Could Air Filtration Reduce COVID-19 Severity and Spread?

Blake Elias and Yaneer Bar-Yam
New England Complex Systems Institute
March 9, 2020

Abstract

We speculate that using air filtering near a coronavirus patient may reduce the viral load in the environment sufficiently to decrease the probability of health care worker infection through flaws in Personal Protective Equipment (PPE). Further, we speculate that a significant mode of disease progression occurs through lung tissue re-infection through air circulation in the environment of the patient. The natural load of disease transmission from one individual to another through the air could serve as a mechanism of self re-infection, expanding the infection across multiple regions of lung tissue. Motivated by this speculation, it may be possible that reduction of the viral load in the environment would lead to substantial decrease of the severity of individual disease. Moreover, it may be possible to enhance this effect through breathing exercises that exhale contaminated air in the lung, decreasing further the viral load inside the lung and its ability to cross contaminate other parts of lung tissue. Finally, it may also be possible to use tubes inserted in the mouth or lung to suction contaminated air, to decrease the severity of disease. These speculations deserve attention because of the dramatic risks that we face. Rapid action on evaluating the validity of these ideas seems vital.

I. Introduction

It is well known that even meticulous observation of protection protocols do not always protect individuals, including health care workers, from contagion. As part of an effort to identify innovations that may help fight the Coronavirus outbreak, we propose considering the possibility that deploying commercial or industrial portable air purifiers with HEPA or ULPA air filters may help reduce the probability of contagion of the SARS-CoV-2 virus in locations where contact among people who have unknown or known risk are needed. Air filters are known to reduce the airborne presence of viral particles. The reduction of airborne particles by collection in the air filters should also reduce the deposition of viral particles on surfaces that are necessarily or inadvertently touched. Their use may reduce the risks that are present due to gaps in Personal Protective Equipment (PPE), reducing the probability that even careful individuals will become infected. While this approach appears promising, additional theoretical and empirical analysis is needed of the dynamics of air flows in the presence of such filters as the air mixing may cause multiple desirable and undesirable effects. These can include inhomogeneous flows that concentrate deposition of particulates in certain parts of the room and disturb clothing and masks that are part of PPEs. Testing of the quality of the air and viral load on surfaces with and without such filters is needed. We describe a number of critical topics, ranging from hospital rooms to transportation vessels such as cruise ships, which might benefit from air filtration. This speculative brief aims to provoke discussion and novel thought, around this and other unconventional approaches that may help slow the current outbreak.

More speculatively, it is possible that recirculation of viral particles breathed out by a patient in the air and then breathed in may contribute to the severity of their disease. Filtering the air around a patient may reduce the viral load in their lungs decreasing the level of immune system activity that is needed for defeating this disease. Deploying air purifiers in the vicinity of a patient may thus lead to reduced severity of disease and improved outcomes. In this context, encouraging breathing that expels viral particles may further help.

In this brief, we invite discussion on what role air filtration technology (i.e. HEPA and ULPA filters) could play in damping the rate of viral spread. We propose a diverse range of scenarios where air filtration might be deployed, and seek the community's comments on these deployment scenarios or others that may warrant investigation. This work is highly speculative, with the aim of pointing to a novel space of approaches receiving little attention. We claim that more investigation into some or all of these areas may be warranted, and seek to engage a large cross section of community participants in conceiving and investigating under-explored approaches.

A. *Air Filtration Capabilities*

Fluid droplets from the cough or sneeze of an infected patient are typically 5 microns ($5 * 10^{-6}$ m) or larger.[*] HEPA filters reliably capture particles of this size, assuming the particle reaches the filter (these filters capture 99.97% of particles that are 0.3 microns in diameter, with efficiency increasing for both smaller and larger particles).[†]

The smallest particle we might be concerned with is a single virion (unattached to any fluid droplet), having diameter of approximately 0.12 microns.[‡] While these are also conceivably filterable by a HEPA filter, ULPA (Ultra-Low Penetration Air) filters are even better, catching 99.99% of particles 0.12 microns and above.† In theory all SARS-CoV-2 virions could be filtered and captured, assuming they can be brought into contact with an air filter.

This points to the possibility of reducing the contamination of a room or space, by cycling air through a HEPA or ULPA filter, so as to catch as many virus particles as possible before they attach to a surface. Some viral particles that have already attached to surfaces, might be removed as well. It may even be possible to continuously aerosolize particles that are sitting on surfaces, using fans or vacuums, for the explicit purpose of capturing them via air filtration — rather than relying

[*] https://www.envirosafetyproducts.com/resources/dust-masks-whats-the-difference.html
[†] https://www.explainthatstuff.com/hepafilters.html
[‡] https://www.britannica.com/science/coronavirus-virus-group

on periodic and more difficult manual sterilization of those surfaces.

