April 17, 2020

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Advanced Air Filtration Systems in Operating Rooms (ORs): Relevance during COVID-19 Pandemic

Executive Summary

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Situation

Patient care in the hospital requires healthcare workers to be in very close proximity to the patient and each other. This is especially evident in the operating room (OR) where staff can spend hours together in a confined space. The focus of this report is to investigate the necessity for specialized air filtration systems in the OR to reduce the transmission of COVID-19, and to compensate for potential flaws in Personal Protective Equipment (PPE). It will also address the presence of clinical evidence to support the role of advanced filtration systems in the OR to mitigate the potential transmission of the coronavirus.

Background

According to the Centers for Disease Control and Prevention (CDC) minimum standards of Personal Protection Equipment (PPE) for Health Care Personnel (HCP) when caring for a patient with confirmed or suspected COVID-19 includes Standard Precautions and use of a facemask, gown, gloves, and eye protection. During Aerosol Generating Procedures (AGPs) a N95 respirator mask or powered air-purifying respirator (PAPR) when available is recommended due to the risk of airborne droplet transmission risk is present. (WHO Scientific Brief, 2020) (CDC, 2020) (LIU, 2020).

Possible AGPs include:

- Intubation, extubation, bag masking, bronchoscopy, chest tubes
- Electrocautery of blood, gastrointestinal tissue, any body fluids
- Laparoscopy/endoscopy
- Use of intraoperative debridement devices with irrigation (e.g., hydrosurgery, pulse
- lavage, low frequency ultrasonic debridement)
- Use of high-speed powered equipment (e.g., saws, drills)

The COVID-19 virus can be transmitted through the air with coughing or sneezing and AGPs. The positive- single stranded RNA virus is reported to be 60-140 nm and when embedded in droplets that range from 1 to 5 microns in diameter, the pathogens can stay airborne for several hours. Considering OR rooms have positive pressure and are not required to be vented to the outside, the potential of pathogen transmission to adjacent areas as well as patients an healthcare workers with compromised Personal Protective Equipment (PPE) is possible (Cascella et al., 2020) (ASHRAE, 2019).

On March 13, 2020 the American College of Surgeons (ACS) released COVID-19 Recommendations for Management of Elective Surgical Procedures. ACS subsequently

released triage criteria for non-emergent surgical procedures, however when emergent surgery is necessary, further guidance is sought for suspected or confirmed COVID-19 surgical cases. In addition to essential PPE and conventional intraoperative air quality measures, consideration of an advanced air filtration system is evaluated, as typical operating rooms are designed to provide positive-pressure relative to the surrounding areas and are not Airborne Infection Isolation Rooms (AIIR).

Assessment

Technology Under Evaluation:
Advanced Air Filtration systems

Goal of the Assessment:

1. Evaluation of the use of advanced air filtration systems in the OR for COVID-19 virus containment.

Technology Description:
Advanced air filtration technology is supplemental technology by which airborne particulate is removed, in addition to conventional air quality measures in place in operating room theaters, which include smoke plume evacuation and ventilation air exchanges > 15 / hour. (CDC, updated 2019).

Advanced Air Filtration systems include mobile, in duct filters and wall mounted units and are categorized below:

HEPA (High-Efficiency Particulate Air)

> HEPA filters use mechanical filtration to remove airborne particles. This technology captures 99.7 of particles larger than 0.3 microns by a combined means of interception, impaction or diffusion. They can be mobile units, ceiling or wall-mounted, or fit into the air ducts(ASHRAE, 2015).

ULPA (Ultra-Low Penetration Air)

> ULPA filters also use mechanical filtration to remove airborne particles. This technology captures 99.99% of particles 0.12 microns and larger by a combined means of interception, impaction or diffusion. They can be mobile units, ceiling or wall-mounted, or fit into the air ducts(Elias and Bar-Yam, 2020).

