

This is an Accepted Manuscript for *Infection Control & Hospital Epidemiology* as part of the Cambridge Coronavirus Collection.

DOI: 10.1017/ice.2021.284

Article Type: Original Article

**Use of portable air cleaners to reduce aerosol transmission
on a hospital COVID-19 ward**

Buising KL, MD, Victorian Infectious Diseases Service Royal Melbourne Hospital,
Melbourne Victoria Australia

Schofield R, Environmental Science Hub, University of Melbourne, Melbourne Victoria
Australia

Irving L, Respiratory Medicine, Royal Melbourne Hospital, Melbourne Victoria Australia

Keywood M, Oceans and Atmosphere, Commonwealth Scientific and Industrial Research
Organization, Melbourne Victoria Australia

Stevens A, Hospital Engineering, Royal Melbourne Hospital, Melbourne Victoria Australia

Keogh N, Hospital Engineering, Royal Melbourne Hospital, Melbourne Victoria Australia

Skidmore G, Department of Mechanical Engineering, University of Melbourne, Melbourne
Victoria Australia

Wadlow I, University of Melbourne, Melbourne Victoria Australia

Kevin K, University of Melbourne, Melbourne Victoria Australia

Rismanchi B, Department of Infrastructure Engineering, University of Melbourne,
Melbourne Victoria Australia

Wheeler AJ, Mary MacKillop Institute for Health Research, Australian Catholic University,
Melbourne Victoria Australia

Humphries RS, Oceans and Atmosphere, Commonwealth Scientific and Industrial Research
Organization, Melbourne Victoria Australia

Kainer M, Infection Prevention Western Health, Melbourne Victoria Australia

McGain F, PhD Intensive Care, Western Health, Melbourne Victoria Australia

Monty J, PhD, Department of Mechanical Engineering, University of Melbourne, Melbourne Victoria Australia

Marshall C, PhD, Infection Prevention and Surveillance Service, Royal Melbourne Hospital, Melbourne Victoria Australia

Corresponding author:

Prof Kirsty Buising, Victorian Infectious Diseases Service, Royal Melbourne Hospital, Grattan St. Parkville Victoria Australia,

Phone: 61 3 93427000,

Email: kirsty.buising@mh.org.au,

Running title: Air cleaners and aerosol transmission in hospitals

Word count: 2998

Abstract

Objective

To study the airflow, transmission and clearance of aerosols in the clinical spaces of a hospital ward that had been used to care for patients with COVID-19, and to examine the impact of portable air cleaners on aerosol clearance.

Design

Observational study.

Setting

A single ward of a tertiary public hospital in Melbourne Australia.

Intervention

Glycerine-based aerosol was used as a surrogate for respiratory aerosols. The transmission of aerosols from a single patient room into corridors and a nurses' station in the ward was measured. The rate of clearance of aerosols was measured over time from the patient room, nurses' station and ward corridors with and without air cleaners (also called portable HEPA filters).

Results

Aerosols rapidly travelled from the patient room into other parts of the ward. Air cleaners were effective in increasing the clearance of aerosols from the air in clinical spaces and reducing their spread to other areas. With two small domestic air cleaners in a single patient room of a hospital ward, 99% of aerosols could be cleared within 5.5 minutes.

Conclusion

Air cleaners may be useful in clinical spaces to help reduce the risk of healthcare acquired acquisition of respiratory viruses that are transmitted via aerosols. They are easy to deploy and are likely to be cost effective in a variety of healthcare settings.

COVID-19 presents a major global health challenge, with extraordinary clinical, societal and economic impacts. While initially there may have been controversy on the role of airborne transmission, now most authorities suggest that transmission of SARS-CoV-2 (the virus causing COVID-19) can occur via contact, droplet and/or airborne routes depending on the circumstances.¹⁻⁸ The different mechanisms of transmission likely arise due to variation in the size of respiratory particles generated, which depends on a number of factors including, but not limited to, the site of primary infection (lower vs upper respiratory tract), exposure to aerosol generating procedures (e.g.; nebulizer use) or aerosol generating behaviours of the source (e.g.; coughing, shouting, singing).⁹⁻¹⁶ The context is also likely to be very important, for example, airborne transmission may be more likely to occur where there are several infected people (sources) in a confined space with a limited clearance of aerosolised particles due to poor ventilation.¹⁷⁻¹⁹

In many countries, an increased risk of infection with SARS-CoV-2 has been reported amongst frontline healthcare workers. At the Royal Melbourne Hospital, 271 healthcare workers acquired COVID-19 infection, and the consequent epidemiologic and genomic investigation suggested that most of these were healthcare acquired.²⁰ Clinicians observed that transmission to healthcare workers seemed to be more common when the number of concurrent COVID-19 infected patients in a given ward was high, and in association with particular behaviours (e.g.; shouting or persistent cough). Staff without patient contact were also noted to become infected, especially if they spent prolonged times in the ward (namely corridors and nurses' stations), but not necessarily in the patient rooms. The high rate of staff infection raised concern about possible aerosol transmission, so staff within the wards were required to wear N95/P2 masks rather than surgical masks in mid-July ahead of state and national guidance. A group of multidisciplinary researchers from engineering, aerosol science, virology, infection prevention, and infectious diseases and respiratory medicine was convened to discuss what was known about aerosol transmission of SARS-CoV-2 in July 2020 and met weekly thereafter. As new evidence emerged to support that hypothesis, the focus quickly moved to considering what mitigation strategies could be used in a clinical space to reduce risks for staff, including the value of portable air cleaners.²¹⁻²⁹ This study aimed to trace airflow and the movement of aerosolized particles within a ward where known COVID-19 patients had been cared for and transmission to staff had occurred, and to document the effectiveness of air cleaners in reducing airborne particle concentrations.