II. Deployment Scenarios

Given the viability of air filtration to capture virion particles, we invite discussion on whether air filters should be widely deployed immediately. To spark initial thoughts, we investigate deployment in the following scenarios:

- **Rooms with infected patients**
- **Air being exhaled from infected patients**
- The site of **any aerosol-generating procedure (AGP)**
- **Health care workers** treating infected patients
- **Hospital environments** more generally
- **Closed vehicles**, especially those used for transporting Patients Under Investigation (PUI).

A. Patient Rooms

Every patient with a known or suspected infection, whether in a hospital room or in self-quarantine, could have a portable air filter which they keep near or on their person at all times. They may leave it by their bedside while resting, and may carry it with them as they move around their room.

The Center for Disease Control is recommending[§] that all persons under investigation for COVID-19 be placed in an Airborne Infection Isolation Room (AIIR) — designated rooms in a hospital, connected to an HVAC system in such a way as to have negative air pressure [1]. **A critical question** (which we seek the community's help answering): **How many AIIRs are there in the United States? In the world?** Should there become a shortage of AIIRs relative to the number of patients who need them, a cleanroom-grade air filtration system can be used to **turn any room into a negative-pressure isolation room**.[¶] Even if there is not an imminent shortage of AIIRs, it may be desirable to purchase such filtration systems anyway, so as to have a surplus of "make-shift" AIIRs available. This could give hospitals more freedom to use these rooms preventatively — the ability to isolate more patients as a precaution, rather than having to reserve their AIIRs for patients with the most severe symptoms. As the CDC broadens its criteria[‖] for which symptoms warrant investigation for COVID-19 — and hence, broadens the set of patients it recommends confining to AIIRs — the demand for AIIRs will increase. We see it as likely that such rooms will become scarce quite soon, no matter how many there are — and the need for a rapid, inexpensive alternative to be quite high.

For example, one product description reads as follows:[**] "The IsoClean® is a portable, self-contained high efficiency particulate air (HEPA) filtration system designed to easily and economically create a negative pressure isolation room that will meet OSHA and CDC TB guidelines. The IsoClean® can be used as a positive pressure clean air recirculating system in clinics, waiting rooms, hospital emergency rooms and other confined areas or as a partial or complete exhausting system to create a negative pressure isolation room for possible use with patients known or suspected of having TB, SARS or other infectious diseases."

B. Aerosol-Generating Procedures (AGPs)

It is controversial whether SARS-CoV-2 is transmitted via aerosols [2]. As the outbreak spreads, the possibility for more diverse routes of infection increases. Additionally, certain medical procedures *can* cause virus particles to become airborne, known as "aerosol-generating procedures" (AGP) [3], [4], [5]. While the CDC recommends[††] that any AGPs be conducted inside of an AIIR, as discussed in Section II-A, the supply of AIIRs may become scarce. While Section II-A presents an alternative method for turning any room into an AIIR, even these may come into short supply — indicating that lower-cost air filtration methods may become necessary for those patients whose condition does not justify a fully-isolating AIIR environment, but on whom an AGP may need to be performed.

C. Patients' Exhalation

In addition to filtering air within a room, we also consider an individual patient's respiratory system as a potential region to filter.

After initial infection, the general pathway for any respiratory virus to propagate through the body is to hijack host cells to replicate the virus' genetic material. This leads to the formation of new virions, which further infect healthy tissue via either:

1) direct cell-to-cell transmission (remaining *internal* to the cellular structure)
2) by budding virions into the cellular environment which travel to other areas (*external* to the cellular structure) [6], [7], [8]

It is conceivable that much of the viral propagation of SARS-CoV-2 is due to virions which are released *external* to the cell, and subsequently are mobile within the respiratory system. We hypothesize this primarily due to the rate of spread of SARS-CoV-2 between individuals, and secondarily the speed at which the infection moves from the upper to lower respiratory tract, both of which seem less feasible if the primary pathway of pathogenesis was via cell-to-cell transmission. We hypothesize that a large proportion of the virion particles which pose the risk of spreading the infection (both within an individual and to others), are present in the *air within a patient's lungs*, and could potentially be removed via exhalation or vacuum suction, as opposed to being bound to the patient's cells. This may be quantifiable, at a crude scale, by applying vacuum suction to lung organoids infected with SARS-CoV-2, and measuring the quantity of viral particles which can be extracted.