UVGI air disinfection (Ultraviolet Germicidal Irradiation with in-room air cleaner system)

> UVGI Filtration systems are a combination of either a HEPA or ULPA filter with UV lamps within the system. Shortwave ultraviolet (UV-C) light (100 - 280 nanometers), also known as ultraviolet germicidal irradiation (UVGI), kills or inactivates microorganisms by destroying nucleic acid, thereby rendering them noninfectious. UV sterilization for virus bandwidths are in the 200-280 nanometer range; 222-nm lamps are typically used in current technology (UV light is also harmful to humans, and therefore the UV lights are

contained inside the unit. Within these systems the contaminated air passes though the filter and over the lights for disinfection. These can be mobile units, ceiling or wall-mounted, or fit into air ducts. It is estimated that depending on the unit they can range from 80% to 99% effective (Ontario Health Assessment Technology, 2005).

Clinical Evidence

Guidelines:
The Association of Operating room Nurses (AORN) provides recommendations on portable air filtration for use in a positive pressure operating room.

- A portable high-efficiency particulate air (HEPA) filtration unit may be used by
    - positioning the unit near the patient's breathing zone
    - obtaining engineering consultation to determine the correct placement, and
    - switching the portable unit off during the surgical procedure.
- A portable anteroom system (PAS)-HEPA combination unit may also be used.

Additional considerations: AORN-COVID-19 FAQs .

American Society of Anesthesiologists (ASAS)
Recommendations:

- When possible, perform procedures in an airborne infection isolation room rather than in an operating room. An airborne isolation room has a negative-pressure relative to the surrounding area.
- A designated OR should be allocated when AIIR not available and signs posted on the doors to minimize staff exposure.
- If general anesthesia is used: Place a HEPA filter between the Y-piece of the breathing circuit and the patient's mask, endotracheal tube or laryngeal mask airway.
- The gas sampling tubing should also be protected by a HEPA filter, and gases exiting the gas analyzer should be scavenged and not allowed to return to the room air.
- If available, use a closed suction system during airway suctioning.

Additional Considerations: Coronavirus Resources for Anesthesiologists

National AIR Filtration Association - COVID-19 and Air Filtration FAQ's

Literature Search and Review:
A search was conducted for COVID-19 bio-aerosols elimination and no peer reviewed published literature was located that addressed the COVID-19 virus specifically.

Given the size of the COVID-19 (0.06 -0.140 microns) (Cascella et al., 2020) and limitations of air filtration systems and PPE, there is no known technology that is 100% effective in eliminating COVID-19. During AGPs pathogenic droplets can become air-borne. Controversy exits on airborne transmission of viruses in general and how long aerosolized droplet nuclei may stay in the air (WHO, 2020) (Shiu et al., 2019) (Medical Advisor Secretariat, 2013).

The American Society of Heating, Refrigeration and Air-conditioning Engineers in their Position Document on Filtration and Air Cleaning suggest some benefit to ultraviolet light and ULPA filtration, but concede uncertainty exists and further research is warranted. Supplemental filtration units may prevent migration of viral particulate to other areas of the department. In-duct HVAC filters should be changed per manufacturer's instructions for use. Regular facility engineer quality control measures need to be in place for air flow studies (Wargocki et al., 2018).

During Intubation and extubation, supplemental air-filtration may be placed near the patient's breathing space with care to turn the unit off during the procedure. Placement can be determined in coordination of facility engineer. One particularly high-risk area to consider is areas where the staff removes their PPE. Placement of a portable air system in the OR- ante room may be of benefit. (AORN, 2020).

The online resource by Wong and colleagues gives an overview of management pearls to minimize aerosolization and suggest a high frequency of air exchanges when a negative pressure operating room is not available.

Abstracts below are provided for informational purposes on the behavior and management of bioaerosols and other biologic particulate and air cleaning technology assessment.

Hayes related report(s):

Illuvia HEPA - Ultraviolet Air Recirculation System (HUAIRS)

Financial Considerations

There is a wide range of cost for this technology, which is dependent on multiple factors. **Ongoing cost associated with this technology (hospital grade) includes filters and UV lamps. Portable and wall mounted hospital grade systems range from $1,000 to $27,000, based upon the technology type, quality of the unit and rated air flow.** Rental prices for industrial grade air scrubbers range from $225 week for 500-700 CFM Air Scrubber to $555 a week for 5000 CFM Air Scrubbers.