Methods

Setting

The Royal Melbourne Hospital is a university affiliated tertiary hospital with 550 acute and 150 subacute (rehabilitation, geriatric medicine) inpatient beds. The hospital has cared for the largest number of inpatients with COVID-19 in Australia to date, namely 525 inpatients, with a peak of 99 concurrent inpatients, in August 2020. The infectious diseases ward has 14 Class N negative pressure rooms with anterooms. In 2020, as the number of concurrent inpatients with COVID-19 infection climbed and the capacity of the infectious diseases ward was exceeded, five other medical and surgical wards were progressively converted to “COVID wards”. All staff entering the wards were required to wear PPE, namely long sleeved gowns, gloves, eye protection (full face shield) and N95/P2 mask, including while in patient rooms, corridors and nurses’ stations. Many patients with COVID-19 who were cared for in these wards were elderly and required high levels of nursing care. Due to patient frailty, the doors to patient rooms sometimes stayed open to provide appropriate supervision.

In December 2020, the research team had full access to one empty ward that had previously been used to care for COVID patients (and where staff acquisitions had occurred), to conduct in-situ experiments assessing airflow and aerosol clearance. This ward has a long central corridor and 11 rooms, which usually accommodate 25 patient beds (four single rooms with own ensuite bathroom and seven three-bed shared rooms each with a shared ensuite bathroom). When the ward was occupied, patients were predominantly cared for with one patient per room and the peak concurrent number of patients in that ward was 15. The nurses’ station is situated halfway along the corridor, directly opposite two single rooms. No rooms in this ward have negative pressure, and the ward has its own closed, ducted heating, ventilation and air conditioning (HVAC) system delivering 12 air changes per hour. No windows in the ward can be opened, and the return air vent for the whole ward is above the single entrance and exit point to the ward (just inside the door to the ward). Rooms all have doors, which have a small gap at the bottom (approximately 5cm) to allow air egress. One of the single patient rooms with a room floor space of 12.8 m² and volume of approximately 37 m³ was selected for the study. The corridor outside the room was approximately 2 m wide, and the patient room was directly opposite the open nurses’ station, which had a front desk with entrance spaces on either side.

Study design

This study was an intervention study that investigated the air flows of aerosols from a room used for the care of patients with COVID to the corridor and the nursing station in that clinical ward. This was studied by flooding the space with a glycerine-based smoke and video recording the pathways taken by visible smoke, as well as monitoring changes in aerosol levels over time in the room and adjacent spaces. The effect of portables air cleaners on the rate of clearance of air particles in these areas was also examined.

Intervention

For each experiment, glycerine-based aerosol (smoke) with a mean aerosol size of 1 μm was injected for 15 seconds into the patient room to ‘flood’ the air space with ‘smoke’. The glycerine-based aerosol's size distribution was measured to confirm that the particle sizes of this smoke roughly approximate the sizes of SARS-CoV-2 infectious aerosols measured in the air of hospitals elsewhere ($<1 \mu\text{m}$) and this was used as a surrogate to replicate respiratory aerosol movement and airborne transmission³⁰. This type of smoke testing forms part of the indoor air assessment industry standard accepted processes for assessing airflows. Once injected, smoke was permitted to mix and visibly fill all corners of the room, which took approximately 30 seconds. The visible pathways of travel of the smoke within the patient room, corridor and nurses’ station were then observed and video recorded.

The sensors used in this experiment to measure aerosols were the TSI DustTrak DRX 8533, (called a “DRX”), and the TSI DustTrak II 8530, (called a “DRII”). The DustTrak sensors measured aerosol concentration using a combination of particle cloud and single particle detection to measure the mass concentration of aerosols per unit volume. The DustTrak’s sensors were both fitted with an identical 2.5 μm inlet that only allowed aerosols 2.5 μm or smaller to pass through. The DRII was placed inside the patient room (or corridor) and the DRX was placed in the nurses’ station to determine the amount of aerosol that could move through the corridor or across into the nurses’ station. Both devices were calibrated by the manufacturer pre study. While the DRX in addition has the ability to detect masses in different aerosol size bins, for this study we used only the common mass observation of aerosols $<2.5\mu\text{m}$ in size for both the DRX and DRII. Side-by-side and zero calibrations assured us that the DRX and the DRII provided identical observations under the same conditions

The air cleaners used were domestic appliances (SamsungTM AX5500K) equipped with H13 HEPA filters capable of filtering 99.97% of particles at a Clean Air Delivery Rate of 467 m³/hr on the highest fan speed setting. Based on laboratory testing, for the size of the hospital room and the capacity of the air cleaner selected, two air cleaners were used and were placed along the patient's bedside and foot of the bed.

Measurements:

Measurements were taken concurrently in the single patient room, and at the nurses' station at 10-second intervals until the aerosols cleared. This was reported as the normalised and absolute aerosol concentration decay over time.

