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Cold and Flu season and the COVID-19 Pandemic

Cold and flu season is approaching and COVID-19 virus is still a significant concern, with the number of active cases across the country rising every day. The 2020 cold and flu season will bring new challenges as SARS-CoV-2, the virus that causes COVID-19 may have similar symptoms and transmission similarities.

**Transmission and Management**

The flu shot is the most effective way to help prevent the flu. However, because cold and flu viruses can spread by touching contaminated surfaces as well as by being in close contact with someone who is ill, safeguarding your environment plays an important role in protecting public health. Influenza viruses can survive on hard non-porous surfaces such as stainless steel and plastic for up to 48 hours. Furthermore, certain high-touch hard surfaces are especially likely to transmit these viruses. Telephones (48%), keyboards and computer mice (38%) are considered germ hotspots in the office during cold and flu season.

All of this points to hard surface disinfection, a key part of any cold and flu prevention and management strategy.

The impact of COVID-19 on how we deal with the 2020 flu season

The COVID-19 pandemic creates several challenges for dealing with the upcoming cold and flu season and delivering the seasonal influenza immunization program. There is a need to create measures to avoid transmitting the COVID-19 virus to staff, volunteers and clients, the need for PPE, the risk of COVID-19 resurgence during the period where flu vaccines are being given, risk of exposure to the COVID-19 virus when accessing immunization and increased demand for the flu vaccine.

Coinfection and the lessons we can learn from Asia and Australia

Early reports from China indicated that coinfection with other respiratory diseases was rare in COVID-19 patients. However, another report showed that 11.8% of patients with COVID-19 were coinfected with influenza A or B. Australia experienced a low flu season this year, due in part to an increase in flu vaccinations and also the measures taken to reduce the spread of the SARS-CoV-2 virus that causes COVID-19, such as wearing masks, social distancing and proper cleaning and disinfection procedures.

While the trends seen in the southern hemisphere may provide clues to what the northern hemisphere can expect for the approaching 2020 cold and flu season, we must also be careful not to make assumptions.

Prevention is key

Following the measures recommended by the Public Health Agency of Canada, and choosing products that clean and disinfect hard non-porous surfaces can help prevent the spread of the viruses that cause COVID-19, cold and the flu.

Cleaning and disinfecting surfaces to kill the viruses that cause colds, the flu and COVID-19 is essential as we prepare for the 2020 cold and flu season.

**DID YOU KNOW?**

The flu is one of the 10 leading causes of death in Canada

- Approximately 12,000 Canadians are hospitalized for the flu each year
- Approximately 3,500 Canadians die from the flu each year

**Infection prevention and control (IPC), including proper cleaning and disinfection procedures are important to reduce the risk of transmitting the COVID-19 virus.**

**References:**


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The flu shot is the most effective way to help prevent the flu. 4  However, because cold and the flu viruses can spread by touching contaminated surfaces as well as by being in close contact with someone who is ill, safeguarding your environment plays an important role in protecting public health. Influenza viruses can survive on hard non-porous surfaces such as stainless steel and plastic for up to 48 hours. 5

Furthermore, certain high-touch hard surfaces are especially likely to transmit these viruses. Telephones (48%), keyboards and computer mice (38%) are considered germ hotspots in the office during cold and flu season. 6

Transmission and Management

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ISSN 1183-5702
Index/abstracted by the Cumulative Index to Nursing and Allied Health Literature (CINAHL)/EBSCO, SilverPlatter Information, Inc. and CrossRef.

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The Board of Directors of IPAC Canada welcomes James Ayukekbong, PhD, CIC as Editor-in-Chief, Canadian Journal of Infection Control.

Dr. Ayukekbong holds a PhD in Medical Science/Epidemiology and Certification in Infection Prevention and Control (CIC®). He is an active member of IPAC Canada and IPAC Northeastern Ontario. To date, he has published 20 peer-reviewed articles, including commissioned reviews and editorials.

Dr. Ayukekbong serves as the Vice President of Infection Prevention and Control at Southbridge Care Homes in Ontario. We welcome Dr. Ayukekbong to his new role with IPAC Canada.

The Board of Directors gives its most profuse thanks to outgoing Editor-in-Chief, Victoria Williams. Her service to IPAC Canada and CJIC has been tireless.

We also wish to thank Devon Metcalf for her continued contributions in her role as Associate Editor.
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The COVID-19 Saga: Lessons for the Future

James A. Ayukekbong

Corresponding author:
Dr. James A. Ayukekbong, Editor-in-Chief, Canadian Journal of Infection Control (CJIC)

EDITORIAL

The severity and impact of the current coronavirus disease (COVID-19) pandemic highlights the need for public health mechanisms to prevent further escalation or future outbreaks. SARS-CoV-2, causative agent of COVID-19, is the third epidemic coronavirus to emerge in the human population in the past two decades. Severe acute respiratory syndrome coronavirus (SARS-CoV-1) occurred in 2002, which reportedly infected 8,098 people and caused 774 deaths worldwide. Ten years later, the Middle East respiratory syndrome coronavirus (MERS-CoV) emerged, causing a total of 2,564 infections, and 881 fatalities as of December 2020 [1]. The current SARS-CoV-2 has resulted in over 95 million cases and 2 million deaths worldwide as of January 17, 2021. Initially, the importation of cases through international travel of infected individuals to uninfected countries was the main cause of the expansion of the pandemic, which has caused unprecedented economic and social impact, ranging from travel restrictions, business closures, and a complete shutdown of social activities. After about one year into the pandemic, it is essential to reflect on the gaps and challenges in response and measures to prevent future outbreaks.

First, there was an apparent delay in recognizing the epidemic as a public health emergency of international concern. It took one month from the time the Chinese government notified the World Health Organization (WHO) about the epidemic on January 3, 2020 to when the WHO declared it a public health emergency of international concern on January 30, and later on March 11, 2020 it was declared a pandemic [2]. Time is obviously of the essence, and if this could be considered in future epidemics of similar magnitude, most countries would institute mechanisms in a timely manner to mitigate the risk of importation or transmission. For example, travel bans or flight restriction from impacted regions.