Air duct filters are system dependent:

-HEPA filters - $25 to $150 (inspected 1 to 2 times per year depending on use)
-ULPA filters - $100 to $350 (inspected 1 to 2 times per year depending on use)
-UVGI lamps - $250 to $400 (replaced 1 to 2 times per year depending on use)

Operational Considerations

Evaluation of current ventilation and air-exchange systems in OR theaters by facility engineers for increasing airborne contaminant removal efficiency is warranted. Air filtration systems have an ongoing consumable and maintenance cost, as well as installation and capital outlay. Before committing to a theater-wide implementation of air filtration systems, providers should consider the high-risk patient mix and all available options. These include installing permanent air filtration systems in rooms for procedures that are performed on high risk patients. Portable or rental units can be used to add to the ORs capacity to treat high risk patients, which should be a consideration when long-term use may not be needed.

Recommendations

Due to the limitations of air filtration systems and PPE, there is no known technology that is 100% effective in eliminating COVID-19 from the air while humans are present. HEPA, ULPA filters and particularly UVGI air disinfection technology offer promise but there are no definitive studies that reflect they are critical for the Operating Room space. ULPA filters and particularly UVGI air disinfection technology can be an added precaution from lingering virus' in the room itself and help stem its' migration to other areas of the department.

One particularly high-risk area to consider is areas where the staff removes their PPE. During this process COVID-19 virus particles can release back into the air while the staff is left unprotected. This perhaps is a target area for advanced air filtration technology.

References

Wargocki P, Kuehn T, Barney, HE, Muller, C, Conrad E, Saputa D, Fisk W. et al., ASHRAE Position Document on Filtration and Air Cleaning (2012-reaffirmed -2018) https://www.ashrae.org/File%20Library/About/Position%20Documents/Filtration-and-Air-Cleaning-PD.PDF accessed April 2, 2020

Elias B, Bar-Yam Y. Could Air Filtration reduce Covid-19 Severity and Spread?, *New England Complex Systems Institute (*2020) https://necsi.edu/could-air-filtration-reduce-covid19-severity-and-spread accessed April 2, 2020.

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Yi Y, Lagniton PNP, Ye S, Li E, Xu RH. COVID-19: what has been learned and to be learned about the novel coronavirus disease. *Int J Biol Sci*. 2020;16(10):1753–1766. Published 2020 Mar 15. doi:10.7150/ijbs.45134

Wong J, Goh QY, Tan Z, Lie SA, Tay YC, Ng SY, Soh CR. (2020). Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore. *Can J Anaesth*. 2020:1-14 Epub ahead of print.

Online resources:

Wong J, Goh QY, Tan Z, Lie SA, Tay YC, Ng SY, Soh CR. (2020). Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore. *Can J Anaesth*. 2020:1-14 Epub ahead of print.

Literature Search

Search Terms: *Coronavirus OR COVID-19 AND Air filtration; Viral aerosols OR Air-borne virus AND Operating; HVAC filtration AND Virus*
Search limits: 20 years
Search yield: 4;11;5
Retrieved:10

1. Can J Anaesth. 2020 Mar 24. doi: 10.1007/s12630-020-01637-0. [Epub ahead of print]

Practical considerations for performing regional anesthesia: lessons learned from the COVID-19 pandemic.