Intervention tests included the following:

- Effect of installation of portable air cleaners in the patient room vs usual HVAC on aerosols within and external to the room
- Effect of patient room door open vs door closed on aerosols outside the room
- Effect of installation of variable number of portable air cleaners in the corridor on aerosols in the corridor
- Effect of installation of different barriers to enclose the nurse's station on aerosols in within the nurses' station

Outcomes:

The effects of each intervention were assessed as changes in the clearance rate of aerosols from the space. For example, the time taken to clear the patient room and the nurses' station from aerosols under existing HVAC settings at an air change rate of 12 times per hour was compared to the time taken when air cleaners were placed in the patient room. The time taken to clear the aerosols from the patient room and the nurses' station opposite was measured when the patient room had the door open and when the door was closed, for comparison. The impact of additional protections for the nurses' station included when the nurses' station was protected by an air cleaner "barrier" or a plastic ZipwallTM. An air cleaner "barrier" consisted of three air cleaners lined up 1m apart directly in front of the desk. The ZipWallTM is a clear plastic barrier that was erected in front of the desk, sealed at the ceiling and walls on either side, with a magnetised self-closing door for people to enter and exit the space.

Measurements of aerosol clearance were also taken in the corridor of the ward which was approximately 50m long, and 2m wide. The corridor was flooded with smoke and the rates of

clearance of aerosols were compared with different numbers of air cleaners positioned along its length to identify the optimum number of air cleaners for that space.

Results

At baseline, the air in the patient room had negligible demonstrable aerosols, and after smoke flooding was applied, the entire room was rapidly and visibly filled with smoke. During the tests with the patient room door closed, within the first minute after the room was flooded with smoke, smoke was observed to escape under the gap at the bottom of the door and move along the corridor towards the return air vent at the entrance of the ward. When the door to the patient room was opened, smoke was observed to immediately move out to the corridor and travel along the corridor to the return air vent.

Using measurements within the patient room, at usual HVAC settings, and with a closed door it took 16 minutes for the aerosols in the patient room to clear back down to 1% of the baseline maximum measurable by the instruments. The concentration of aerosols concurrently reaching the nurses' station even when the patient room door was closed were high and decreased at the same rate as aerosols inside the room. The relative amount of aerosols in the nurses' station compared to the patient room was highly variable representing 25-50% of the room's concentration with the door closed using two air cleaners. When two air cleaners were placed in the patient room with the door closed or open, the room cleared of 99% aerosols in 5.5 minutes – a 67% reduction compared with no air cleaners – and the smoke at the nurses' station cleared even more quickly, at under 3 minutes (Figure 1). Having the bathroom door open with exhaust fan running made a negligible difference to the clearance time (~50 seconds, and within the variability of the observations).

When the door to the patient room was opened, high levels of aerosols had crossed the corridor and entered the nurses' station at baseline measurement, as the air cleaners were used in the patient room the aerosols cleared from the nurses' station over 4 minutes. When the door to the patient room was closed, and air cleaners were used in the patient room, very low levels of aerosol were detectable at the nurses' station at baseline and 99% of these cleared within approximately 2 minutes (Figure 2)

Two different barriers were tested to determine the most effective way to provide protection to the nurses' station. When the air cleaner barrier was used, negligible smoke particles from the patient room were measured at the nurses' station (Figure 3). Similarly the ZipWall™ substantially reduced the ability of the aerosolized smoke particles from entering the nurses' station (Figure 3).

When the corridor was flooded with smoke, between 4 and 12 air cleaners were evenly spaced along its length. Adding extra air cleaners did not increase the clearance much beyond that which was achieved with 8 air cleaners, which achieved 99% clearance in 5 minutes (Figure 4).

Discussion

This study demonstrated that the existing ward HVAC system alone was quite poor at clearing a patient room of aerosols, and suggests that commercially available air cleaners may have a role in clearing aerosolised particles that may contain respiratory viruses, such as SARS-CoV-2, in clinical environments. We found that the actual 99% clearance of aerosols from the air in patient rooms using existing HVAC alone at 12 air exchanges/hour was quite slow. Aside from isolation rooms, HVAC systems in hospitals and other places are designed for comfort rather than infection control. It may be worth noting that air exchange rates of 2 would not be uncommon in an office environment. In an Australian hospital environment 6 air exchanges/hour is the standard, and 10 has been suggested for wards managing COVID-19 patients. These data demonstrate that the relationship between reported air exchanges and actual aerosol clearance from rooms is not predictable, probably because it does not account for flow recirculation regions or other air flow anomalies. Theoretically, to clean 99% of the air of a well-mixed room in under 10 minutes would require the same air exchange equivalent to air exchanges of 30/hour.³¹ For context, typical operating theatres have 20 air exchanges/hour,^{32,33} and there is advice to wait for 5 full air exchanges (18 minutes for 99.3% clearance) until staff can enter without airborne precautions where necessary.³⁴ Air exchanges greater than 30 are impossible to achieve with the typical hospital ward HVAC systems alone, but not difficult with air cleaners.

Our data suggest that any air that enters a patient room needs to travel to reach a return air vent. In some cases, return air vents are placed in the patient room or in the ensuite bathroom. In the ward we studied, the position of the return air vent meant that air was leaving the patient room and travelling along the corridor. It is important to understand where and how air exits a patient's room so that the path of least resistance for air to travel from the patient to the return air vent can be considered when patients are placed on a ward. On the ward studied, the preference would now be to utilise rooms close to that air return for higher risk patients (e.g.; earlier in their illness, actively coughing) where possible. These findings also confirmed that the doors to the patient rooms should be kept closed wherever possible to protect areas outside the recognised patient zone, appreciating that air and the aerosols