Second, there was also a delay by some countries in taking swift measures. In the most initially impacted countries of the world such as the United States, Italy, Spain, and France, there was an apparent delay in instituting mandatory lockdowns and maintaining social distancing [3]. For example, the decision to lockdown Northern Italy was leaked before being approved and the population started to escape from the North to the South.

In some parts of Italy, soccer matches with a huge number of spectators were ongoing during the COVID-19 outbreak and this may have impacted the spread of the disease within the country. Other countries, especially those in Africa, were caught up in the misconception that Africans may be genetically resistant to coronaviruses, or that the virus does not survive in warmer, more humid climates. All these factors delayed public health response efforts. In addition, there were also gaps in contact tracing and enforcing self-isolation for those who had been involved in recent international travels.

Third, the risk of healthcare transmission was not seriously considered. Although COVID-19 transmission occurs within the community, healthcare-associated transmission was the main driver of spread in the first wave in highly impacted countries like Italy. There was a prompt need for healthcare workers to be tested, and for those who tested positive to be restricted from work and asked to self-isolate while asymptomatic personnel would wear appropriate PPE (e.g., universal mask and face shield) at work. Furthermore, each healthcare establishment should have an Infection Prevention and Control (IPAC) program with a dedicated and trained team, with at least one trained IPAC focal person. The basic component of such a program must include hand hygiene, appropriate PPE donning/doffing, staff education and retraining, surveillance, outbreak investigation and management, transmission-based precautions, environmental cleaning and disinfection, audits and continuous quality improvement activities related to infection rates and IPAC activities.

In order to prevent further escalation of the current pandemic and prevent future outbreaks, the following considerations are essential: Research for vaccines and therapeutics against coronaviruses must be expanded with focus on protein structures in the virus that are comparatively stable in order to protect from novel and emerging viral strains of pandemic potential [4].

Strengthening of national laboratory systems for early detection of emerging pathogens along with zoonotic disease surveillance. Land use activities such as deforestation and farming bring humans and wild animals in close contact and disrupt habitats, thereby providing opportunities for diseases to spill over. Therefore, there is need for a comprehensive

Conflict of interest: None
investigation of animal reservoirs, mapping of the value chains and networks, and assessing human behaviours that predispose to zoonotic diseases. Also, there is need to improve local capacity and strengthening of the local workforce through a one health approach – that recognizes that the health of people is closely connected to the health of animals and our shared environment.

The COVID-19 pandemic has exposed the weaknesses of the health system in many countries of the world. Therefore, the need for proactive measures to improve health systems and surge capacity (e.g., ventilators, Personal Protective Equipment, etc.) cannot be overemphasized. Scaling up of preparedness plans prior to the onset of a public health emergency should be a priority for every country. For example, the absence or shortage of mechanical ventilators to support COVID-19 patients with breathing difficulties could severely impact the prognosis of the disease.

Despite the proactive preparedness measures, outbreaks may still be inevitable, therefore, measures to effectively respond must be in place. The first consideration in the control of all future epidemics will be timely identifying and mapping out the epicentre of the outbreak and multi-sectoral interventions to prevent or control the spread from the source. For example, travel restrictions to prevent exportation of cases out of the epicentre, or importation to outbreak-free regions.

As soon as an epidemic of pandemic potential is declared, a national state of emergency has to be instituted, and an intersectoral collaboration to enforce social distancing, contact tracing, mass screening, self-isolation and quarantine should be a priority [2].

Considering the long incubation period of coronaviruses (1-14 days) and high rate of asymptomatic infections, wearing of masks by the population is a key source control measure to prevent transmission. Contact tracing, mass screening, self-isolation and quarantine should be avoided, and the population should be advised to stay at home and only come to the hospital for critical care needs. This will reduce the depletion of PPE, minimize the overwhelming of the health system, thereby reducing hospital transmission. It has also been shown that SARS-CoV-2 can persist in the air for hours, or on different environmental surfaces for days [5]. Therefore, regular cleaning and disinfection is essential to prevent transmission and the immediate transfer of non-COVID-19 patients into rooms previously occupied by COVID-19 patients should be avoided. The use of UV-C disinfection, air purification technologies and HVAC system enhancement may be relevant in creating a safer environment of care.

Finally, it is important to mention that the most devastated pandemic in history was the Spanish flu of 1918 that lasted for two years, in three waves with 500 million people infected and 50 million deaths. Most of the fatalities occurred in the second wave because the population was tired of self-isolation, quarantine and social distancing measures that when they were first lifted, people jumped out in the streets giving way to the second wave that resulted in tens of millions of deaths. A similar trend is being observed in the current COVID-19 pandemic. Fortunately, one year into the pandemic, vaccine candidates are being used to vaccinate vulnerable and high-risk populations with the ultimate goal of slowing further spread of the virus and reducing fatalities.

Together, the trend of novel coronavirus emergence suggests that coronaviruses will continue to emerge periodically, inducing serious infectious diseases of huge global health impact. The recognition of animals (e.g., bats, camels, snakes, rodents, etc.) as the natural reservoirs for coronaviruses should necessitate intersectoral (one health) targeted surveillance in these animals and in high-risk populations. The world needs a global response system for outbreaks, as an outbreak anywhere is a risk everywhere.

REFERENCES

Conflict of interest: None
POSITION STATEMENT: Reprocessing of Critical and Semi-Critical Devices in Community Healthcare Settings

This position statement was developed by the Reprocessing Interest Group and has been reviewed by the Community Healthcare Interest Group
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Publication Date
Original: 2019 November

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BACKGROUND
Reprocessing of critical and semi-critical medical equipment/devices [1] in community healthcare settings, when not performed according to current standards [2], has been linked with healthcare-associated infections and outbreaks [3-15]. The purpose of this document is to provide infection prevention and control (IPAC) recommendations for the management and reprocessing of critical and semi-critical medical equipment/devices used in community healthcare settings so that consistent reprocessing standards are applied in all healthcare settings. This includes cleaning, disinfection, sterilization, and storage. This position statement does not address the cleaning and disinfection of endoscopes.