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Coronavirus disease (COVID-19) was declared a pandemic by the World Health Organization on 11 March 2020 because of its rapid worldwide spread. In the operating room, as part of hospital outbreak response measures, anesthesiologists are required to have heightened precautions and tailor anesthetic practices to individual patients. In particular, by minimizing the many aerosol-generating procedures performed during general anesthesia, anesthesiologists can reduce exposure to patients' respiratory secretions and the risk of perioperative viral transmission to healthcare workers and other patients. To avoid any airway manipulation, regional anesthesia should be considered whenever surgery is planned for a suspect or confirmed COVID-19 patient or any patient who poses an infection risk. Regional anesthesia has benefits of preservation of respiratory function, avoidance of aerosolization and hence viral transmission. This article explores the practical considerations and recommended measures for performing regional anesthesia in this group of patients, focusing on control measures geared towards ensuring patient and staff safety, equipment protection, and infection prevention. By doing so, we hope to address an issue that may have downstream implications in the way we practice infection control in anesthesia, with particular relevance to this new era of emerging infectious diseases and novel pathogens. The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is not the first, and certainly will not be the last novel virus that will lead to worldwide outbreaks. Having a well thought out regional anesthesia plan to manage these patients in this new normal will ensure the best possible outcome for both the patient and the perioperative management team.

DOI: 10.1007/s12630-020-01637-0
PMCID: PMC7095295
PMID: 32212103

2. Ecotoxicol Environ Saf. 2018 Nov 30;164:277-282. doi: 10.1016/j.ecoenv.2018.08.034. Epub 2018 Aug 17.

Concentration and type of bioaerosols before and after conventional disinfection and sterilization procedures inside hospital operating rooms.

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Operating rooms (ORs) in hospitals are sensitive wards because patients can get infections. This work aimed to characterize the type and concentration of bioaerosols in nine ORs of an educational hospital before and after sterilization and disinfection. During 2017, fungal samples were incubated at 25-28 °C for 3-7 days and bacterial samples at 37 °C for 24-48 h. The study results showed that the concentrations of fungi before cleaning procedures (for both of disinfection and sterilization) were limited from 4.83 to 18.40 CFU/m3 and after cleaning procedures ranged from 1.90 to 8.90 CFU/m3. In addition, the concentrations of bacteria before cleaning procedures were limited 14.65-167.40 CFU/m3 and after cleaning procedures ranged from 9.50 to 38.40 CFU/m3. The difference between the mean concentrations of airborne bioaerosols before and after sterilization was significantly different than the suggested value of 30 CFU/m3 ($p \leq 0.05$). The bacterial concentration was higher than the recommended value (30 CFU/m3) in 41% of the ORs. The main fungal species identified in the indoor air of ORs (before vs. after sterilization) were A. fumigatus (25.6 vs. 18.3%), A. Niger (11.6 vs. 5.8%), Penicillium spp. (5.5 vs. 3.3%), Alternaria spp. (2.8 vs. 0.7%), Fusarium spp. (9.7 vs. 3.7%), Mucor spp. (15 vs. 12.7%), Cephalotrichum spp. (1.7 vs. 0.8%), A. Flavus (24.6 vs. 18.5%), Cladosporium spp. (2.6 vs. 0.8%), and Trichoderma spp. (0 vs. 0.9%). The growth of biological species even after sterilization and disinfection likely resulted from factors including poor ventilation, sweeping of OR floors, inadequate HVAC filtration, high humidity, and also lack of optimum management of infectious waste after surgery. Designing well-constructed ventilation and air-conditioning systems, replacing HEPA filters, implementing more stringent, frequent, and comprehensive disinfection procedures, and controlling temperature and humidity can help decrease bioaerosols in ORs.

DOI: 10.1016/j.ecoenv.2018.08.034
PMCID: PMC6151147
PMID: 30121503 [Indexed for MEDLINE]

3. AORN J. 2018 Nov;108(5):503-515. doi: 10.1002/aorn.12391.

OR Air Quality: Is It Time to Consider Adjunctive Air Cleaning Technology?: 1.3
www.aornjournal.org/content/cme.

Barnes S, Twomey C, Carrico R, Murphy C, Warye K.