carried in it may still travel. This study showed that air cleaners in the patient room limit how much aerosol is likely to escape into the corridor or nurses' station, which likely provides protection for staff. It also showed that air cleaners placed along the corridor should be considered (in addition to cleaners in the patient room) if the ward was filled with patients infected with SARS-CoV-2, again to help clear the air of potentially infected aerosols that may have escaped from the patient's room. Finally a physical barrier, such as a ZipWall™, may provide additional protection for the staff if they spend time at a workstation. Importantly this work used glycerine based aerosol as a proxy for respiratory aerosols that contain live virus. Extrapolation must be made from other studies in which viral RNA or culturable virus has been identified in aerosols from clinical spaces caring for people with SARS-CoV-2 infection.^{26, 27, 29, 35} Nevertheless, it demonstrates that aerosols of the same size as respiratory particles can travel long distances. Viral transmission via aerosols is likely to be very variable, both between patients, and at different times in a given patient's infection course and may be impacted by other factors such as relative humidity and temperature.³⁶ We hypothesise that if multiple patients are in a given confined space, each producing some respiratory particles, then the density of infectious aerosols in the air may become high enough to put staff at increased risk of acquisition via aerosols, even in corridors or nurses' stations of dedicated COVID-19 wards. Given that the air cleaners remove aerosols from the air before it leaves the patient room, it is likely that they would help protect staff inside and outside the patient room. These air cleaners are a relatively low cost, readily implementable mitigation strategy that should be considered in clinical spaces. These findings may also have implications outside healthcare institutions that warrant further investigation.

Conclusion

Despite exceeding recommended air exchange rates for a hospital, the HVAC alone did not effectively remove aerosols from the clinical space in a timely matter. In addition, depending on the location of the return air duct, the existing HVAC system promoted the dispersal of aerosols beyond the patient room. However, we were able to demonstrate that relatively low-cost air cleaners could dramatically increase the clearance rate of aerosols. Air in clinical spaces does travel, and with it any respiratory aerosols containing potentially infectious virus. An understanding of directional airflow is important to help limit the risk to staff, and will likely be different in different spaces. Air cleaners enabled the air to be cleaned locally, providing protection equivalent to >30 air exchanges/hour to staff in common areas, far in excess of current best practice guidelines for hospital indoor air ventilation rates. Based on the findings of this work, the hospital studied has adopted air cleaners for use in rooms of patients with suspected or confirmed COVID-19, with appropriate policies, procedures and training to ensure their safe and effective use.

Acknowledgements

Financial support: The work was funded by The Royal Melbourne Hospital

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article

References

1. World Health Organization. Transmission of SARS-CoV-2: implications for infection prevention precautions <https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions> Accessed March 27, 2021.
2. Shiu EY, Leung NH, Cowling BJ. Controversy around airborne versus droplet transmission of respiratory viruses: implication for infection prevention. *Curr Op Infect Dis* 2019; 32: 372-9.
3. Morawska L, Cao J. Airborne transmission of SARS-CoV-2: the world should face the reality. *Environ Intern* 2020 Jun;139: 105730. doi: 10.1016/j.envint.2020.105730
4. Tang S, Mao Y, Jones RM, et al. Aerosol transmission of SARS-CoV-2? Evidence, prevention and control. *Environ Intern* 2020; 144: 106039.
5. Dancer SJ, Tang JW, Marr LC, Miller S, Morawska L, Jimenez JL. Putting a balance on the aerosolization debate around SARS-CoV-2. *J Hosp Infect* 2020; 105: 569-70
6. Tang JW, Bahnfleth WP, Bluysen PM, et al. Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus (SARS-CoV-2). *J Hosp Infect* 2021; 110:89-96.
7. Asadi S, Bouvier N, Wexler AS, Ristenpart WD. The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles? *Aerosol Sci Technol* 2020; Apr 3;0(0):1-4.
8. Morawska L, Milton DK. It is time to address airborne transmission of coronavirus disease 2019 (COVID-19). *Clin Infect Dis* 2020; 71: 2311-3.
9. Fennelly KP. Particle sizes of infectious aerosols: implications for infection control. *Lancet Resp Med* 2020 Sep;8(9):914-924.

10. Somsen GA, van Rijn C, Kooij S, Bem RA, Bonn D. Small droplet aerosols in poorly ventilated spaces and SARS-CoV-2 transmission. *Lancet Resp Med* 2020; 8: 658-9
- 11 Bahl P, de Silva C, Bhattacharjee S, et al. Droplets and Aerosols Generated by Singing and the Risk of Coronavirus Disease 2019 for Choirs. *Clin Infect Dis* 2020 Sep 18;ciaa1241. doi: 10.1093/cid/ciaa1241.
12. Meyerowitz EA, Richterman A, Gandhi RT, Sax PE. Transmission of SARS-CoV-2: a review of viral, host, and environmental factors. *Ann Intern Med* 2021 Jan;174(1):69-79.
- 13 Edwards DA, Ausiello D, Langer R, et al. Exhaled aerosol increases with COVID-19 infection, and risk factors of disease symptom severity. *medRxiv* 2020
- 14 Mürbe D, Kriegel M, Lange J, Schumann L, Hartmann A, Fleischer M. Aerosol emission of adolescents voices during speaking, singing and shouting. *Plos One* 2021 Feb 10;16(2):e0246819.
15. Echternach M, Gantner S, Peters G, et al. Impulse Dispersion of Aerosols during Singing and Speaking: A Potential COVID-19 Transmission Pathway. *Am J Resp Crit Care Med* 2020; 202: 1584-7
16. Morawska L, Johnson G, Ristovski Z, et al. Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *J Aero Sci* 2009; 40: 256-69.
17. Bourouiba L. Turbulent gas clouds and respiratory pathogen emissions: potential implications for reducing transmission of COVID-19. *JAMA* 2020; 323: 1837-8
18. Hamner L. High SARS-CoV-2 attack rate following exposure at a choir practice—Skagit County, Washington, March 2020. *MMWR Morbidity and mortality weekly report* 69 2020 May 15;69(19):606-610.
19. Morawska L, Tang JW, Bahnfleth W, et al. How can airborne transmission of COVID-19 indoors be minimised? *Environ Int* 2020 Sep;142:105832.