POSITION STATEMENT
1. Clients expect and require safe care regardless of where the procedure is performed and standards of reprocessing shall be met in any setting where it is carried out.

2. All employers and healthcare providers are responsible for:
   • Adhering to best practices and standards for reprocessing when using any semi-critical and critical equipment/devices during provision of care [2,16].
   • Complying with standards for transportation and storage of reprocessed medical equipment/devices and Transportation of Dangerous Goods Act requirements on transportation of soiled equipment/devices [2, 17-19, 20].
   • Having written procedures based on current standards [2,19].
   • Ensuring individuals who clean, disinfect or sterilize reusable medical equipment/devices are educated, trained, and have competency assessments to meet the national and provincial guidelines. This training shall be documented and reviewed yearly and when there are updates [2,16,18].
   • As a minimum, have sufficient medical equipment/devices/kits available to accommodate daily client needs.
   • Having a documented process for recall of medical equipment/devices in the event of reprocessing failure [2].
   • Follow IPAC and Occupational Health and Safety guidelines, such as Routine Practices and Additional Precautions, personal protective equipment, safe sharps management, hand hygiene, disposal of high-level disinfectants (HLD), and procedures for staff exposures that occur during reprocessing [2].

3. Reprocessing critical and semi-critical medical equipment/devices (including loaned, leased or borrowed medical equipment/devices) shall be in accordance with Spaulding’s classification [1], meet manufacturers’ instructions for use (MIFU) and current national guidelines (i.e., Canadian Standards Association (CSA) [2], the Public Health Agency of Canada [PHAC/Health Canada]), and provincial standards [17,21], including specialized staffing, auditing [22], and dedicated space. If there is a disagreement between the MIFU and published guidelines, the more stringent level shall be used [2].

Conflict of interest: None
4. Prior to purchasing medical equipment/devices:
   • The employer and healthcare provider shall determine that the recommended reprocessing methods, as validated by the manufacturer, meet current recommended standards and the reprocessing methods can be met by those responsible for reprocessing.
   • The employer and healthcare provider shall determine if it can be cleaned/reprocessed according to MIFU. Items that cannot be cleaned/reprocessed according to the MIFU shall not be purchased. If already purchased, the item shall be replaced or be designated single-use.

5. Medical equipment/devices that are labelled as single-use by the manufacturer have not been validated to be reprocessed, therefore, these devices shall be disposed of after use. All needles and all syringes are single-use only and shall be discarded after one use [2,16,17].

6. Critical and semi-critical medical equipment/devices labelled as single use must not be reprocessed and reused unless the reprocessing is done by a licensed reprocessor. There are reprocessors in the USA licensed by the United States Food and Drug Administration [2], but none are currently based in Canada. Third party reprocessors must also be licensed in Canada [23].

7. “Non-critical and semi-critical medical equipment/devices that are owned by the client; re-used by that client and used only by that client in their home; and not used for another purpose, do not require disinfection between uses, provided that they are adequately cleaned and stored dry between uses [16].” Examples include respiratory equipment and lancet holding devices.

8. All semi-critical equipment/devices that can be sterilized, will be sterilized according to the MIFU. If a semi-critical device cannot be sterilized, then it shall, at a minimum, be high-level disinfected according to the MIFU between patient uses [2] (e.g., trans-vaginal probe).

   **Note:** In some jurisdictions (e.g., Ontario), high-level disinfection is not permitted in dentistry. Semi-critical reusable dental instruments that contact the mucous membranes or non-intact skin (e.g., mouth mirrors, amalgam condensers, reusable impression trays, handpieces,) shall be cleaned followed by sterilization [24].

9. The use of liquid chemicals for sterilization of instruments is not recommended for critical medical equipment/devices that are used for sterile procedures due to the limitations in maintaining sterility to point of use. “Devices cannot be wrapped or adequately contained during processing in a liquid chemical sterilant to maintain sterility following processing and during storage [19].”

10. Immediate-Use Steam Sterilization (I USS, formerly referred to as flash sterilization) is not recommended, except where there is an urgent, unplanned need, with no other options available.

11. Glass bead sterilizer, microwave oven, boiling, chemiclave, and ultraviolet irradiation are unacceptable as means of sterilization [16].

**Option 1:** Use single-use disposable equipment/devices and discard after use [2,19].

**Option 2:** Reusable critical and semi-critical medical equipment/devices reprocessed using the contracted services of a Medical Device Reprocessing Department (MDRD) such as a hospital or private service-provider. The employer and healthcare provider are responsible to verify the MDRD meets current CSA standards (e.g., sterilization verification documents provided upon request, and documentation to demonstrate reprocessor technician training) [2]. Accreditation Canada states: “Preferably, medical device reprocessing (MDR) is done through a centralized system that provides reprocessing services to multiple areas within the organization. From a safety and cost-effectiveness perspective, centralizing reprocessing services is preferred to replicating them in several areas of the organization. If reprocessing services are decentralized, they are held to the same standards as the MDR department [18].”

**Option 3:** The healthcare provider and/or organization chooses to reprocess reusable equipment/devices themselves. The current pertinent CSA standards shall be followed for reprocessing practices. If there is sufficient capacity to reprocess the critical and semi-critical medical equipment/devices to meet current CSA standards, then the reprocessing may occur on the site.

   In addition to #1-11 above, the employer and healthcare provider must follow quality assurance recommendations:
   • Monitor and document physical, chemical and biological indicators, for all sterilizers following MIFU [2].
   • Monitor and document high-level disinfectants (e.g., minimum effective concentration, date of dilution/replacement, contact time) following the MIFU.
   • Incorporate a preventative maintenance schedule according to medical equipment/device MIFUs.

