PART 2: NON-ENGINEERING CONTROLS

A. High Efficiency Particulate Air (HEPA) Filtration Units

In A Clinic Without A Proper HVAC System
It is possible to modify the ACH without resorting to major structural renovations by using portable HEPA filtration units with the goal of increasing the ACH. These units should be capable of recirculating all or nearly all of the room air, and achieve the equivalent of **12 ACH** (the recommended minimum for an AIIR or workplace where AGPs are performed).

However, the effectiveness of the portable unit is also dependent on the following: 1.) configuration of the room, 2.) the furniture inside, 3.) persons in the room, and the 4.) placement of the unit relative to the contents and layout of the room.

How do we choose a HEPA filtration unit appropriate for our clinic?
It is important to note that the recommended floor area coverage of commercially available units for home use were calculated based on ACH of 3 to 5.

To approximate 12 ACH in your clinic, please do the following steps.
First, check if the manufacturer has information on Clean Air Delivery Rate (CADR) for Smoke or Dust. Smoke or Dust contains fine particles similar in size to Aerosol droplets (~5 micron). While SARS-CoV-2 virus particles have been shown to be as small as 0.07 micron, we use droplet size because this is the only parameter available for comparison in commercially available HEPA filtration devices.

Next, calculate the minimum CADR appropriate for your room using the following formula:
CADR = Floor area in meters (Length x Width) x Ceiling Height in meters x 12 ACH

For example, if the room is 3 meters long, 3 meters wide and has a ceiling height of 2.4 meters, then CADR is 3 x 3 x 2.4 x 12 = 259.2 Cubic Meters per Hour (CMH). If the posted CADR of the portable HEPA Filtration device is in Cubic Feet per Minute (CFM), multiply CMH by conversion factor of 0.58858, so 259.2 CMH is equal to 152.56 CFM.

Alternatively, you may use the following table.

Table 1. Minimum CADR based on Floor Area (at 12 ACH, with ceiling height of 2.4m)

Floor Area in Meter^2	**Minimum Clean Air Delivery Rate (CADR)** in Cubic Meters per Hour (CMH)	**Minimum Clean Air Delivery Rate (CADR)** in Cubic Feet per Minute (CFM)
9	259.20	152.56
12	345.60	203.41
15	432.00	254.27
18	518.40	305.12
21	604.80	355.97
24	691.20	406.82

Where do we position the HEPA filtration unit?
According the the World Health Organization's Severe Acute Respiratory Infections (SARI) Treatment Centre Practical Manual released in March 2020, placement of a portable filtration unit in any area must be done with consideration of the following:

1. The unit must not create an obstruction that would interfere with the proper delivery of health care.
2. The unit should be placed as close to the expected source of the contamination as possible to increase effective capture of the infectious or hazardous agents.
3. The air flowing out of the unit must not be directed in a way that would cause discomfort to patients, visitors or staff.
4. Keep all doors and windows to the room closed as much as possible.
5. Place the unit at the maximum distance across the room from the door.
6. The unit should normally be run at the highest fan setting since this will provide the maximum filtration and ACH.
7. The operating panel must be unobstructed and should face the room.

How long do we keep the unit running?
It is recommended to keep the unit running while the room is occupied. In an empty room with no aerosol-generating source, it takes 23 minutes to achieve 99% and 35 minutes for 99.9% efficiency of particulate removal.

Caveats:

1. Portable HEPA Filtration devices should never be considered 100% effective. Of particular importance is the understanding that filtration is only as good as the air that the device takes in.
2. Be aware that the particles trapped in the filter are not inactivated. Take precautions during filter changing and device cleaning.
3. Don't be lulled into a false sense of security. The device is just one of many ways to add another layer of protection on top of standard infection prevention and control practices.
4. Always remember that proper screening of patients, administrative controls, and PPE are still necessary to lessen the risk of infection.

B. Ultraviolet Germicidal Irradiation (UVGI)

UVGI lamps resemble ordinary fluorescent lamps, but are specially designed to emit germicidal UV wavelength of **253.7 nm (UV-C)**. Exposure to UV light at this wavelength is a practical adjunctive method of inactivating microbes on surfaces. Inactivation of microorganisms results from destruction of nucleic acid through induction of thymine dimers.

Germicidal effectiveness is proportional to the exposure dose (fluence, J/m2), which is the product of the dose-rate (irradiance, W/m2) and time (typically in seconds). A logarithmic reduction relationship exists between UV exposure and germicidal efficacy. If a certain UV exposure kills 90% of a microbe population (one-log kill), doubling the intensity or exposure time can kill only 90% of the residual 10%. In practice, a GUV dose of interest is 3 or 4 log-kills, corresponding to 99.9% or 99.99% inactivation, respectively.