20. Buising KL, Williamson D, Cowie BC, et al. A hospital-wide response to multiple outbreaks of COVID-19 in health care workers: lessons learned from the field. *Med J Aust* 2021 Feb;214(3):101-104.e1.
21. Islam MS, Rahman KM, Sun Y, et al. Current knowledge of COVID-19 and infection prevention and control strategies in healthcare settings: A global analysis. *Infect Cont Hosp Epi* 2020; 41: 1196-206.
22. Goldman E. Exaggerated risk of transmission of COVID-19 by fomites. *Lancet Infect Dis* 2020; 20: 892-3
23. Liu Y, Ning Z, Chen Y, et al. Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. *Nature* 2020; 582: 557-60.
24. Setti L, Passarini F, De Gennaro G, et al. Airborne transmission route of COVID-19: why 2 meters/6 feet of inter-personal distance could not be enough. *Int J Env Res Pub Health* 2020 Apr 23;17(8):2932.
25. Sommerstein R, Fux CA, Vuichard-Gysin D, et al. Risk of SARS-CoV-2 transmission by aerosols, the rational use of masks, and protection of healthcare workers from COVID-19. *Antimicrob Resist Infect Cont* 2020; 9: 1-8.
26. Guo Z-D, Wang Z-Y, Zhang S-F, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. *Emerg Infect Dis* 2020; 26: 1586.
27. Chia PY, Coleman KK, Tan YK, et al. Detection of air and surface contamination by SARS-CoV-2 in hospital rooms of infected patients. *Nature Comm* 2020; 11: 1-7.
28. Santarpia JL, Rivera DN, Herrera VL, et al. Aerosol and surface contamination of SARS-CoV-2 observed in quarantine and isolation care. *Scient Rep* 2020; 10: 1-8.

29. Lednicky JA, Lauzard M, Fan ZH, et al. Viable SARS-CoV-2 in the air of a hospital room with COVID-19 patients. *Int J Infect Dis* 2020; 100: 476-82.
30. Birgand G, Peiffer-Smadja N, Fournier S, Kerneis S, Lescure F-X, Lucet J-C. Assessment of Air Contamination by SARS-CoV-2 in Hospital Settings. *JAMA Network Open* 2020; 3: e2033232-e.
31. Centers for Disease Control and Prevention C. Healthcare Infection Control Practices Advisory Committee (HICPAC): Guidelines for Environmental Infection Control in Health-Care Facilities, 2003. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_hcf_03.pdf
Accessed March 26th, 2021
32. The Victorian Department of Health and Human Services. Design guidelines for hospitals and day procedure centres. Part E - Building services and environmental design. 2004. Available from <http://www.healthdesign.com.au/vic.dghdp/> Accessed March 20th 2021.
33. Cook T, Harrop-Griffiths W. Aerosol clearance times to better communicate safety after aerosol-generating procedures. *Anaes* 2020; 75: 1122-3.
34. Cook T, El-Boghdadly K, McGuire B, McNarry A, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19. *Anaes* 2020 Jun;75(6):785-799.
35. Zhou L, Yao M, Zhang X, et al. Breath-, air- and surface-borne SARS-CoV-2 in hospitals. *J Aerosol Sci* 2021 Feb;152:105693.
36. Memarzadeh F. Literature Review of the Effect of Temperature and Humidity on Viruses. *ASHRAE Transact* 2012; 118(1): 1049-1060.

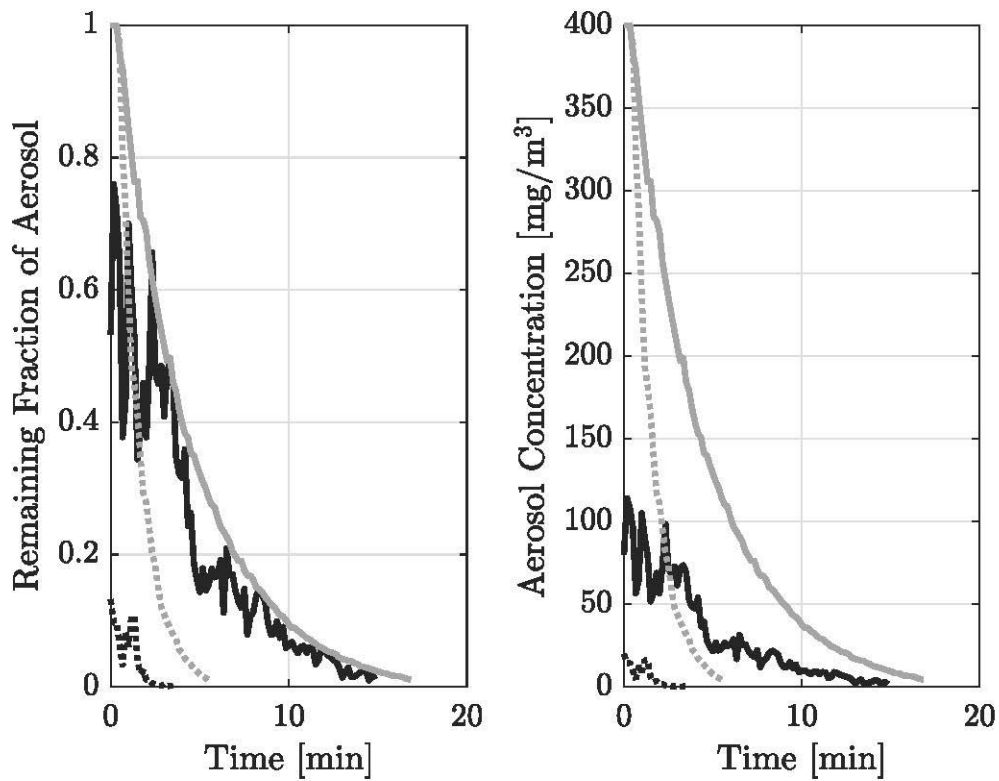


Figure 1: The effect of no air cleaners versus 2 air cleaners on aerosol clearance and transmission of aerosols within a patient room with the door closed.

