandemic COVID-19 in confined spaces. Rationales behind these two strategies, however, were debated, especially regarding quantitative recommendations. The answers to "what is the safe distance" and "what is sufficient ventilation" are crucial to the upcoming reopening of businesses and schools, but rely on many medical, biological, and engineering factors. This study introduced two new indices into the popular while perfect-mixing-based Wells-Riley model for predicting airborne virus related infection probability - the underlying reasons for keeping adequate social distance and space ventilation. The distance index Pd can be obtained by theoretical analysis on droplet distribution and transmission from human respiration activities, and the ventilation index Ez represents the system-dependent air distribution efficiency in a space. The study indicated that 1.6-3.0m (5.2-9.8ft) is the safe social distance when considering aerosol transmission of exhaled large droplets from talking, while the distance can be up to 8.2m (26ft) if taking into account of all droplets under calm air environment. Because of unknown dose response to COVID-19, the model used one actual pandemic case to calibrate the infectious dose (quantum of infection), which was then verified by a number of other existing cases with short exposure time (hours). Projections using the validated model for a variety of scenarios including transportation vehicles and building spaces illustrated that (1) increasing social distance (e.g., halving occupancy density) can significantly reduce the infection rate (20-40 %) during the first 30min even under current ventilation practices; (2) minimum ventilation or fresh air requirement should vary with distancing condition, exposure time, and effectiveness of air distribution systems.
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ABSTRACT: Coronavirus spread is more serious in urban metropolitan cities compared to rural areas. It is observed from the data on the infection rate available in the various sources that the cold and dry conditions accelerate the spread of coronavirus. In the present work, the existing theory of respiratory droplet drying is used to propose the mechanism of virus spread under various climates and the indoor environment conditions which plays a greater role in the virus spread. This concept is assessed using four major parameters such as population density, climate severity, the volume of indoor spaces, and air-conditioning usage which affect the infection spread and mortality using the data available for various states of India. Further, it is analysed using the data from various states in India along with the respective climatic conditions. It is found that under some indoor scenarios, the coronaviruses present in the respiratory droplets become active due to size reduction that

occurs both in sessile and airborne droplet nuclei causing an increase in the spread. Understanding this mechanism will be very useful to take the necessary steps to reduce the rate of transmission by initiating corrective measures and maintaining the required conditions in the indoor built environment.
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ABSTRACT: In response to the COVID-19 pandemic, numerous countries worldwide declared national states of emergency and implemented interventions to minimise the risk of transmission among the public. Evidence was needed to inform strategies for limiting COVID- 19 transmission on public transport. On 20 March 2020, we searched MEDLINE, CENTRAL, Web of Science and the World Health Organization's database of 'Global research on coronavirus disease (COVID-19)' to conduct a rapid review on interventions that reduce viral transmission on public ground transport. After screening 74 records, we identified 4 eligible studies. These studies suggest an increased risk of viral transmission with public transportation use that may be reduced with improved ventilation. International and national guidelines suggest the following strategies: keep the public informed, stay at home when sick, and minimise public transport use. Where use is unavoidable, environmental control, respiratory etiquette and hand hygiene are recommended, while a risk-based approach needs to guide the use of non-medical masks.
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ABSTRACT: Strategies to protect building occupants from the risk of acute respiratory infection (ARI) need to consider ventilation for its ability to dilute and remove indoor bioaerosols. Prior studies have described an association of increased self-reported colds and influenza-like symptoms with low ventilation but have not combined rigorous characterization of ventilation with assessment of laboratory confirmed infections. We report a study designed to fill this gap. We followed laboratory confirmed ARI rates and measured CO_2 concentrations for four months during the winter-spring of 2018 in two campus residence halls: (1) a high ventilation building (HVB) with a dedicated outdoor air system that supplies 100% of outside air to each dormitory room, and (2) a low ventilation building (LVB) that relies on infiltration as ventilation. We enrolled 11 volunteers for a total of 522 person-days in the HVB and 109 volunteers for 6069 person-days in the LVB, and tested upper-respiratory swabs from symptomatic cases and their close contacts for the presence of 44 pathogens using a molecular assay. We observed one ARI case in the HVB (0.70/person-year) and 47 in the LVB (2.83/person-year). Simultaneously, 154 CO_2 sensors distributed primarily in the dormitory rooms collected