Critical factors that affect the efficacy of UVGI include the following:
1. **Relative humidity (RH)**. Effectiveness of UVGI decreases as humidity increases, possibly because under high RH, water adsorption onto the virus surface might provide protection against damage. For optimal efficiency, RH should be controlled to 60% or less, consistent with American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) recommendations in ASHRAE Standard 170.

2. **Airflow pattern.** This affects how long the infectious agents are exposed to the UV radiation. A high frequency of ACH limits the exposure time of the infectious particles. It is recommended to bring down the ACH to 6 when UVGI is being done.
3. **Distance from the UV-C lamp.** The distance of infectious agents from the fixture will determine the irradiance level and thus the germicidal efficacy. The farther the lamp is to target distance, the greater the increase in irradiance or exposure time needed to achieve the intended exposure dose.
4. **Fixture used to house the UV-C lamp.** This determines how much of the radiation discharged from the UV lamp is actually emitted and how it is distributed. Take note that just like any light source, UV-C rays are most effective in direct line of sight exposure, and less in shadowed recesses or areas covered with dust and or other materials.
5. **Cleanliness and Age of UV-C lamp.** The lamps should be checked periodically, approximately every 6 months, to ensure sufficient UV light intensity for germicidal activity. The intensity of germicidal wavelength light decreases with age, thus decreasing effectiveness.
6. **Target surface or object.** Surface properties such as irregularity and reflectance should be taken into account. In general, solid surfaces, granular material and packaging (plastic, glass, metal, cardboard, foil, etc.) need more intense irradiation than contaminated air. For objects such as filtering facepiece respirators (FFR), penetration through the full depth up to the inner filtering medium necessitates higher irradiance or increased exposure time by as much as 10 to 50 fold.

Ceiling-Mounted Tubular UV Lamps

In a clinic which does not have access to medical grade UVGI systems, commercially available ceiling mounted T5 (5/8 inch) tubular UV lamps may be considered. It is strongly advised that the critical factors mentioned above be seriously taken into consideration when using these adaptive modifications.

How much UV-C exposure is required, AND how long does it take to disinfect a surface?

There is no current consensus on the amount of UV-C radiation required to inactivate SARS-CoV-2. For single-stranded RNA (ssRNA) viruses, the UV dose needed to inactivate 99% (2-log) of virus on a surface was 25 to 65 J/m2. On the other hand, for SARS-CoV-1, the dose for reasonably effective disinfection (3-log or 99.9%) ranged from 1,620 to 6,020 J/m2 (median of 2000 J/m2). For FFRs or related material experimentally contaminated with various viruses such as MS2 (ssRNA bacteriophage) and H1N1 (Influenza), exposure dose was from 1,000 to as high as 43,200 J/m2.

To achieve surface disinfection it appears reasonable to arbitrarily use **2,000 J/m2 as the minimum dose.** This translates to *43.4 minutes of UV-C exposure from a height of 2.4 meters using a T5 UV lamp with irradiance at 1 meter of 4.42 W/m2 to achieve 3-log kill or 99.9% inactivation of the virus.* Take note that the irradiance and not the wattage of the lamp determines the exposure dose. The following table illustrates the different exposure times relative to the irradiance of the lamp.

Table 2. Exposure time in minutes relative to Irradiance rating of lamp to achieve Exposure dose of 2000J/m2 (3-log kill, 99.9% viral inactivation) from UV-C lamp installed at a height of 2.4 meters

Lamp Irradiance at distance of 1 meter (Watts per square meter)	**Exposure time** (Minutes)
1.44	133.33
2.30	83.48
2.80	68.57
4.42	43.44

To achieve FFR disinfection would require a much higher exposure dose or time. It is not advisable to perform such in your clinic because there are no pre-existing safety controls such as radiation barriers, etc.

The Ceiling mounted UVGI set-up using commercially available UV-C lamps and the derivative dose calculation is not intended for total room air disinfection. Airflow dynamics, temperature, humidity and other physical factors have to be accounted for. Complex calculations involving Computational Fluid Dynamics (CFD) modeling and dosimetry are required.

Are UV-C lamps harmful to humans?
UVGI lamp emissions are a potential workplace safety and health hazard to the eyes and skin if improperly used. Based on CDC/NIOSH Recommended Exposure Limits (REL), the maximum exposure to UV is 60 J/m2 for a daily 8 hour work shift. For comparison, less than ten minutes of summer sun exposure at a UV Index of 10 can deliver the equivalent limiting daily safety dose because of its much more-penetrating UV-A and UV-B. Take note that our intended UV-C dose of 2,000 J/m2 exceeds the daily REL by more than 60 times.