Patients undergoing surgery may be at risk for infection from airborne particles such as dust, skin scales, respiratory aerosols, and hair fibers emanating from multiple sources in the OR, including personnel, heater-cooler devices, and surgical smoke. This risk is increased in surgical patients undergoing procedures involving implanted devices. Surgical personnel also are at risk from exposure to surgical smoke, which can contain viable viral particles including human papillomavirus infection. Air quality in the OR is improved by engineering controls (eg, maintaining positive pressure). During the past decade, innovations in the field of adjunctive technology designed to improve OR air quality include using ultraviolet disinfection and mobile ultraviolet disinfection plus high-efficiency particulate air filtration. Some of these technologies additionally provide continuous monitoring of circulating air particle counts. Additional research regarding the benefits of adjunctive air-cleaning technology in the OR is warranted.

DOI: 10.1002/aorn.12391
PMID: 30376172 [Indexed for MEDLINE]

4. Indoor Air. 2016 Feb;26(1):61-78. doi: 10.1111/ina.12174. Epub 2014 Dec 27.

Indoor bioaerosol dynamics.

Nazaroff WW(1).

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(1) Department of Civil and Environmental Engineering, University of California, Berkeley, CA, USA.

Inhaling indoor air is the primary means by which humans are exposed to bioaerosols. Considering bacteria, fungi, and viruses, this study reviews the dynamic processes that govern indoor concentrations and fates of biological particulate material. Bioaerosol behavior is strongly coupled to particle size; this study emphasizes the range 0.1-10 μm in aerodynamic diameter. The principle of material balance allows concentrations to be determined from knowledge of

important source and removal processes. Sources reviewed here include outdoor air introduced by air exchange plus indoor emission from occupants, occupant activities, and moldy materials. Important mechanisms that remove bioaerosols from indoor air include air exchange, deposition onto indoor surfaces, and active filtration. The review summarizes knowledge about size-dependent particle deposition in different regions of the respiratory tract, techniques for measuring indoor bioaerosols, and evidence for diseases caused by airborne exposure to bioaerosols. Future research challenges and opportunities are highlighted.

DOI: 10.1111/ina.12174
PMID: 25483392 [Indexed for MEDLINE]

5. Masui. 2011 Nov;60(11):1347-50.

[Design, equipment, and management for air conditioning in operating room].

[Article in Japanese]

Fuji K(1), Mizuno J.

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In order to maintain air cleanliness in the operating room (OR) permanently, air exchange rate in the OR should be more than 15 times x hr(-1), the laminar air flow should be kept, and the numbers of the persons in the OR and the numbers of opening and closing OR door should be limited. High efficiency particulate air (HEPA) filter is effective in collection and removal of airborne microbes, and is used in the biological clean room. We need to design, equip, and manage the OR environment according to Guideline for Design and Operation of Hospital HVAC Systems HEAS-02-2004 established by Healthcare Engineering Association of Japan and Guideline for Prevention of Surgical Site Infection (SSI) established by the Center for Disease Control and Prevention (CDC) in the USA.

PMID: 22175178 [Indexed for MEDLINE]

6. Southeast Asian J Trop Med Public Health. 2009 Sep;40(5):1113-20.

Evaluation of an electronic air filter for filtrating bacteria and viruses from indoor air.

Malaithao K(1), Kalambaheti T, Worakhunpiset S, Ramasoota P.

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This study compared the filtrating efficiency (FE) of a commercial electronic air filter for filtering bacteria and viruses from contaminated air with a high efficiency particulate air (HEPA) filter. An enclosed chamber was constructed, in the middle of which an air filter was placed for testing. MTB H37Ra and T7 virus at concentrations of 5x10(8) each were sprayed into one side of the chamber using a nebulizer and the sprayed samples were collected by an impinger air-sampler on the other side. MTB and T7 viruses were detected by PCR and culture. The PCR could detect samples down to 10 fg for MTB H37Ra and 1 pg for T7 virus. Most MTB H37Ra sprayed failed to culture. S. aureus at a concentration of 10(5) cfu and E. coli at a concentration of 10(4) cfu along with T7 virus were filtered out with a FE of more than 99%. T7 virus has a particle size of 0.04 microm, S. aureus has a particle size of 1 microm and E. coli has a particle size of 2 microm.