**STAKEHOLDERS**

All employers and healthcare providers (HCPs) in community settings include, but are not limited to, client homes in which healthcare is provided, ambulatory clinics, physicians, and other healthcare practitioners’ offices, outreach settings, and other community settings where reusable medical equipment is used. Also, healthcare organizations and policymakers whose patients receive care in the same community and which could play a role in facilitating their community partners to meet the applicable standards.
GLOSSARY/DEFINITIONS

Capacity: Employer and healthcare provider has sufficient resources (e.g., financial, equipment, space, personnel) to verify they meet all the current national reprocessing guidelines: CSA, the Public Health Agency of Canada (PHAC/Health Canada).

Client: Includes patient, resident, or any other person who receives treatment.

Community healthcare setting: (Adapted from CSA [2]): Any location outside of an acute care hospital where healthcare is provided, which includes (but is not limited to):
- client homes in which healthcare is provided
- medical clinics or the clinics/offices of other healthcare providers (with or without treatment spaces/overnight stays);
- laser eye clinics;
- outpatient and other office surgical facilities;
- dental general and surgical facilities;
- standalone laboratory facilities and diagnostic imaging centres;
- nursing homes, long-term care facilities, assisted living facilities;
- mental health facilities;
- group homes;
- hospice care facilities;
- stand-alone dialysis clinics; and
- public health clinics.

Critical Medical Equipment/Devices: Medical equipment/devices that enter sterile tissues, including the vascular system (e.g., biopsy forceps, foot care equipment, dental hand pieces, etc.). Critical medical equipment/devices present a high risk of infection if the equipment/device is contaminated with microorganisms, including bacterial spores. Reprocessing critical equipment/devices involves meticulous cleaning followed by sterilization [1].

Healthcare provider: Any healthcare professional delivering healthcare service to a client as well as those performing reprocessing duties.

High-Level Disinfection (HLD): The level of disinfection required when processing semi-critical medical equipment/devices. A process capable of killing vegetative bacteria, mycobacteria (including Mycobacterium tuberculosis, fungi, and lipid and non-lipid viruses), as well as some, but not necessarily high numbers of, bacterial spores [2].

Immediate-use steam sterilization (IUSS) (formerly referred to as flash): The shortest possible time between a sterilized item’s removal from the sterilizer and its aseptic transfer to the sterile field. Immediacy implies that a sterilized item is used during the procedure for which it was sterilized and in a manner that minimizes its exposure to air and other environmental contaminants. A sterilized item intended for immediate use is not stored for future use, nor held from one case to another.

Immediacy, rather than being defined according to a specific time frame, is established through the critical analysis and expert collaboration of the healthcare team [2].

Loan Equipment: Medical equipment/devices used in more than one facility, including borrowed, shared or consigned equipment/devices, which are used on patients/clients/residents. Reprocessing is carried out at both loaning and receiving sites. Loaned equipment may also be manufacturer-owned and loaned to multiple healthcare facilities [2].

Limited Capacity: Employer and healthcare providers have insufficient resources (including space, personnel, financial, equipment) to meet all the current national reprocessing guidelines CSA, the PHAC/Health Canada. If these minimum standards cannot be met, single-use disposable items, or a centralized Medical Device Reprocessing Center should be used.

Manufacturer’s Instructions for use (MIFU): The written instructions for use provided by the manufacturer or distributor of a product, which contain the necessary information for the safe and effective use of the product [7].

Medical Device Reprocessing Department (MDRD): Any reprocessing area/department whose sole industry is reprocessing of medical devices [2].

Minimum effective concentration (MEC): The lowest concentration of the active ingredient(s) in a disinfectant solution at which the product is still effective.

Semi-Critical Medical Equipment/Device: Medical equipment/device that comes in contact with non-intact skin or mucous membranes, but ordinarily does not penetrate them (e.g., respiratory therapy equipment, transrectal probes, and specula).

Single-use/Disposable: Medical equipment/devices designated by the manufacturer for single-use only. Single-use equipment/devices shall not be reprocessed.

Single patient use: Medical equipment/devices that may be used on a single client and may be reused on the same client, but may not be used on other clients.

Sterilization: The level of reprocessing required when processing critical medical equipment/devices. Sterilization results in the destruction of all forms of microbial life, including bacteria, viruses, spores and fungi. Equipment/devices shall be cleaned thoroughly before effective sterilization can take place.

As per the Canadian Standard Association (CSA) [2]: “SHALL” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard. “SHOULD” is used to express a recommendation, or that which is advised but not required and “MAY” is used to express an option, or that which is permissible within the limits of the standard, an advisory or optional statement.
CROSS REFERENCES


REFERENCES

The Cost of Contact Precautions: A Systematic Analysis

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ABSTRACT
Background: There is a need for robust estimates of per hour cost of contact precautions in hospitals. Our study aims to formulate and apply a methodology for estimating this cost.

Methods: A formula was established with components including patient room entries by Healthcare Worker (HCW), proportion of entries by HCW categories, time taken to don and doff Personal Protective Equipment (PPE), price of PPE, and HCW employment cost. A literature review for the period 2000-2020 was conducted to estimate room entries per hour; we applied proportion of room entries reported in literature; a local study was used for estimating time taken to don and doff gown and gloves; the price of PPE was provided by Alberta Health Services; and employment cost was captured from public sources.

Results: Results of the literature review suggest an average 4.35 entries per hour by HCW and most entries were made by nurses. The local study data suggested that on average it took 85 seconds in total for HCW to don and doff PPE. Using all the components of the formula, the total cost per hour per patient associated with additional PPE was estimated to be C$8.95 (US$6.82).

Conclusion: A simple framework for estimating hourly costs of contact precautions was presented. Although the hourly cost was modest, the implications are significant when considering annual number of patient-hours of contact precautions.