668,390 useful data points from over 1 million recorded data points. Average and standard deviation of CO2 concentrations were 1230 ppm and 408 ppm in the HVB, and 1492 ppm and 837 ppm in the LVB, respectively. Importantly, this study developed and calibrated multi-zone models for the HVB with 229 zones and 983 airflow paths, and for the LVB with 529 zones and 1836 airflow paths by using a subset of CO2 data for model calibration. The models were used to calculate ventilation rates in the two buildings and potential for viral aerosol migration between rooms in the LVB. With doors and windows closed, the average ventilation rate was 12 L/s in the HVB dormitory rooms and 4 L/s in the LVB dormitory rooms. As a result, residents had on average 6.6 L/(s person) of outside air in the HVB and 2.3 L/(s person) in the LVB. LVB rooms located at the leeward side of the building had smaller average ventilation rates, as well as a somewhat higher ARI incidence rate and average CO2 concentrations when compared to those values in the rooms located at the windward side of the building. Average ventilation rates in twenty LVB dormitory rooms increased from 2.3 L/s to 7.5 L/s by opening windows, 3.6 L/s by opening doors, and 8.8 L/s by opening both windows and doors. Therefore, opening both windows and doors in the LVB dormitory rooms can increase ventilation rates to the levels comparable to those in the HVB. But it can also have a negative effect on thermal comfort due to low outdoor temperatures. Simulation results identified an aerobiologic pathway from a room occupied by an index case of influenza A to a room occupied by a possible secondary case.
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DOI: 10.3201/eid2510.190130

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ABSTRACT: Identifying the exact transmission route(s) of infectious diseases in indoor environments is a crucial step in developing effective intervention strategies. In this study, we proposed a comparative analysis approach and built a model to simulate outbreaks of 3 different in-flight infections in a similar cabin environment, that is, influenza A H1N1, severe acute respiratory syndrome (SARS) coronavirus (CoV), and norovirus. The simulation results seemed to suggest that the close contact route was probably the most significant route (contributes 70%, 95% confidence interval [CI]: 67%-72%) in the in-flight transmission of influenza A H1N1 transmission; as a result, passengers within 2 rows of the index case had a significantly higher infection risk than others in the outbreak (relative risk [RR]: 13.4, 95% CI: 1.5-121.2, P = .019). For SARS CoV, the airborne, close contact, and fomite routes contributed 21% (95% CI: 19%-23%), 29% (95% CI: 27%-31%), and 50% (95% CI: 48%-53%), respectively. For norovirus, the simulation results suggested that the fomite route played the dominant role (contributes 85%, 95% CI: 83%-87%) in most cases; as a result, passengers in aisle seats had a significantly higher infection risk than others (RR: 9.5, 95% CI: 1.2-77.4, P = .022). This work highlighted a method for using observed outbreak data to analyze the roles of different infection transmission routes.

URL: https://www.ncbi.nlm.nih.gov/pubmed/29244221
DOI: 10.1111/ina.12445

43. Qian H, Zheng X. Ventilation control for airborne transmission of human exhaled bio-aerosols in buildings. J Thorac Dis. 2018;10(Suppl 19):S2295-S304. DOI: 10.21037/jtd.2018.01.24

ABSTRACT: The emergence of respiratory diseases, i.e., severe acute respiratory syndrome (SARS) epidemic in 2003, H1N1 influenza epidemic in 2011 and Middle East respiratory syndrome (MERS) outbreak, reiterated the significance of ventilation in buildings. The role of ventilation in removing exhaled airborne bio-aerosols and preventing cross infections has been multidisciplinary extensively studied after the SARS outbreak in 2003. The characteristics of droplet-borne, short-range airborne and long-range airborne transmission of infectious diseases were identified. Increasing ventilation rate can effectively reduce the risk of long-range airborne transmission, while it may be of little useful in preventing the droplet-borne transmission. To maintain the airflow direction from clean cubicles to dirty cubicles is an effective way to prevent the cross infection between cubicles, which is widely used in hospital isolation rooms. Field measurements showed that wrong air flow direction was due to poor construction quality or maintenance. The impacts of different airflow patterns on removing large droplets and fine droplet nuclei were discussed. Some new concepts in general ventilation systems and local personalized equipment were also introduced. This review updates current knowledge of the airborne transmission of pathogens and the improvement of ventilation efficiency concerning the infection prevention.
URL: https://www.ncbi.nlm.nih.gov/pubmed/30116608
DOI: 10.21037/jtd.2018.01.24