PMID: 19842396 [Indexed for MEDLINE]

7. Indoor Air. 2008 Apr;18(2):106-12. doi: 10.1111/j.1600-0668.2007.00512.x.

Removal of viable bioaerosol particles with a low-efficiency HVAC filter enhanced by continuous emission of unipolar air ions.

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Continuous emission of unipolar ions has been shown to improve the performance of respirators and stationary filters challenged with non-biological particles. In this study, we investigated the ion-induced enhancement effect while challenging a low-efficiency heating, ventilation and air-conditioning (HVAC) filter with viable bacterial cells, bacterial and fungal spores, and viruses. The aerosol concentration was measured in real time. Samples were also collected with a bioaerosol sampler for viable microbial analysis. The removal efficiency of the filter was determined, respectively, with and without an ion emitter. The ionization was found to significantly enhance the filter efficiency in removing viable biological particles from the airflow. For example, when challenged with viable bacteria, the filter efficiency increased as much as four- to fivefold.

For viable fungal spores, the ion-induced enhancement improved the efficiency by a factor of approximately 2. When testing with virus-carrying liquid droplets, the original removal efficiency provided by the filter was rather low: 9.09 +/- 4.84%. While the ion emission increased collection about fourfold, the efficiency did not reach 75-100% observed with bacteria and fungi. These findings, together with our previously published results for non-biological particles, demonstrate the feasibility of a new approach for reducing aerosol particles in HVAC systems used for indoor air quality control.PRACTICAL IMPLICATIONS: Recirculated air in HVAC systems used for indoor air quality control in buildings often contains considerable number of viable bioaerosol particles because of limited efficiency of the filters installed in these systems. In the present study, we investigated - using aerosolized bacterial cells, bacterial and fungal spores, and virus-carrying particles - a novel idea of enhancing the performance of a low-efficiency HVAC filter utilizing continuous emission of unipolar ions in the filter vicinity. The findings described in this paper, together with our previously published results for non-biological particles, demonstrate the feasibility of the newly developed approach.

DOI: 10.1111/j.1600-0668.2007.00512.x
PMID: 18333990 [Indexed for MEDLINE]

8. Infect Control Hosp Epidemiol. 2006 May;27(5):523-5. Epub 2006 Apr 26.

Airborne severe acute respiratory syndrome coronavirus concentrations in a negative-pressure isolation room.

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This study used a sensitive polymerase chain reaction method coupled with filter sampling to detect the presence of airborne severe acute respiratory syndrome (SARS) coronavirus in an isolation patient room with a patient with severe acute respiratory syndrome receiving mechanical ventilatory support. Polymerase chain reaction results were negative for SARS coronavirus in room air both before and after patient extubation.

DOI: 10.1086/504357
PMID: 16671039 [Indexed for MEDLINE]

9. Ont Health Technol Assess Ser. 2005;5(17):1-52. Epub 2005 Nov 1.

Air cleaning technologies: an evidence-based analysis.

Medical Advisory Secretariat.