Left image shows the values normalized to the saturation value of the sensor whereas right shows the measured value.

Grey solid line = measures taken within the standard patient room,

Black solid line = measures taken at nurses' station (NS).

Grey dotted line = measures taken within the patient room with 2 air cleaners running.

Black dotted line = measures taken at NS when the 2 air cleaners were in the patient room.

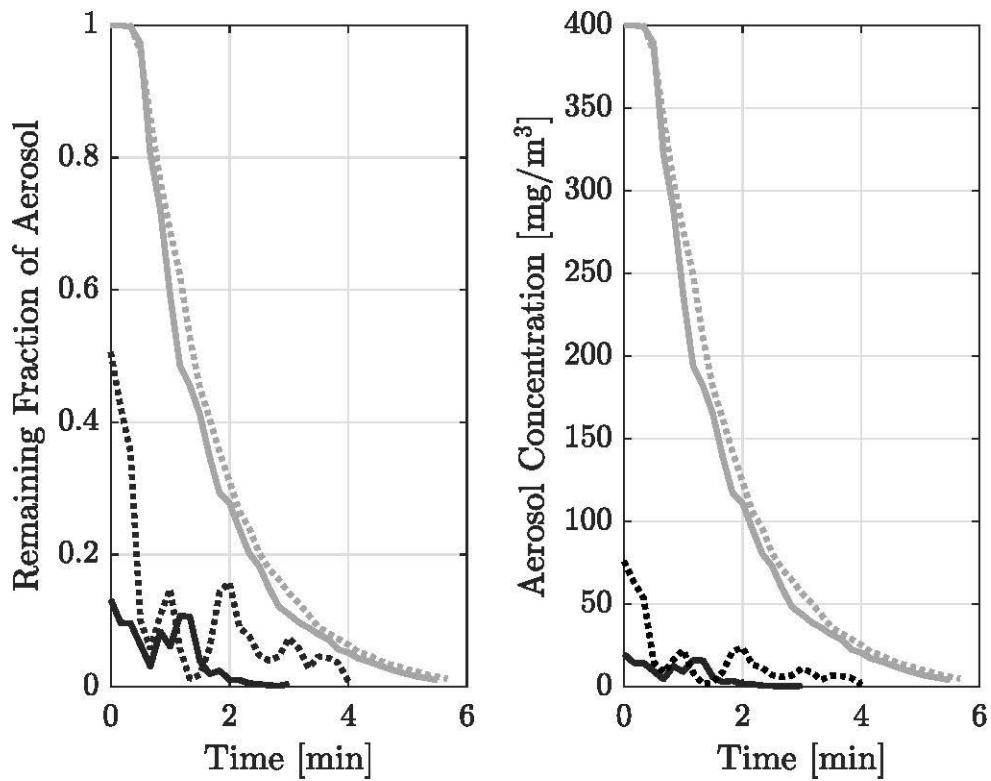


Figure 2: The effect of open vs closed door to patient room on aerosol clearance and transmission of aerosols.

Left image shows the values normalized to the saturation value of the sensor whereas right shows the measured value.

Note that the measurements were taken with 2 air cleaners in the patient room.

Grey solid line = measures taken within the patient room with door to the corridor closed.

Black solid line = measures taken at the nurses' station (NS) when the door was closed.

Grey dotted line = measures taken within the patient room with door to the corridor open.

Black dotted line = measures taken at the nurses' station (NS) when the door was open.