44. Wolkoff P. Indoor air humidity, air quality, and health - An overview. Int J Hyg Environ Health. 2018;221(3):376-90. DOI: 10.1016/j.ijheh.2018.01.015

ABSTRACT: There is a long-standing dispute about indoor air humidity and perceived indoor air quality (IAQ) and associated health effects. Complaints about sensory irritation in eyes and upper airways are generally among top-two symptoms together with the perception "dry air" in office environments. This calls for an integrated analysis of indoor air humidity and eye and airway health effects. This overview has reviewed the literature about the effects of extended exposure to low humidity on perceived IAQ, sensory irritation symptoms in eyes and airways, work performance, sleep quality, virus survival, and voice disruption. Elevation of the indoor air humidity may positively impact perceived IAQ, eye symptomatology, and possibly work performance in the office environment; however, mice inhalation studies do not show exacerbation of sensory irritation in the airways by low humidity. Elevated humidified indoor air appears to reduce nasal symptoms in patients suffering from obstructive apnea syndrome, while no clear improvement on voice production has been identified, except for those with vocal fatigue. Both low and high RH, and perhaps even better absolute humidity (water vapor), favors transmission and survival of influenza virus in many studies, but the relationship between temperature, humidity, and the virus and aerosol dynamics is complex, which in the end depends on the individual virus type and its physical/chemical properties. Dry and humid air perception continues to be reported in offices and in residential areas, despite the IAQ parameter "dry air" (or "wet/humid air") is semantically misleading, because a sensory organ for humidity is non-existing in humans. This IAQ parameter appears to reflect different perceptions among other odor, dustiness, and possibly exacerbated by desiccation effect of low air humidity. It is salient to distinguish between indoor air humidity (relative or absolute) near the breathing and ocular zone and phenomena caused by moisture-damage of the building construction and emissions therefrom. Further, residential versus public environments should be considered as separate entities with different characteristics and demands of humidity. Research is needed about particle, bacteria and virus dynamics indoors for improvement of quality of life and with more focus on the impact of absolute humidity. "Dry (or wet) air" should be redefined to become a meaningful IAQ descriptor.
URL: https://www.ncbi.nlm.nih.gov/pubmed/29398406
DOI: 10.1016/j.ijheh.2018.01.015

45. Majumder MS, Brownstein JS, Finkelstein SN, et al. Nosocomial amplification of MERS-coronavirus in South Korea, 2015. Trans R Soc Trop Med Hyg. 2017;111(6):261-9. DOI: 10.1093/trstmh/trx046
ABSTRACT: Background: Nosocomial amplification resulted in nearly 200 cases of Middle East respiratory syndrome (MERS) during the 2015 South Korean MERS-coronavirus outbreak. It remains unclear whether certain types of cases were more likely to cause secondary infections than others, and if so, why. Methods: Publicly available demographic and transmission network data for all cases were collected from the Ministry of Health and Welfare. Statistical analyses were conducted to determine the relationship between demographic characteristics and the likelihood of human-to-human transmission. Findings from the statistical analyses were used to inform a hypothesis-directed literature review, through which mechanistic explanations for nosocomial amplification were developed. Results: Cases that failed to recover from MERS were more likely to cause secondary infections than those that did. Increased probability of direct, human-to-human transmission due to clinical manifestations associated with death, as well as indirect transmission via environmental contamination (e.g., fomites and indoor ventilation systems), may serve as mechanistic explanations for nosocomial amplification of MERS-coronavirus in South Korea. Conclusions: In addition to closely monitoring contacts of MERS cases that fail to recover during future nosocomial outbreaks, potential fomites with which they may have had contact should be sanitized. Furthermore, indoor ventilation systems that minimize recirculation of pathogen-bearing droplets should be implemented whenever possible.
URL: https://www.ncbi.nlm.nih.gov/pubmed/29044371
DOI: 10.1093/trstmh/trx046