OBJECTIVE: This health technology policy assessment will answer the following questions: When should in-room air cleaners be used?How effective are in-room air cleaners?Are in-room air cleaners that use combined HEPA and UVGI air cleaning technology more effective than those that use HEPA filtration alone?What is the Plasmacluster ion air purifier in the pandemic influenza preparation plan?The experience of severe acute respiratory syndrome (SARS) locally, nationally, and internationally underscored the importance of administrative, environmental, and personal protective infection control measures in health care facilities. In the aftermath of the SARS crisis, there was a need for a clearer understanding of Ontario's capacity to manage suspected or confirmed cases of airborne infectious diseases. In so doing, the Walker Commission thought that more attention should be paid to the potential use of new technologies such as in-room air cleaning units. It recommended that the Medical Advisory Secretariat of the Ontario Ministry of Health and Long-Term Care evaluate the appropriate use and effectiveness of such new technologies. Accordingly, the Ontario Health Technology Advisory Committee asked the Medical Advisory Secretariat to review the literature on the effectiveness and utility of in-room air cleaners that use high-efficiency particle air (HEPA) filters and ultraviolet germicidal irradiation (UVGI) air cleaning technology. Additionally, the Ontario Health Technology Advisory Committee prioritized a request from the ministry's Emergency Management Unit to investigate the possible role of the Plasmacluster ion air purifier manufactured by Sharp Electronics Corporation, in the pandemic influenza preparation plan.
CLINICAL NEED: Airborne transmission of infectious diseases depends in part on the concentration of breathable infectious pathogens (germs) in room air. Infection control is achieved by a combination of administrative, engineering, and personal protection methods. Engineering methods that are usually carried out by the building's heating, ventilation, and air conditioning (HVAC) system function to prevent the spread of airborne infectious pathogens by diluting (dilution ventilation) and removing (exhaust ventilation) contaminated air from a room, controlling the direction of airflow and the air flow patterns in a building. However, general wear and tear over time may compromise the HVAC system's effectiveness to maintain adequate indoor air quality. Likewise, economic issues may curtail the completion of necessary renovations to increase its effectiveness. Therefore, when exposure to airborne infectious pathogens is a risk, the use of an in-room air cleaner to reduce the concentration of airborne pathogens and prevent the spread of airborne infectious diseases has been proposed as an alternative to renovating a HVAC system. Airborne transmission is the spread of infectious pathogens over large distances through the air. Infectious pathogens, which may include fungi, bacteria, and viruses, vary in size and can be dispersed into the air in drops of moisture after coughing or

sneezing. Small drops of moisture carrying infectious pathogens are called droplet nuclei. Droplet nuclei are about 1 to 5µm in diameter. This small size in part allows them to remain suspended in the air for several hours and be carried by air currents over considerable distances. Large drops of moisture carrying infectious pathogens are called droplets. Droplets being larger than droplet nuclei, travel shorter distances (about 1 metre) before rapidly falling out of the air to the ground. Because droplet nuclei remain airborne for longer periods than do droplets, they are more amenable to engineering infection control methods than are droplets. Droplet nuclei are responsible for the airborne transmission of infectious diseases such as tuberculosis, chicken pox (varicella), measles (rubeola), and dessiminated herpes zoster, whereas close contact is required for the direct transmission of infectious diseases transmitted by droplets, such as influenza (the flu) and SARS.
THE TECHNOLOGY: In-room air cleaners are supplied as portable or fixed devices. Fixed devices can be attached to either a wall or ceiling and are preferred over portable units because they have a greater degree of reliability (if installed properly) for achieving adequate room air mixing and airflow patterns, which are important for optimal effectiveness. Through a method of air recirculation, an in-room air cleaner can be used to increase room ventilation rates and if used to exhaust air out of the room it can create a negative-pressure room for airborne infection isolation (AII) when the building's HVAC system cannot do so. A negative-pressure room is one where clean air flows into the room but contaminated air does not flow out of it. Contaminated room air is pulled into the in-room air cleaner and cleaned by passing through a series of filters, which remove the airborne infectious pathogens. The cleaned air is either recirculated into the room or exhausted outside the building. By filtering contaminated room air and then recirculating the cleaned air into the room, an in-room air cleaner can improve the room's ventilation. By exhausting the filtered air to the outside the unit can create a negative-pressure room. There are many types of in-room air cleaners. They vary widely in the airflow rates through the unit, the type of air cleaning technology used, and the technical design. Crucial to maximizing the efficiency of any in-room air cleaner is its strategic placement and set-up within a room, which should be done in consultation with ventilation engineers, infection control experts, and/or industrial hygienists. A poorly positioned air cleaner may disrupt airflow patterns within the room and through the air cleaner, thereby compromising its air cleaning efficiency. The effectiveness of an in-room air cleaner to remove airborne pathogens from room air depends on several factors, including the airflow rate through the unit's filter and the airflow patterns in the room. Tested under a variety of conditions, in-room air cleaners, including portable or ceiling mounted units with either a HEPA or a non-HEPA filter, portable units with UVGI lights only, or ceiling mounted units with combined HEPA filtration and UVGI lights, have been estimated to be between 30% and 90%, 99% and 12% and 80% effective, respectively. However, and although their effectiveness is variable, the United States Centers for Disease Control and Prevention has acknowledged in-room air cleaners as alternative technology for