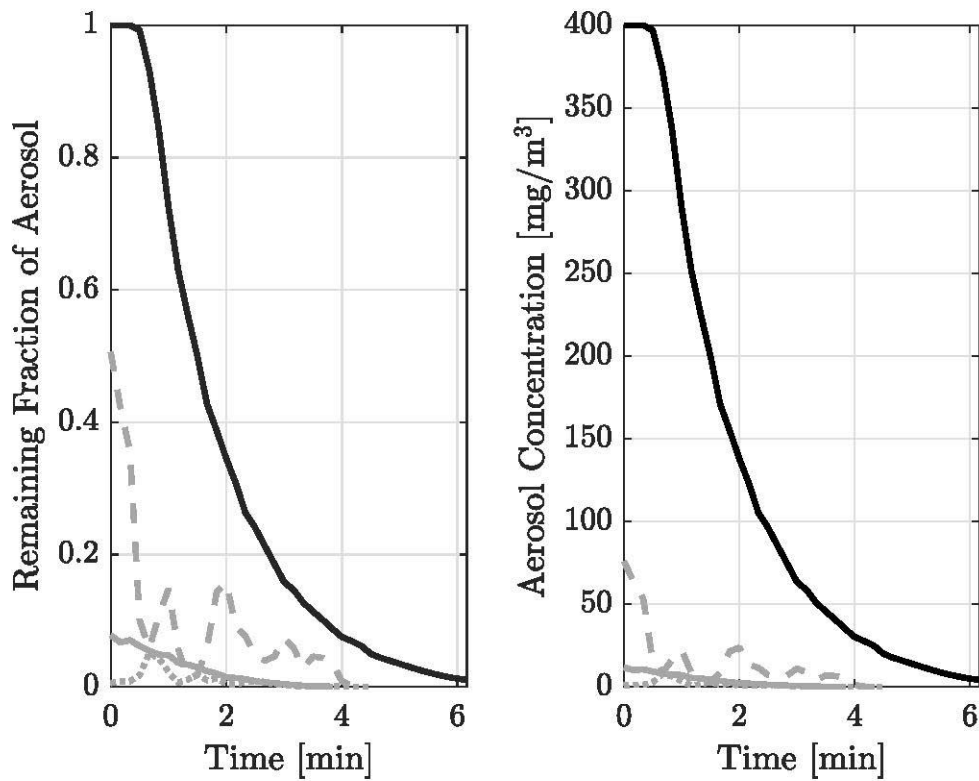


Figure 3: Comparing different interventions at the nurses' station on aerosol clearance and transmission of aerosols.

Left image shows the values normalized to the saturation value of the sensor whereas right shows the measured value.

Note that the measurements were taken with 2 air cleaners in the patient room.

Black solid line = measures taken within the patient room.

Grey solid line = measures taken at the nurses' station (NS) with Zipwall™ present.

Grey dashed line = measures taken at NS without barrier.

Grey dotted line = measures taken at NS with air cleaner barrier present (3 air cleaners in front of desk).

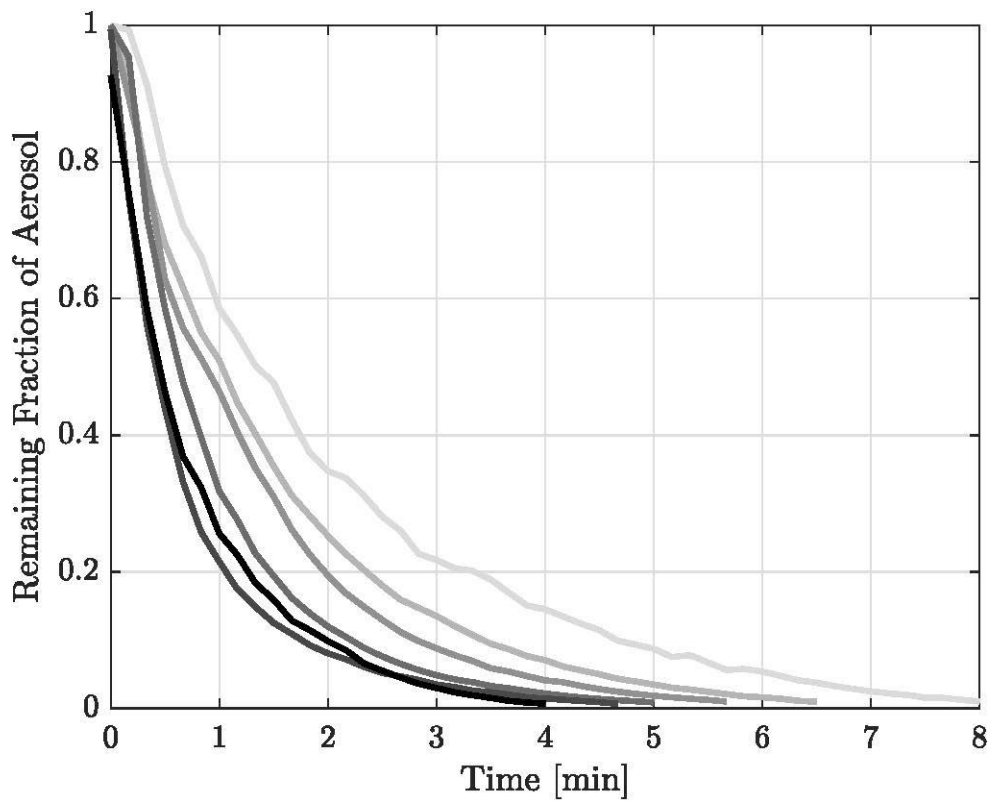


Figure 4: Rate of clearance of aerosolized smoke particles in the corridor with differing numbers of air cleaners. Note that some sources also called these “Portable HEPA filters”. Line color goes from light to dark for cases with progressively more air cleaners, with 0, 4, 6, 8, 10, and 12 evenly spaced air cleaners considered in the corridor.

Supplemental Material

Supplementary figures

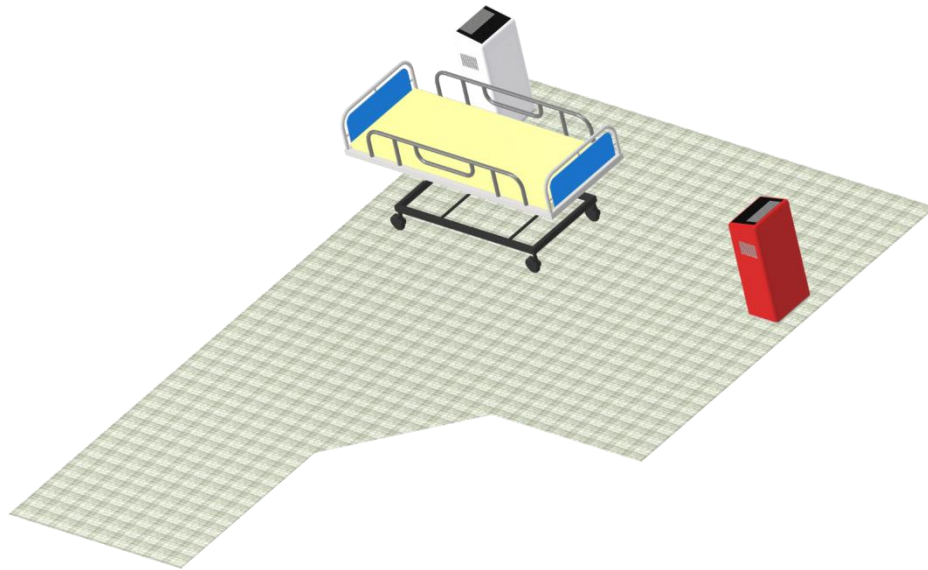


Figure S1: Isometric view of a computer rendering of the single patient room. Room entry would be from the lower left hand corner of the image.