46. Prussin AJ, 2nd, Schwake DO, Marr LC. Ten Questions Concerning the Aerosolization and Transmission of Legionella in the Built Environment. Build Environ. 2017;123:684-95. DOI: 10.1016/j.buildenv.2017.06.024
ABSTRACT: Legionella is a genus of pathogenic Gram-negative bacteria responsible for a serious disease known as legionellosis, which is transmitted via inhalation of this pathogen in aerosol form. There are two forms of legionellosis: Legionnaires' disease, which causes pneumonia-like symptoms, and Pontiac fever, which causes influenza-like symptoms. Legionella can be aerosolized from various water sources in the built environment including showers, faucets, hot tubs/swimming pools, cooling towers, and fountains. Incidence of the disease is higher in the summertime, possibly because of increased use of cooling towers for air conditioning systems and differences in water chemistry when outdoor temperatures are higher. Although there have been decades of research related to Legionella transmission, many knowledge gaps remain. While conventional wisdom suggests that showering is an important source of exposure in buildings, existing measurements do not provide strong support for this idea. There has been limited research on the potential for Legionella transmission through heating, ventilation, and air conditioning (HVAC) systems. Epidemiological data suggest a large proportion of legionellosis cases go unreported, as most people who are infected do not seek medical attention. Additionally, controlled laboratory studies examining water-to-air transfer and source tracking are still needed. Herein, we discuss ten questions that spotlight current knowledge about Legionella transmission in the built environment, engineering controls that might prevent future disease outbreaks, and future research that is needed to advance understanding of transmission and control of legionellosis.
URL: https://www.ncbi.nlm.nih.gov/pubmed/29104349
DOI: 10.1016/j.buildenv.2017.06.024

47. Cheng YH, Wang CH, You SH, et al. Assessing coughing-induced influenza droplet transmission and implications for infection risk control. Epidemiol Infect. 2016;144(2):333-45. DOI: 10.1017/S0950268815001739
ABSTRACT: Indoor transmission of respiratory droplets bearing influenza within humans poses high risks to respiratory function deterioration and death. Therefore, we aimed to develop a framework for quantifying the influenza infection risk based on the relationships between inhaled/exhaled respiratory droplets and airborne transmission dynamics in a ventilated airspace. An experiment was conducted to measure the size distribution

of influenza-containing droplets produced by coughing for a better understanding of potential influenza spread. Here we integrated influenza population transmission dynamics, a human respiratory tract model, and a control measure approach to examine the indoor environment-virus-host interactions. A probabilistic risk model was implemented to assess size-specific infection risk for potentially transmissible influenza droplets indoors. Our results found that there was a 50% probability of the basic reproduction number (R0) exceeding 1 for small-size influenza droplets of 0.3-0.4 microm, implicating a potentially high indoor infection risk to humans. However, a combination of public health interventions with enhanced ventilation could substantially contain indoor influenza infection. Moreover, the present dynamic simulation and control measure assessment provide insights into why indoor transmissible influenza droplet-induced infection is occurring not only in upper lung regions but also in the lower respiratory tract, not normally considered at infection risk.
URL: https://www.ncbi.nlm.nih.gov/pubmed/26211781
DOI: 10.1017/S0950268815001739