increasing room ventilation when this cannot be achieved by the building's HVAC system with preference given to fixed recirculating systems over portable ones. Importantly, the use of an in-room air cleaner does not preclude either the need for health care workers and visitors to use personal protective equipment (N95 mask or equivalent) when entering AII rooms or health care facilities from meeting current regulatory requirements for airflow rates (ventilation rates) in buildings and airflow differentials for effective negative-pressure rooms. The Plasmacluster ion technology, developed in 2000, is an air purification technology. Its manufacturer, Sharp Electronics Corporation, says that it can disable airborne microorganisms through the generation of both positive and negative ions. (1) The functional unit is the hydroxyl, which is a molecule comprised of one oxygen molecule and one hydrogen atom. Plasmacluster ion air purifier uses a multilayer filter system composed of a prefilter, a carbon filter, an antibacterial filter, and a HEPA filter, combined with an ion generator to purify the air. The ion generator uses an alternating plasma discharge to split water molecules into positively and negatively charged ions. When these ions are emitted into the air, they are surrounded by water molecules and form cluster ions which are attracted to airborne particles. The cluster ion surrounds the airborne particle, and the positive and negative ions react to form hydroxyls. These hydroxyls steal the airborne particle's hydrogen atom, which creates a hole in the particle's outer protein membrane, thereby rendering it inactive. Because influenza is primarily acquired by large droplets and direct and indirect contact with an infectious person, any in-room air cleaner will have little benefit in controlling and preventing its spread. Therefore, there is no role for the Plasmacluster ion air purifier or any other in-room air cleaner in the control of the spread of influenza. Accordingly, for purposes of this review, the Medical Advisory Secretariat presents no further analysis of the Plasmacluster.

REVIEW STRATEGY: The objective of the systematic review was to determine the effectiveness of in-room air cleaners with built in UVGI lights and HEPA filtration compared with those using HEPA filtration only. The Medical Advisory Secretariat searched the databases of MEDLINE, EMBASE, Cochrane Database of Systematic Reviews, INAHATA (International Network of Agencies for Health Technology Assessment), Biosis Previews, Bacteriology Abstracts, Web of Science, Dissertation Abstracts, and NIOSHTIC 2. A meta-analysis was conducted if adequate data was available from 2 or more studies and where statistical and clinical heterogeneity among studies was not an issue. Otherwise, a qualitative review was completed. The GRADE system was used to summarize the quality of the body of evidence comprised of 1 or more studies.

SUMMARY OF FINDINGS: There were no existing health technology assessments on air cleaning technology located during the literature review. The literature search yielded 59 citations of which none were retained. (ABSTRACT TRUNCATED)

PMCID: PMC3382390

PMID: 23074468

10. Clin Orthop Relat Res. 2001 Jun;(387):225-31.

Contamination risk of the surgical team through ROBODOC's high-speed cutter.

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During cutting of the femoral cavity in the ROBODOC procedure, an aerosol cloud of irrigation fluid, blood, and tissue debris was seen. This cloud potentially is contaminated with bacterial and viral vectors, which is an infection risk for the surgical team. A flat and a ball cutter were tested in four standard situations macroscopically with a colored solution. In a second experiment, the cutter was exposed to a fluid contaminated with Staphylococcus aureus, and bacterial room contamination was detected using standard cultures. The aerosol cloud was seen in a 6 x 3.6-m area. Extension and concentration varied, depending on the irrigation situation. ROBODOC's high-speed cutter produces an aerosol cloud in an area in which all members of the surgical team are affected. Sufficient protection is necessary for everyone in the operating room.

DOI: 10.1097/00003086-200106000-00030
PMID: 11400889 [Indexed for MEDLINE]