KEYWORDS
Contact precautions, PPE, cost

INTRODUCTION

With the recent development of many rapid diagnostic tests for infection, hospitals are facing challenging questions about which ones to implement [1,2]. One potential benefit of rapid tests is allowing the early discontinuation of contact precautions where appropriate. Contact precautions are used in hospitals with an aim to reduce the transmission of pathogens, including antibiotic-resistant organisms [3]. While shown to be effective in limiting pathogen transmission in hospital settings, implementing contact precautions can also add cost burden related to additional use of personal protective equipment (PPE) and designated isolation rooms [4-6]. Most studies on costs associated with PPE for any contact precautions have used a random average or proxy for number of room entries to determine the number of PPE used per isolation day/hour [6-10]. Contact precautions require little PPE, with patients on droplet or airborne precautions needing additional (and more costly) PPE.

The objective of this study was to formulate and apply a methodology for estimating the cost per hour of contact precautions. An accurate estimation of additional costs associated with contact precautions may enable better assessment of the financial benefit from appropriate early discontinuation. The methodology may be extended to address costs of other isolation regimes, such as those required for airborne precautions.

METHODS

In this study, we estimated the time and material cost associated with the use of gowns and gloves for contact precautions. We do not consider other potentially associated costs, such as private accommodation or additional cleaning.

To estimate all costs of keeping a patient on contact precautions, there are multiple components requiring assessment. These can be summarized as \( C = E \times (T \times \sum_i f_i W_i + P) \), where \( E \) represents the number of room entries per hour, \( T \) the time it takes to don and doff gown and gloves, \( f_i \) the fraction of each
type of Healthcare Worker (HCW) among all room entries, \( W \), the hourly employment cost of each type of HCW, and \( P \) the price of gown and gloves. We therefore estimate each of these components separately and then calculate the total estimated cost per hour of contact precautions \( C \). All dollar values are shown in 2020 Canadian dollars.

**Patient Room Entries (E)**

**Search strategy and study selection**

Literature search strategies (detailed in the Appendix) were each formulated for EMBASE and PubMed abstract databases, and all articles published on or before March 28, 2020 were included. There was no restriction imposed on the language of the articles.

In this literature review, inclusion criterion was defined as all articles that studied HCW or personal visitor entries to isolated patient rooms as compared to non-isolated patient rooms in a hospital. The exclusion criterion was defined as the absence of reported mean room entries for isolated patient rooms.

The study selection procedure was independently performed by two authors (AS and AH) in two phases. Firstly, screening of titles and abstracts were done based on the inclusion criterion. In the second phase, an independent manual review of the full text of these articles was conducted based on the exclusion criterion.

**Data extraction and synthesis**

The selected studies were utilized to obtain data points independently by two authors (AS and AH). These data points included study designs, reasons for isolation precautions, population characteristics, data collection period, data collection time of the day, type of room entries included, room type, number of patients in isolated and/or non-isolated groups, and mean patient room entries and p-values.

**Statistical analysis and estimations**

All analysis was performed using Microsoft Excel. Mean number of room entries per hour per patient along with p-values of test of the difference between isolated and non-isolated groups from studies selected in literature review were tabulated.

**Time to Don and Doff Gown and Gloves (T)**

**Local study for time to don and doff PPE at Foothills Medical Centre, Calgary, Canada**

The data was originally collected as part of a Quality Improvement (QI) project. The objective of this study was to remove additional precautions for a set of patients (those colonized with Vancomycin-Resistant Enterococci and no other risk factors). Volunteer data collectors were trained by one author (CP) to time and record donning and doffing. They sat at the end of a hallway and, for 1 hour, recorded each time an HCW entered the room. Volunteers collected information on time taken by HCWs to don and doff gown and gloves, not including time for hand hygiene. HCWs were distinguished by their clothing types.

**Statistical analysis and estimations**

All analysis was performed using Microsoft Excel. Mean time to don and doff gown and gloves from the local study data were calculated and tabulated. Estimated time to don and doff gown and gloves from the local study were compared with a tutorial video posted by Public Health Ontario.

**Proportion of Room Entries by HCW from the Literature (F)**

For data on the proportion of room entries by HCW, we used articles that reported such proportions from our literature review of patient room entries. We used the average of the proportions from the shortlisted articles.

**Mean employment cost of HCW from Open-Source Website (W)**

Mean hourly wage rate of HCW categories, including doctors, nurses and housekeeping staff in Canada was abstracted from https://www.salaryexpert.com. To calculate employment costs, we grossed up wages to account for non-salary benefits, using the same proportions of salary to non-salary benefits as those shown in Schedule 2 of the 2020 Alberta Health Services Annual report for each category of HCW. This allowed us to calculate the hourly employment costs.

**Cost of Gown and Gloves (P)**

Cost of gown and gloves used for contact precautions in hospitals was collected from Alberta Health Services. The cost of laundering a gown was $0.42 and cost of purchasing a pair of nitrile gloves was $0.10.

**RESULTS**

**Room Entries: Literature Review**

The flow of the literature search selection process was depicted in Figure 1. There were 191 literature abstracts found on EMBASE and PubMed. There were seven duplicates found and removed. Out of the remaining 184 articles, 156 were excluded in the first screening of titles and abstracts because they did not meet the inclusion criteria. This left 28 articles for the full-text screening based on the exclusion criterion. Only six out of these publications had relevant results for analysis.