48. Gao X, Wei J, Cowling BJ, et al. Potential impact of a ventilation intervention for influenza in the context of a dense indoor contact network in Hong Kong. Sci Total Environ. 2016;569-570:373-81. DOI: 10.1016/j.scitotenv.2016.06.179
ABSTRACT: Emerging diseases may spread rapidly through dense and large urban contact networks. We constructed a simple but novel dual-contact network model to account for both airborne contact and close contact of individuals in the densely populated city of Hong Kong. The model was then integrated with an existing epidemiological susceptible-exposed-infectious-recovered (SEIR) model, and we used a revised Wells-Riley model to estimate infection risks by the airborne route and an exponential dose-response model for risks by the contact and droplet routes. A potential outbreak of partially airborne influenza was examined, assuming different proportions of transmission through the airborne route. Our results show that building ventilation can have significant effects in airborne transmission-dominated conditions. Moreover, even when the airborne route only contributes 20% to the total infection risk, increasing the ventilation rate has a strong influence on transmission dynamics, and it also can achieve control effects similar to those of wearing masks for patients, isolation and vaccination.
URL: https://www.ncbi.nlm.nih.gov/pubmed/27351145
DOI: 10.1016/j.scitotenv.2016.06.179

49. Gao X, Wei J, Lei H, et al. Building Ventilation as an Effective Disease Intervention Strategy in a Dense Indoor Contact Network in an Ideal City. PLoS ONE. 2016;11(9):e0162481. DOI: 10.1371/journal.pone.0162481
ABSTRACT: Emerging diseases may spread rapidly through dense and large urban contact networks, especially they are transmitted by the airborne route, before new vaccines can be made available. Airborne diseases may spread rapidly as people visit different indoor environments and are in frequent contact with others. We constructed a simple indoor contact model for an ideal city with 7 million people and 3 million indoor spaces, and estimated the probability and duration of contact between any two individuals during one day. To do this, we used data from actual censuses, social behavior surveys, building surveys, and ventilation measurements in Hong Kong to define eight population groups and seven indoor location groups. Our indoor contact model was integrated with an existing epidemiological Susceptible, Exposed, Infectious, and Recovered (SEIR) model to estimate disease spread and with the Wells-Riley equation to calculate local infection risks, resulting in an integrated indoor transmission network model. This model was used to estimate the probability of an infected individual infecting others in the city and to study the disease transmission dynamics. We predicted the infection probability of each sub-population under different ventilation systems in each location type in the case of a hypothetical airborne disease outbreak, which is assumed to have the same natural history and infectiousness as smallpox. We compared the effectiveness of controlling ventilation in each location type with other intervention strategies. We conclude that increasing building ventilation rates using methods such as natural ventilation in classrooms, offices, and homes is a relatively effective strategy for airborne diseases in a large city.
URL: https://www.ncbi.nlm.nih.gov/pubmed/27611368

DOI: 10.1371/journal.pone.0162481

50. Ijaz MK, Zargar B, Wright KE, et al. Generic aspects of the airborne spread of human pathogens indoors and emerging air decontamination technologies. Am J Infect Control. 2016;44(9 Suppl):S109-20. DOI: 10.1016/j.ajic.2016.06.008
ABSTRACT: Indoor air can be an important vehicle for a variety of human pathogens. This review provides examples of airborne transmission of infectious agents from experimental and field studies and discusses how airborne pathogens can contaminate other parts of the environment to give rise to secondary vehicles leading air-surface-air nexus with possible transmission to susceptible hosts. The following groups of human pathogens are covered because of their known or potential airborne spread: vegetative bacteria (staphylococci and legionellae), fungi (Aspergillus, Penicillium, and Cladosporium spp and Stachybotrys chartarum), enteric viruses (noro- and rotaviruses), respiratory viruses (influenza and coronaviruses), mycobacteria (tuberculous and nontuberculous), and bacterial spore formers (Clostridium difficile and Bacillus anthracis). An overview of methods for experimentally generating and recovering airborne human pathogens is included, along with a discussion of factors that influence microbial survival in indoor air. Available guidelines from the U.S. Environmental Protection Agency and other global regulatory bodies for the study of airborne pathogens are critically reviewed with particular reference to microbial surrogates that are recommended. Recent developments in experimental facilities to contaminate indoor air with microbial aerosols are presented, along with emerging technologies to decontaminate indoor air under field-relevant conditions. Furthermore, the role that air decontamination may play in reducing the contamination of environmental surfaces and its combined impact on interrupting the risk of pathogen spread in both domestic and institutional settings is discussed.
URL: https://www.ncbi.nlm.nih.gov/pubmed/27590695
DOI: 10.1016/j.ajic.2016.06.008