We thus propose the possibility of slowing the process of pathogenesis by filtering the air a patient exhales. This can be accomplished as described in Sections II-A or , but also

[§] https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html
[¶] http://www.hepafilters.com/products-page/cleanroom-products/portable-isolation-room-filtration-sys/portable-isolation-room-filtration-system/
[‖] https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-criteria.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fclinical-criteria.html
[**] http://www.hepafilters.com/products-page/cleanroom-products/portable-isolation-room-filtration-sys/portable-isolation-room-filtration-system/
[††] https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html

points to the desirability of going more "direct to the source". A wearable, battery-operated HEPA filter could actively filter exhaled air, to prevent re-inhalation of viral particles. This active filtering of exhaled air could *remove* more viral particles as opposed to simply containing their spread. This stands in contrast to having patients wear surgical masks — which, while lowering the transmission of viral particles to the environment, may in fact come at the patient's expense by increasing the concentration of viral particles which they re-inhale.

It may be possible to implement breathing exercises for patients to actively expel viral particles, beyond what would naturally be exhaled. Furthermore, it may be possible to insert tubes into the mouth, trachea, or lungs to suction contaminated air. Suctioning has been widely used for removing mucous fluids when patients have trouble breathing due to congestion; however, we propose the possibility of suctioning even when mucous buildup is minimal.

If a large proportion of the viral particles which will continue infecting the patient are external to the cell surface, then it is conceivable that they could be moved upward through the lungs and airway via a combination of active breathing and mechanical suctioning. This could prevent their downward spread through the lungs, and even result in a reduction of the number of viral particles in the body. Such interventions could reduce the rate at which the infection spreads, reducing the amount of immune response needed to defeat the disease. Since the worst effects of COVID-19 come from the immune system's hyper-activity (cytokine storm) [9], [10], decreasing the viral load even by a small fraction might bring the level of immune response back into the regime where the body's immune system is able to effectively stop the infection.

The vast majority of individuals do have the appropriate immune capability to fight the disease, without devolving into cytokine storm. There is, however, a "long tail" of cases where this balance goes beyond its critical point. Hence we propose various ways to decrease the viral load at certain key junctures, with the hope that even a slight reduction in viral load may greatly shrink this long tail.

D. Health Care Workers

Besides health care workers' use of passive respirator masks (e.g. N95 or P100), or even powered, air-purifying respirators (PAPR),[‡‡] there is a question of whether additional filtration may be desirable for *surrounding* air. This could catch particles which may land on the hands, clothing, medical instruments, cell phones, tablets, pen and paper, or other objects the health care worker may use.

One of the highest-risk activities is the removal of contaminated PPE. Having an additional filter to purify surrounding air — not just the air being breathed — may reduce the amount of contamination of PPE and other objects and surfaces in the vicinity. The subtle, innocent pathways by which virus particles can "jump" from surface to surface (e.g. as illustrated here: https://twitter.com/covid_virus/status/1235228963741609990), prompt creative discussion as to the best way to stop such spread at the source.

E. Hospital environments

The above-described scenarios raise the question of whether treatment rooms, waiting rooms and corridors should have HEPA filtration installed rapidly. Empirical investigations of air viral loads and deposition patterns of viral particles on surfaces should be used to determine whether this approach has merit and the urgency for further testing and implementation. While hospital HVAC systems contain HEPA filtration, we propose that localized filtering in high-traffic spaces may further decrease the number of viral particles present.

A low-cost air purifier containing a HEPA filter can cost on the order of \$100 and circulate the air in a 155 square-foot room 5 times per hour (i.e. once every 12 minutes, or 120 times per day), and could be deployed widely in hospital environments. Hospitals may look into adding HEPA filters to more places in their HVAC systems, and for any existing HEPA filters, test their current efficiency and replace if needed. It may be worth taking any measures possible to increase airflow speed in existing HVAC systems, and to avoid recirculating air between rooms.

One open question is to what extent such filtration can capture virion particles clinging to solid surfaces. A negative pressure environment would do a lot to prevent particles from settling onto horizontal surfaces in the first place (though a horizontal projectile landing on a vertical surface may still have the ability to cling). And in other environments that do not justify the cost of a negative pressure system, it is still conceivable that measures could be taken to explicitly lift such particles into the air by applying additional force to stimulate air circulation (fans, vacuum suction, etc.)

F. Closed Vehicles

Taking any form of public transit poses an infection risk, be it via airline, bus, train or taxi-cab. There may be cause for installing portable air filtration in such transit vessels powered with batteries. Ambulances transporting potentially-infected patients may also be a critical locations for air filtration. Even private automobiles pose risk of person-to-person spread, if an infected person is driven to a hospital by a family member, and may be a place to explore the use of air filtration. Evaluation of which vehicles can benefit from air filtration by providing a more sterile environment, including both air and surfaces, would be a critical area of investigation.