A summary of the studies which had relevant results for analysis was presented in Table 1. The studies included observational, quasi-experimental, case control and randomized controlled trial designs, which included both children and adult populations. All but one study examined the impact of contact precautions for antibiotic-resistant organisms. Data collection period in terms of total hours of room entry observations was greater than 490 hours in all but one study with a range of 91 to 10,080 hours [12]. There were two studies that collected entry data using electronic monitors, which allowed observation for a full 24 hours of the day [13,14]. Other studies collected only day and evening time data [12,15-17]. All studies recorded HCW visits and three studies included personal visitors. Most studies included both Intensive Care Unit (ICU) and Non-ICU wards, and one study included an Intermediate Care Unit (IMCU).
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Study Design</th>
<th>Population Characteristics</th>
<th>Data Collection Period</th>
<th>Data Collection Time of the Day</th>
<th>Reasons for Isolation</th>
<th>Type of Entries</th>
<th>Room Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evans H.L., et al. (2003)</td>
<td>Observational</td>
<td>Mean age: Isolated patients = 47.8 years, Non-Isolated patients = 58.3 years.</td>
<td>Monday through Friday between 8.00 A.M. and 1:00 P.M.</td>
<td>91 hours</td>
<td>MRSA (69%), VRE (40%), Clostridium difficile (15%), multidrug-resistant Acinetobacter spp (4%), and multiresistant S. maltophilia (4%).</td>
<td>17 (54.3%) patients isolated for MRSA, three (9.7%) patients isolated for Clostridium difficile, two (6.5%) patients isolated for VRE, two (6.5%) patients isolated for tigecycline-resistant, or Clostridium difficile.</td>
<td>Non-Isolation (N) = 48</td>
<td>ICU and Non-ICU</td>
<td>—</td>
</tr>
<tr>
<td>Morgan D.J. (2013)</td>
<td>Observational—HCW and Personal Visitors</td>
<td>—</td>
<td>19-month study period, 7,543 HCW visits were observed over 1,989 hours of observation</td>
<td>1 hour at random times</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rizzo A., et al. (2010)</td>
<td>Prospective case-controlled</td>
<td>Median age = 62</td>
<td>From July 2008 to July 2009</td>
<td>Full 24 hours using photoelectric sensor</td>
<td>MRSA (69%), VRE (40%), Clostridium difficile (19%), multidrug-resistant Acinetobacter spp (4%), and multiresistant S. maltophilia (4%).</td>
<td>17 (54.3%) patients isolated for MRSA, three (9.7%) patients isolated for Clostridium difficile, two (6.5%) patients isolated for VRE, two (6.5%) patients isolated for tigecycline-resistant, or Clostridium difficile.</td>
<td>Non-Isolation (N) = 31</td>
<td>ICU and Non-ICU</td>
<td>—</td>
</tr>
<tr>
<td>Swoboda S.M., et al. (2004)</td>
<td>Quasi-experimental</td>
<td>Median age = 62</td>
<td>From July 2008 to July 2009</td>
<td>Full 24 hours</td>
<td>283,488 electronically monitored entries into a room with 251,526 exits (420 days, 10,080 hrs, and 3,549 patient days)</td>
<td>17 (54.3%) patients isolated for MRSA, three (9.7%) patients isolated for Clostridium difficile, two (6.5%) patients isolated for VRE, two (6.5%) patients isolated for tigecycline-resistant, or Clostridium difficile.</td>
<td>Non-Isolation (N) = 50</td>
<td>ICU and Non-ICU</td>
<td>—</td>
</tr>
<tr>
<td>Cohen B., et al. (2012)</td>
<td>Observational—Adults and Children</td>
<td>—</td>
<td>Between 5:00 A.M. and 8:00 P.M.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Harris A.D., et al. (2013)</td>
<td>Cluster-randomized trial</td>
<td>Mean age: Isolated patients = 59.6, Non-Isolated patients = 57.9. Male sex (%): Isolated patients = 52.4, Non-Isolated patients = 56.7.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Note:** 1Healthcare Workers; 2Intensive Care Unit; 3Methicillin-resistant Staphylococcus aureus; 4Vancomycin-Resistant Enterococci; 5Tuberculosis

Mean Room Entries from Literature Review
The mean room entries reported in the selected studies are presented in Table 2, and ranged from 2.78 to 5.3 per hour per patient for isolated patients and from 4.37 to 10.90 per hour per patient for non-isolated patients. In general, HCW entered more in non-isolated patient rooms than the isolated rooms and this difference was statistically significant.

For the purpose of cost estimation, we used the average of the mean number of entries into isolated patient rooms from five studies and mean number of entries into all patient rooms from one study. (Since the latter was almost equal to the mean number for isolated patients, removing it would not have any effect on our estimates [13].) This average was 4.35 entries per hour per patient. We did not differentiate between ICU and non-ICU patients, since there was no clear pattern of differences in the number of entries.

Time to Don and Doff PPE from Local Study
The analysis from the QI study presented in Table 3 showed that on an average, it took 56.07 seconds for HCW to don gown and gloves and 28.92 seconds to doff gown and gloves. We examined the tutorial videos for how to don and doff gown and gloves posted by Public Health Ontario (https://www.youtube.com/watch?v=6YybqihL9lM and https://www.youtube.com/watch?v=s4A96fW8bQ). The examples in these videos take 68 (41) seconds to don (doff) gown and gloves, slightly longer than the means from the QI study. There are a few cases in the QI study in which HCWs took much longer than the mean to don or doff gowns and gloves, in which case, it is possible that the HCWs were involved in some other activity – such as a conversation – at the same time. We have not attempted to adjust for this formally.

Proportion of Room Entries by HCW Categories
Three studies reported a breakdown of room entries by HCW categories [12,15,16]. Of these, two studies that reported proportions by isolated and non-isolated patient groups were used [12,15]. These studies categorized HCW into three broad types i.e., nurses, doctors and others. Others included hospital housekeeping staff.

The proportion of entries by HCW categories in the literature presented in Table 4 showed that the majority of patient room entries was made by nurses, followed by others and doctors. The average proportion of patient room entries in the isolated patient rooms by HCW categories from these two studies was calculated as 16% for doctors, 53% for nurses and 31% for others.