51. Luongo JC, Fennelly KP, Keen JA, et al. Role of mechanical ventilation in the airborne transmission of infectious agents in buildings. Indoor Air. 2016;26(5):666-78. DOI: 10.1111/ina.12267
ABSTRACT: Infectious disease outbreaks and epidemics such as those due to SARS, influenza, measles, tuberculosis, and Middle East respiratory syndrome coronavirus have raised concern about the airborne transmission of pathogens in indoor environments. Significant gaps in knowledge still exist regarding the role of mechanical ventilation in airborne pathogen transmission. This review, prepared by a multidisciplinary group of researchers, focuses on summarizing the strengths and limitations of epidemiologic studies that specifically addressed the association of at least one heating, ventilating and/or air-conditioning (HVAC) system-related parameter with airborne disease transmission in buildings. The purpose of this literature review was to assess the quality and quantity of available data and to identify research needs. This review suggests that there is a need for well-designed observational and intervention studies in buildings with better HVAC system characterization and measurements of both airborne exposures and disease outcomes. Studies should also be designed so that they may be used in future quantitative meta-analyses.
URL: https://www.ncbi.nlm.nih.gov/pubmed/26562748
DOI: 10.1111/ina.12267

52. Nardell EA. Indoor environmental control of tuberculosis and other airborne infections. Indoor Air. 2016;26(1):79-87. DOI: 10.1111/ina.12232
ABSTRACT: Tuberculosis (TB) remains the airborne infection of global importance, although many environmental interventions to control TB apply to influenza and other infections with airborne potential. This review focuses on the global problem and the current state of available environmental interventions. TB transmission is facilitated in overcrowded, poorly ventilated congregate settings, such as hospitals, clinics, prisons, jails, and refugee camps. The best means of TB transmission control is source control- to identify unsuspected infectious cases and to promptly begin effective therapy. However, even with active case finding and rapid diagnostics, not every unsuspected case will be identified, and environmental control measures

remain the next intervention of choice. Natural ventilation is the main means of air disinfection and has the advantage of wide availability, low cost, and high efficacy-under optimal conditions. It is usually not applicable all year in colder climates and may not be effective when windows are closed on cold nights in warm climates, for security, and for pest control. In warm climates, windows may be closed when air conditioning is installed for thermal comfort. Although mechanical ventilation, if properly installed and maintained, can provide adequate air disinfection, it is expensive to install, maintain, and operate. The most cost-effective way to achieve high levels of air disinfection is upper room germicidal irradiation. The safe and effective application of this poorly defined intervention is now well understood, and recently published evidence-based application guidelines will make implementation easier.
URL: https://www.ncbi.nlm.nih.gov/pubmed/26178270
DOI: 10.1111/ina.12232

53. Sattar SA. Indoor air as a vehicle for human pathogens: Introduction, objectives, and expectation of outcome. Am J Infect Control. 2016;44(9 Suppl):S95-S101. DOI: 10.1016/j.ajic.2016.06.010
ABSTRACT: Airborne spread of pathogens can be rapid, widespread, and difficult to prevent. In this international workshop, a panel of 6 experts will expound on the following: (1) the potential for indoor air to spread a wide range of human pathogens, plus engineering controls to reduce the risk for exposure to airborne infectious agents; (2) the behavior of aerosolized infectious agents indoors and the use of emerging air decontamination technologies; (3) a survey of quantitative methods to recover infectious agents and their surrogates from indoor air with regard to survival and inactivation of airborne pathogens; (4) mathematical models to predict the movement of pathogens indoors and the use of such information to optimize the benefits of air decontamination technologies; and (5) synergy between different infectious agents, such as legionellae and fungi, in the built environment predisposing to possible transmission-related health impacts of aerosolized biofilm-based opportunistic pathogens. After the presentations, the panel will address a set of preformulated questions on selection criteria for surrogate microbes to study the survival and inactivation of airborne human pathogens, desirable features of technologies for microbial decontamination of indoor air, knowledge gaps, and research needs. It is anticipated that the deliberations of the workshop will provide the attendees with an update on the significance of indoor air as a vehicle for transmitting human pathogens with a brief on what is currently being done to mitigate the risks from airborne infectious agents.
URL: https://www.ncbi.nlm.nih.gov/pubmed/27590701
DOI: 10.1016/j.ajic.2016.06.010