III. Contributions and Future Work

Here, we propose several novel approaches to reduce the spread of COVID-19 with the use of air filtration, and invite others to pursue further inquiry.

This paper makes the following primary contributions:

- We noted that **air filtration can conceivably lower the amount of virus particles** from the environment, both from the air and potentially from surfaces.
- We have proposed the creation of **make-shift Airborne Infection Isolation Rooms (AIIR)**.

[‡‡]https://en.wikipedia.org/wiki/Powered_air-purifying_respirator

https://www.homedepot.com/p/Honeywell-True-HEPA-155-sq-ft-Allergen-Remover-Air-Purifier-HA106WHDV2/204390558?MERCH=REC-_-Pip_Alternatives_Non_HDhome-_-308820630-_-204390558-_-N

https://www.airsystems-inc.com/air-purification-news/air-quality/the-use-of-hepa-filters-is-vital-in-medical-facilities/

- We have proposed other environments where air filtration may be usable to decrease the number of viral particles present, spanning **transit vehicles and other hospital environments**.
- We have proposed using air filtration to **augment PPE for health care workers**, especially at the site of any aerosol-generating procedure.

We invite the community's input in the following areas:

- **Empirical investigations of air viral loads and deposition patterns** of viral particles on surfaces, to assess viability of the approaches presented in Section II which use air filtration within closed rooms.
- Estimating the number of AIIRs currently available, in the hope of determining what quantity of new make-shift AIIRs may need to be created, and at what level(s) of air purity (as proposed in II-A).
- **Quantifying the ability to remove viral particles from the lungs or airways**, to determine viability of the approach presented in Section II-C.

Our aim has been to surface approaches that have received little attention thus far. We intend for this briefing to prompt subsequent discussion into the viability of such approaches, and which scenario(s) may be worth further exploration. We call on the broader community to help answer the questions posed.

References

[1] Marko Hyttinen, Anna Rautio, Pertti Pasanen, Tiina Reponen, G Scott Earnest, Andrew Streifel, and Pentti Kalliokoski. Airborne infection isolation rooms–a review of experimental studies. *Indoor and Built Environment*, 20(6):584–594, 2011.

[2] Eunice YC Shiu, Nancy HL Leung, and Benjamin J Cowling. Controversy around airborne versus droplet transmission of respiratory viruses: implication for infection prevention. *Current opinion in infectious diseases*, 32(4):372–379, 2019.

[3] Khai Tran, Karen Cimon, Melissa Severn, Carmem L Pessoa-Silva, and John Conly. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. *PloS one*, 7(4), 2012.

[4] Jiayu Li, Anna Leavey, Wang Yang, Caroline O'Neil, Meghan Wallace, Adrianus Boon, Pratim Biswas, Carey-Ann D Burnham, and Hilary M Babcock. Defining aerosol generating procedures and pathogen transmission risks in healthcare settings. In *Open forum infectious diseases*, volume 4, pages S34–S35. Oxford University Press US, 2017.

[5] Robinson Sabino-Silva, Ana Carolina Gomes Jardim, and Walter L Siqueira. Coronavirus covid-19 impacts to dentistry and potential salivary diagnosis. *Clinical Oral Investigations*, pages 1–3, 2020.

[6] Anthony R Fehr and Stanley Perlman. Coronaviruses: an overview of their replication and pathogenesis. In *Coronaviruses*, pages 1–23. Springer, 2015.

[7] Tadanobu Takahashi and Takashi Suzuki. Function of membrane rafts in viral lifecycles and host cellular response. *Biochemistry research international*, 2011, 2011.

[8] Samuel Baron, Michael Fons, and Thomas Albrecht. Viral pathogenesis. In *Medical Microbiology. 4th edition*. University of Texas Medical Branch at Galveston, 1996.

[9] Kaijin Xu, Hongliu Cai, Yihong Shen, Q Ni, Y Chen, S Hu, J Li, H Wang, L Yu, H Huang, et al. Management of corona virus disease-19 (covid-19): the zhejiang experience. *Zhejiang da xue xue bao. Yi xue ban= Journal of Zhejiang University. Medical sciences*, 49(1):0, 2020.

[10] C Chen, XR Zhang, ZY Ju, and WF He. Advances in the research of cytokine storm mechanism induced by corona virus disease 2019 and the corresponding immunotherapies. *Zhonghua shao shang za zhi= Zhonghua shaoshang zazhi= Chinese journal of burns*, 36:E005, 2020.