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**TABLE 2: Mean room entries per hour per patient**

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean Room Entries for all Patients (Per Hour Per Patient)</th>
<th>Mean Room Entries for Isolated Patients (Per Hour Per Patient)</th>
<th>Mean Room Entries for Non-Isolated Patients (Per Hour Per Patient)</th>
<th>Isolated vs. Non-Isolated (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morgan D.J. (2013) [15]</td>
<td>—</td>
<td>2.78</td>
<td>4.37</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cohen B., et al. (2012) [16]</td>
<td>5.5 (Min-Max; 0-28)</td>
<td>5 (Min-Max; 0-28)</td>
<td>6 (Min-Max; 0-26.4)</td>
<td>—</td>
</tr>
<tr>
<td>Harris A.D., et al. (2013) [17]</td>
<td>—</td>
<td>4.28 (95% CI, 3.95-4.64)</td>
<td>5.24 (95% CI, 4.46-6.16)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**TABLE 3: Mean time to don and doff gown and gloves (in seconds)**

<table>
<thead>
<tr>
<th>PPE¹ Activity</th>
<th>N</th>
<th>Mean</th>
<th>SD²</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don (Gown &amp; Gloves)</td>
<td>30</td>
<td>56.07</td>
<td>23.34</td>
<td>50.00</td>
</tr>
<tr>
<td>Doff (Gown &amp; Gloves)</td>
<td>12</td>
<td>28.92</td>
<td>26.88</td>
<td>18.50</td>
</tr>
<tr>
<td>PPE¹ Activity</td>
<td>Q1³</td>
<td>Q3⁴</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Don (Gown &amp; Gloves)</td>
<td>37.63</td>
<td>70.00</td>
<td>27.00</td>
<td>103.00</td>
</tr>
<tr>
<td>Doff (Gown &amp; Gloves)</td>
<td>5.00</td>
<td>52.00</td>
<td>5.00</td>
<td>75.00</td>
</tr>
</tbody>
</table>

Note: PPE: ¹Personal Protective Equipment; SD: ²Standard Deviation; Q1: ³First quartile; Q3: ⁴Third quartile.
The total-per-hour cost associated with additional PPE was $8.76 (Table 6). The chief component in total cost was the labour cost of HCW related to time required for donning and doffing PPE, which was estimated to be $6.49. The estimated daily cost of contact precautions was $210 (or US$153) per day. The study imply that it takes HCWs 85 seconds to don and doff gown and gloves on average. This time is shorter than in the Ontario demonstration videos we examined, which may be intentionally slow to clarify the steps required. Using these numbers along with average hourly wage rate of HCWs in Canada, our study estimated that the per-hour cost of gown and gloves attributed to contact precautions was approximately $8.95.

The approach that we have used, with accurately reported room entries from published literature and new data on time to don and doff gown and gloves, gives our estimates a high degree of credibility. In addition, our study allows hospitals or researchers to apply components of our costing (e.g., number of room entries per hour) mixed with other location-specific components (e.g., salaries) to obtain estimates of additional cost of contact precautions. Similarly, the formula may be applied in other settings, such as long-term care facilities, where contact precautions are applied, with appropriate adjustments. The formula used in our study can also be easily extended to other types of isolation precautions. There may be other costs related to additional precautions, which were not included in our calculation. For example, a previous study estimated per-day costs of anxiety and depression in terms of quality adjusted life-year (QALYs) at approximately US$9.83 [18]. These costs can be used to evaluate cost-benefit analysis of implementing rapid diagnostic tests for infectious diseases.

Existing studies on the cost of contact precautions in terms of use of gown and gloves have a large range of estimates from as low as US$14.40 (accounting for materials only) to as high as GBP300 per day [5-10]. The estimated cost of contact precautions examined in this study falls in the middle at approximately $210 (US$153) per day.

Unnecessary additional precautions may be costly. In order to evaluate the added value of rapid diagnostic tools that may aid in timely discontinuation of isolation precautions, accurate estimation of costs associated with HCWs, nurses, and others (31%) and doctors (16%). Estimates from the local QI work with data on time to don and doff gown and gloves from a QI study, along with specific data on employment costs and PPE costs, within a transparent framework to estimate the hourly cost of contact precautions. Results from the literature review on patient room entries suggests that HCWs, on average, entered isolated patient rooms 4.35 times in an hour and most of these entries were made by nurses (53%) followed by others (31%) and doctors (16%).

**TABLE 4: Proportion of room entries by HCW categories**

<table>
<thead>
<tr>
<th>Studies</th>
<th>Isolated Patients</th>
<th>Non-Isolated Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Doctor</td>
<td>Nurse</td>
</tr>
<tr>
<td>Evans H.L., et al. (2003) [12]</td>
<td>50 (10%)</td>
<td>247 (51%)</td>
</tr>
<tr>
<td>Morgan D.J. (2013) [15]</td>
<td>367 (22%)</td>
<td>890 (53.5%)</td>
</tr>
</tbody>
</table>

**TABLE 5: Mean hourly wage of HCW in Canada**

<table>
<thead>
<tr>
<th>HCW1</th>
<th>Mean Hourly Wage ($)</th>
<th>Mean Employment Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor (Hospitalist)</td>
<td>124</td>
<td>184.76</td>
</tr>
<tr>
<td>Nurse</td>
<td>41</td>
<td>54.53</td>
</tr>
<tr>
<td>Others (Housekeeper Hospital)</td>
<td>17</td>
<td>21.08</td>
</tr>
</tbody>
</table>

**TABLE 6: Estimation of per hour cost of PPE**

<table>
<thead>
<tr>
<th>Gown and Gloves Cost Category</th>
<th>Cost Per Hour ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Cost of Gown ($0.42 per unit * 4.35 entries)</td>
<td>1.83</td>
</tr>
<tr>
<td>Unit Cost of Gloves ($0.10 per unit * 4.35 entries)</td>
<td>0.44</td>
</tr>
<tr>
<td>Labour Cost of Doctor (4.35 entries * 16% * $184.76 employment cost * 85 seconds to don and doff PPE)</td>
<td>3.04</td>
</tr>
<tr>
<td>Labour Cost of Nurse (4.35 entries * 53% * $54.53 employment cost * 85 seconds to don and doff PPE)</td>
<td>2.97</td>
</tr>
<tr>
<td>Labour Cost of Others (4.35 entries * 31% * $21.08 employment cost * 85 seconds to don and doff PPE)</td>
<td>0.67</td>
</tr>
</tbody>
</table>