54. Sattar SA, Kibbee RJ, Zargar B, et al. Decontamination of indoor air to reduce the risk of airborne infections: Studies on survival and inactivation of airborne pathogens using an aerobiology chamber. Am J Infect Control. 2016;44(10):e177-e82. DOI: 10.1016/j.ajic.2016.03.067
ABSTRACT: BACKGROUND: Although indoor air can spread many pathogens, information on the airborne survival and inactivation of such pathogens remains sparse. METHODS: Staphylococcus aureus and Klebsiella pneumoniae were nebulized separately into an aerobiology chamber (24.0 m(3)). The chamber's relative humidity and air temperature were at 50% +/- 5% and 20 degrees C +/- 2 degrees C, respectively. The air was sampled with a slit-to-agar sampler. Between tests, filtered air purged the chamber of any residual airborne microbes. RESULTS: The challenge in the air varied between 4.2 log10 colony forming units (CFU)/m(3) and 5.0 log10 CFU/m(3), sufficient to show a >/=3 log10 (>/=99.9%) reduction in microbial viability in air over a given contact time by the technologies tested. The rates of biologic decay of S aureus and K pneumoniae were 0.0064 +/- 0.00015 and 0.0244 +/- 0.009 log10 CFU/m(3)/min, respectively. Three commercial devices, with ultraviolet light and HEPA (high-efficiency particulate air) filtration, met the product efficacy criterion in 45-210 minutes; these rates were statistically significant compared with the corresponding rates of biologic decay of the bacteria. One device was also tested with repeated challenges with aerosolized S aureus to simulate ongoing fluctuations in indoor air quality; it could reduce each such recontamination to an undetectable level in approximately 40 minutes. CONCLUSIONS: The setup described is suitable for work with all major classes of pathogens and also

complies with the U.S. Environmental Protection Agency's guidelines (2012) for testing air decontamination technologies.
URL: https://www.ncbi.nlm.nih.gov/pubmed/27375064
DOI: 10.1016/j.ajic.2016.03.067

55. Zheng L, Chen Q, Xu J, et al. Evaluation of intervention measures for respiratory disease transmission on cruise ships. Indoor and Built Environment. 2016;25(8):1267-78. DOI: 10.1177/1420326x15600041
ABSTRACT: Respiratory diseases are common infectious illnesses on cruise ships. This study integrated an individual-to-individual probability model, a susceptible-exposed-infected-recovered epidemic model at the individual scale, and an onboard indoor social contact network model for evaluating the infection risk on a typical cruise ship voyage. The integrated model was validated by data from a previous influenza outbreak and was able to simulate the infection spreading. The model was used to assess the effects of various intervention measures on controlling influenza on a cruise ship with one index passenger. The results show that individuals in crew cabins and restaurants faced the highest infection risk. Increasing the air change rate in some or all locations could reduce the infection risk to some extent. High-efficiency particulate air filters and ultraviolet germicidal irradiation devices in ventilation systems were the most effective measures. Surgical masks worn by crew members or a quarantine of the index passenger and his/her roommate could reduce the attack rate only to a moderate extent.
URL: https://journals.sagepub.com/doi/abs/10.1177/1420326X15600041
DOI: 10.1177/1420326x15600041