The white air cleaner (or portable HEPA filter) is the one on the patient bedside and the red air cleaner (portable HEPA filter) is flush with the wall

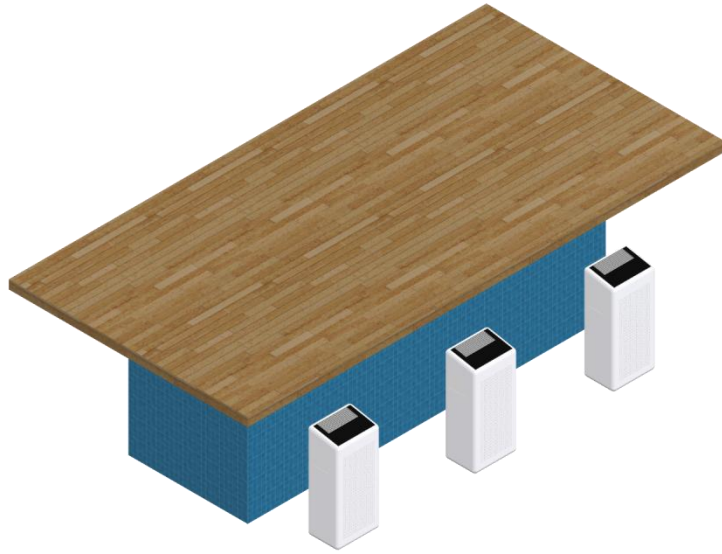


Figure S2: Isometric view of a computer rendering of the air cleaner barrier in front of the nurses' station table.



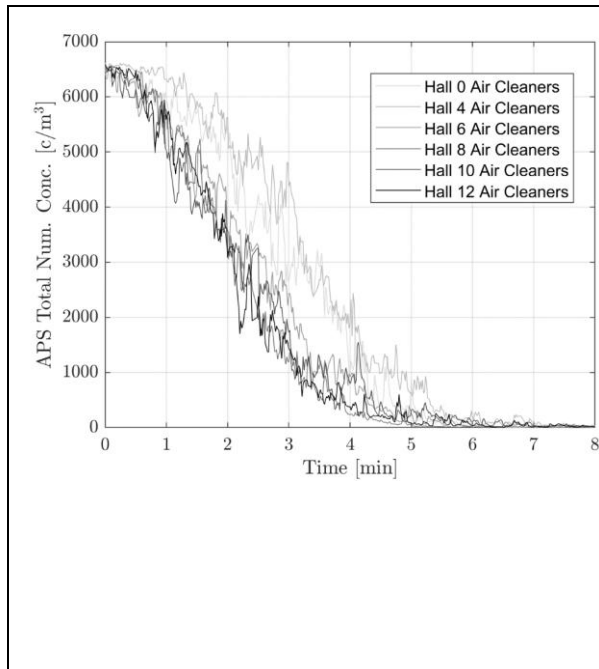
Figure S3: Photo of installed ZipWall™ at nurses' station



Figure S4: Comparison of smoke exiting the patient room with the door closed (left) and open (right).

Note that the figures were taken at approximately the same time after the room was flooded with smoke.

S5a



S5b

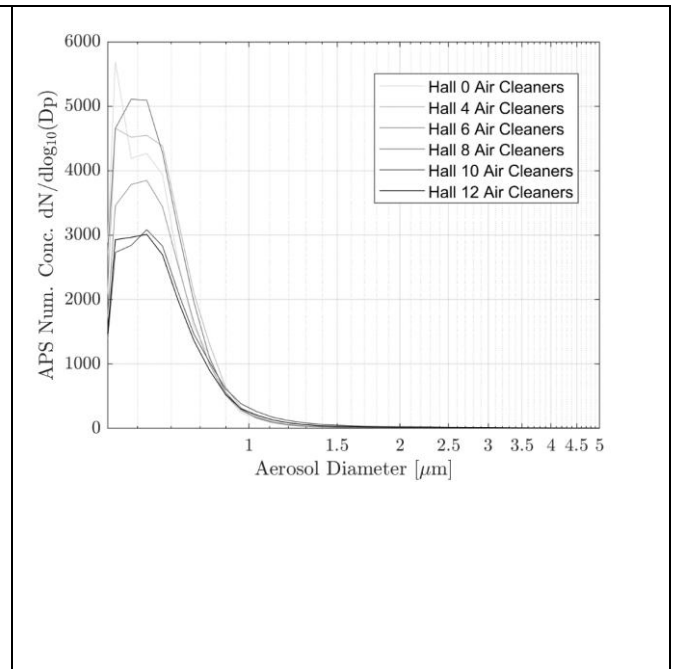


Figure S5: Aerodynamic Particle Sizer™ (APS) particle number size distribution observations for the variable number of air cleaners during corridor clearance experiment. S5a is the same as 4b but showing the APS observed number concentrations S5b shows the APS observed size number concentrations.