Additionally, be wary of UV lamps which release ozone. Some vendors promote ozone as an additional protective feature. It is strongly advised that these types of UV lamps should not be used. Instead, use lamps which have protective coating that blocks out the wavelength producing the ozone. Ozone can irritate nasal passages, cause nausea, and extended exposure can lead to lung inflammation. Based on CDC/NIOSH REL, the maximum exposure to ozone is 0.1 ppm (0.2 mg/m3). Ozone generators have been shown to produce from 0.5 to 0.8 ppm which is 5-10 times higher than public health limit. At ACH between 5 and 8, ozone has a half-life of as short as thirty minutes, thus, it may take more than 3 hours or six half-lives to clear the ozone.

Caveats:
1. UV-C disinfection should never be considered 100% effective. As discussed in the critical factors section, there are many variables that need to be addressed. Of particular importance is the understanding that UVGI works best on line of sight exposure.
2. Pathogen risk is dependent on the initial load of microbes. A very high load may still leave enough viable infectious agents after UV-C disinfection.
3. Don’t be lulled into a false sense of security, the device is just one of many ways to add another layer of protection on top of standard infection prevention and control practices.
4. Always remember that proper screening of patients, administrative controls, and PPE are still necessary to lessen the risk of infection.

C. Barriers And Instrument Modification

1. Furniture material
The room set-up should facilitate easy cleaning at the end of the patient encounter and before the next session. Consider installing furniture having nonporous and seamless material that can be cleaned (or can withstand repeated cleaning), is durable or easy to maintain and repair, and resistant to microbial growth.

2. Use of modern instrumentation and technology in doing the physical examination
The use of camera systems should be considered to keep a safe distance between the patient and the Otolaryngologist, provide better visualization, and shorten examination time. These systems may also be incorporated to telemedicine and video-call remote consultations. Moreover, digital and information technology allow sharing of live or recorded endoscopic evaluation, CT/MRI imaging, hearing test results, and others. This would be an area of great interest in the practice of ORL-HNS in the future.

3. Use of physical barriers (e.g., acrylic boxes, plastic drapes, etc.)
The use of physical barriers tailored to the physical set up of the clinic, like plastic wrappings in equipment, modified masks (e.g. Valved Endoscopy of the Nose and Throat (VENT) mask[20]) or shields and others may provide additional protection from aerosols, ease disinfection of other instruments during examination, and help optimize PPE supply. Over-all, barriers work best in reducing direct contact and droplet exposure and are considered only as an adjunct to established engineering safety, PPE, and best practices standards.

How do I choose the appropriate barrier material for my clinic?
Most literature on barriers are based on anecdotal evidence, testimonials and personal modifications. If not properly used, these can further contaminate the field and create a false sense of security. Additionally, barriers can be difficult to completely disinfect, giving rise to the possible liability of these becoming fomites. With the above warning in mind, you may refer to the following table to choose the barrier material suited for your needs.

Table 3. Comparison of barrier material properties

PROPERTIES	Polycarbonate	Propionate	Acetate	Acrylic
Clarity	+ Slight yellowing in time & exposure to sunlight	++ Clear & glossy	+++ Best Clarity	++ More translucent and glossier; No yellowing or blue haze
Scratch-Resistance	+ Easy to scratch, cannot be polished	+++ Hard to Scratch	++ Fair scratch-resistance	+ Easy to scratch, but can be polished
Impact-Resistance	+++ Strongest; High resilience	++ Good impact resistance	_ Low impact resistance	++ Good impact resistance (17x resistance vs glass)
Drilling Compatibility	Can be drilled w/o cracking	No	No	Yes but easy to crack
Weight	Lighter than acrylic	Light weight	Lightest	Light weight
Cost	Moist expensive	Cheap	Cheapest	Cheaper than polycarbonate
Alcohol Compatibility	No	No	Yes, with diluted alcohol	No
Bleach Compatibility	Yes, with diluted bleach	No	No	Yes, with diluted bleach

References:

1. Information for Healthcare Professionals about Coronavirus (COVID-19). Available from: https://www.cdc.gov/coronavirus/2019-ncov/hcp/
2. Sehulster LM, Chinn RYW, Arduino MJ, Carpenter J, Donlan R, Ashford D, et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for Healthcare Engineering/American Hospital Association; 2004 (Updated on July 2019)
3. Atkinson J, Chartier Y, Pessoa-Silva CL, et al., editors. Natural Ventilation for Infection Control in Health-Care Settings. Geneva: World Health Organization; 2009.
4. Severe acute respiratory infections treatment centre: practical manual to set up and manage a SARI treatment centre and SARI screening facility in health care facilities. Geneva: World Health Organization; 2020 (WHO/2019-nCoV/SARI_ treatment_center/2020.1). Licence: CC BY-NC-SA 3.0 IGO.
5. Kowalski W. Ultraviolet Germicidal Irradiation Handbook UVGI for Air and Surface Disinfection. New York, NY: Springer-Verlag, 2009.
6. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. Ventilation of health care facilities. ANSI/ASHRAE/ASHE Standard 170, 2017. Available from: https://www.ashrae.org/technical-resources/bookstore/health-care-facilities-resources
7. Commission Internationale de l´Eclairag Technical Report on Ultraviolet Air Disinfection, 2003. Available from: http://cie.co.at/news/cie-releases-two-key-publications-uv-disinfection
8. Illuminating Engineering Society Photobiology Committee Report, Germicidal Ultraviolet (GUV) – Frequently Asked Questions, 2020. Available from: https://www.ies.org/standards/committee-reports/
9. Lindblad M, Tano E, Lindahl C, Huss F. Ultraviolet-C decontamination of a hospital room: Amount of UV light needed. Burns. 2019 Oct. DOI: 10.1016/j.burns.2019.10.004.
10. Memarzadeh F, Olmsted RN, Bartley JM. 2010. Applications of ultraviolet germicidal irradiation disinfection in health care facilities: effective adjunct, but not stand-alone technology. Am J Infect Control 38:S13–S24. doi:10.1016/j.ajic.2010.04.208
11. Tseng CC, Li CS. Inactivation of viruses on surfaces by ultraviolet germicidal irradiation. J Occup Environ Hyg. 2007;4(6):400-405. doi:10.1080/15459620701329012
12. Lytle CD, Sagripanti JL. Predicted inactivation of viruses of relevance to biodefense by solar radiation. J Virol. 2005;79(22):14244-14252. doi:10.1128/JVI.79.22.14244-14252.2005
13. Darnell ME, Subbarao K, Feinstone SM, Taylor DR. Inactivation of the coronavirus that induces severe acute respiratory syndrome, SARS-CoV. J Virol Methods. 2004 Oct;121(1):85-91. doi: 10.1016/j.jviromet.2004.06.006. PMID: 15350737; PMCID: PMC7112912.
14. Duan SM, Zhao XS, Wen RF, et al. Stability of SARS coronavirus in human specimens and environment and its sensitivity to heating and UV irradiation. Biomed Environ Sci. 2003;16(3):246-255.
15. Eickmann M, Gravemann U, Handke W, et al. Inactivation of three emerging viruses - severe acute respiratory syndrome coronavirus, Crimean-Congo haemorrhagic fever virus and Nipah virus - in platelet concentrates by ultraviolet C light and in plasma by methylene blue plus visible light. Vox Sang. 2020;115(3):146-151. doi:10.1111/vox.12888
16. Kariwa H, Fujii N, Takashima I. Inactivation of SARS coronavirus by means of povidone-iodine, physical conditions, and chemical reagents. Jpn J Vet Res. 2004;52:105-112.
17. Fisher EM, Shaffer RE. A method to determine the available UV-C dose for the decontamination of filtering facepiece respirators. J Appl Microbiol. 2011;110(1):287-295. doi:10.1111/j.1365-2672.2010.04881.x
18. Mills D, Harnish DA, Lawrence C, Sandoval-Powers M, Heimbuch BK. Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators. Am J Infect Control. 2018;46(7):e49-e55. doi:10.1016/j.ajic.2018.02.018
19. Vo E, Rengasamy S, Shaffer R. Development of a test system to evaluate procedures for decontamination of respirators containing viral droplets. Appl Environ Microbiol. 2009;75(23):7303-7309. doi:10.1128/AEM.00799-09
20. Weschler CJ, Ozone in indoor environments: concentration and chemistry. Indoor Air, 2000;10:269-288.
21. Ozone Generators that are Sold as Air Cleaners. Indoor Air Quality (IAQ).United States Environmental Protection Agency. Available from: https://www.epa.gov/indoor-air-quality-iaq/ozone-generators-are-sold-air-cleaners#intro
22. Ozone. NIOSH Pocket Guide to Chemical Hazards (2005-149) 3rd printing. Available from: https://www.cdc.gov/niosh/npg/npgd0476.html
23. Workman AD, Welling DB, Carter BS, Curry WT, Holbrook EH, Gray ST, et al. Endonasal instrumentation and aerosolization risk in the era of COVID-19: simulation, literature review, and proposed mitigation strategies. International Forum of Allergy & Rhinology. 2020.
24. Roberge RJ. Face shields for infection control: A review. J Occup Environ Hyg. 2016;13(4):235-242. doi:10.1080/15459624.2015.1095302
25. Occupational Safety and Health Administration Nonmandatory Compliance Guidelines for Hazard Assessment and Personal Protective Equipment Selection. Available from: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910SubpartIAppB
26. Healthcare Infection Prevention and Control FAQs for Covid-19 (https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-faq.html)
27. ASHRAE Position Document on Airborne Infectious Diseases. Approved January 19, 2014, Reaffirmed February 5, 2020, Expires August 5, 2020.