56. Rewar S, Mirdha D, Rewar P. Treatment and Prevention of Pandemic H1N1 Influenza. Ann Glob Health. 2015;81(5):645-53. DOI: 10.1016/j.aogh.2015.08.014
ABSTRACT: BACKGROUND: Swine influenza is a respiratory infection common to pigs worldwide caused by type A influenza viruses, principally subtypes H1N1, H1N2, H2N1, H3N1, H3N2, and H2N3. Swine influenza viruses also can cause moderate to severe illness in humans and affect persons of all age groups. People in close contact with swine are at especially high risk. Until recently, epidemiological study of influenza was limited to resource-rich countries. The World Health Organization declared an H1N1 pandemic on June 11, 2009, after more than 70 countries reported 30,000 cases of H1N1 infection. In 2015, incidence of swine influenza increased substantially to reach a 5-year high. In India in 2015, 10,000 cases of swine influenza were reported with 774 deaths. METHODS: The Centers for Disease Control and Prevention recommend real-time polymerase chain reaction as the method of choice for diagnosing H1N1. Antiviral drugs are the mainstay of clinical treatment of swine influenza and can make the illness milder and enable the patient to feel better faster. FINDINGS: Antiviral drugs are most effective when they are started within the first 48 hours after the clinical signs begin, although they also may be used in severe or high-risk cases first seen after this time. The Centers for Disease Control and Prevention recommends use of oseltamivir (Tamiflu, Genentech) or zanamivir (Relenza, GlaxoSmithKline). CONCLUSION: Prevention of swine influenza has 3 components: prevention in swine, prevention of transmission to humans, and prevention of its spread among humans. Because of limited treatment options, high risk for secondary infection, and frequent need for intensive care of individuals with H1N1 pneumonia, environmental control, including vaccination of high-risk populations and public education are critical to control of swine influenza out breaks.
URL: https://www.ncbi.nlm.nih.gov/pubmed/27036721
DOI: 10.1016/j.aogh.2015.08.014

SEARCH STRATEGIES

Embase <1974 to 2020 August 25>
1 exp disease transmission/ or (transmissibility or transmission or infectiousness or infectivity or communicability).ti,ab. (596321)

2 exp coronavirinae/ or exp coronavirus infection/ or exp influenza/ or (coronavirus* or coronavirinae* or CoV or SARS or MERS or influenza or flu).ti,ab. (192251)
3 air conditioning/ or indoor air pollution/ or heating/ or exp air filter/ or (air condition* or aircondition* or HVAC or ventilation system* or environmental control or indoor air pollution or indoor air quality).ti,ab. (75953)
4 1 and 2 and 3 (173)
5 exp health care facility/ (1537334)
6 4 not 5 (118)
7 limit 6 to (english language and yr="2015 -Current") (57)

Ovid MEDLINE(R) ALL <1946 to August 25, 2020>
1 exp Disease Transmission, Infectious/ or (transmissibility or transmission or infectiousness or infectivity or communicability).ti,ab. (433702)
2 exp Coronavirus/ or exp Coronavirus Infections/ or exp Influenzavirus A/ or (coronavirus* or coronavirinae* or CoV or SARS or MERS or influenza or flu).ti,ab. (163870)
3 Ventilation/ or Air Pollution, Indoor/ or Heating/ or Air Conditioning/ or Air Filters/ or (air condition* or aircondition* or HVAC or ventilation system* or environmental control or indoor air pollution or indoor air quality).ti,ab. (30744)
4 1 and 2 and 3 (119)
5 exp Health Facilities/ (785941)
6 4 not 5 (84)
7 limit 6 to (english language and yr="2015 -Current") (44)

Search terms for other resources used in various combinations:
- Air conditioning or ventilation or air circulation or HVAC
- COVID-19
- Enclosed space or indoor or inside

Google and Google Scholar:
(“ventilation system*” or HVAC or aircondition* or “air condition*” or “indoor” or “enclosed space” or “confined space”) AND
(coronaviru* OR "corona virus" OR ncov* OR n-cov* OR COVID-19 OR COVID19 OR COVID-2019 OR COVID2019 OR SARS-COV-2 OR SARSCOV-2 OR SARSCOV2 OR SARSCOV19 OR SARS-COV-19 OR SARSCOV-19 OR SARSCOV2019 OR SARS-COV-2019 OR SARSCOV-2019 OR "severe acute respiratory syndrome cov 2" OR "severe acute respiratory syndrome coronavirus*" OR "2019 ncov" OR 2019ncov OR Hcov*) from:2020