**Total Cost** 8.95

Note: Personal Protective Equipment

**Mean wage rate of HCW Categories**

<table>
<thead>
<tr>
<th>Studies</th>
<th>Doctor</th>
<th>Nurse</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evans H.L., et al. (2003) [12]</td>
<td>97 (10%)</td>
<td>501 (50%)</td>
<td>394 (40%)</td>
</tr>
<tr>
<td>Morgan D.J. (2013) [15]</td>
<td>1328 (22%)</td>
<td>3261 (53.5%)</td>
<td>1491 (24.5%)</td>
</tr>
</tbody>
</table>


**Summary of PPE Costs Attributed to Contact Precautions**

The approach that we have used, with accurately reported room entries from published literature and new data on time to don and doff gown and gloves, gives our estimates a high degree of credibility. In addition, our study allows hospitals or researchers to apply components of our costing (e.g., number of room entries per hour) mixed with other location-specific components (e.g., salaries) to obtain estimates of additional cost of contact precautions. Similarly, the formula may be applied in other settings, such as long-term care facilities, where contact precautions are applied, with appropriate adjustments. The formula used in our study can also be easily extended to other types of isolation precautions. There may be other costs related to additional precautions, which were not included in our calculation. For example, a previous study estimated per-day costs of anxiety and depression in terms of quality adjusted life-year (QALYs) at approximately US$9.83 [18]. These costs can be used to evaluate cost-benefit analysis of implementing rapid diagnostic tests for infectious diseases.

Existing studies on the cost of contact precautions in terms of use of gown and gloves have a large range of estimates from as low as US$14.40 (accounting for materials only) to as high as GBP300 per day [5-10]. The estimated cost of contact precautions examined in this study falls in the middle at approximately $210 (US$153) per day.
isolation precautions is imperative. While the estimated cost per hour was modest, given the number of hours of contact precautions, the implications are not insubstantial. For example, an analysis of VA hospitals in the US reported that within 8,318,675 patient-days during the years 2007-2010, about 13.6% were for patients with MRSA on contact precautions, which approximates 27 million hours [19]. At Foothills Medical Centre in Calgary, Alberta, internal data show that the proportion of patients on contact precautions has varied from 5% to 10% over the years 2014-2019. However, it is also important to acknowledge that not applying contact precautions, or terminating them too early, may also be costly and harmful to patients, depending on the specific circumstances [4].

While we have focused on the dollar cost of contact precautions, another perspective on contact precautions is that compliance requires significant time. If unnecessary contact precautions are lifted, HCWs will have additional time to devote to patient care. As we show above, HCWs spend about 6 minutes in donning and doffing gowns and gloves for every hour that patients are on contact precautions.

Our study has many limitations. There was variability in population characteristics of the studies used in the literature review on patient room entries. Additionally, only two of the reviewed studies counted room entries over the entire 24-hour period. All other studies focused on daytime hours only and therefore would capture only the busiest time for room entry. The sample size of the local study on time to don and doff gown and gloves was small with considerable variation, and compliance with PPE varies by location. We did not account for the difference between ICU and other wards. Also, we did not include any post-hospital discharge enhanced terminal cleaning specific to contact precautions as our focus was on the effect of shortening or extending contact precautions. In conclusion, our study provides a simple framework to estimate the hourly costs of contact precautions, which may be used and adapted by other healthcare settings using local information on practices and costs. Future studies should consider mechanisms to improve the measurement of entries into isolation and non-isolation rooms, by different healthcare workers, over a 24-hour period.

FUNDING ACKNOWLEDGEMENT
The authors gratefully acknowledge support from Canadian Institutes of Health Research, grant 389455.

APPENDIX

Literature search strategy: EMBASE and PubMed

EMBASE = (‘infection’:ab,ti OR ‘infections’:ab,ti OR ‘infectious’:ab,ti OR ‘contagious’:ab,ti) AND (‘hospital’:ab,ti OR ‘hospitals’:ab,ti OR ‘hospitalized’:ab,ti OR ‘inpatient’:ab,ti OR ‘in-patient’:ab,ti) AND (‘isolation’:ab,ti OR ‘quarantine’:ab,ti OR ‘contact precaution’:ab,ti OR ‘contact precautions’:ab,ti) AND (‘room entry’:ab,ti OR ‘ward entry’:ab,ti OR ‘ward entries’:ab,ti OR ‘visit’:ab,ti OR ‘visits’:ab,ti) AND (‘human’/de)

PubMed = (((((‘isolation’/Title/Abstract) OR quarantine/Title/Abstract)) OR contact precautions/Title/Abstract)) OR contact precaution/Title/Abstract) OR patient contact/Title/Abstract) AND (hospital/Title/Abstract) OR hospitals/Title/Abstract) OR in-hospital/Title/Abstract) OR in-hospital/Title/Abstract) OR hospitalization/Title/Abstract) OR hospitalisation/Title/Abstract) OR hospitalised/Title/Abstract) OR hospitalized/Title/Abstract) OR inpatient/Title/Abstract) OR in-patient/Title/Abstract) AND (infection/Title/Abstract) OR infections/Title/Abstract) OR contagious/Title/Abstract) OR contagion/Title/Abstract) OR entry/Title/Abstract) AND (ward/Title/Abstract) OR room/Title/Abstract) OR (hcw/Title/Abstract) AND visits/Title/Abstract) OR (healthcare worker/Title/Abstract) AND visits/Title/Abstract) OR (healthcare worker/Title/Abstract) AND visits/Title/Abstract)

AND “humans”[MeSH Terms]

REFERENCES
5. Jan A. Roth, MD; Claudia Hornung-Winter PIR. (2018). Direct costs of a contact isolation day: A prospective cost analysis at a Swiss university hospital. Infection Control and Hospital Epidemiology, 39, 9–11.


Surface and Air: What Impact Does UV-C at the Room Level Have on Airborne and Surface Bacteria?

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Corresponding Author:
Dr. Linda Lee, American Green Technology, 52129 State Route 933, South Bend, IN 46637

ABSTRACT

Background: Short-wave ultraviolet light (UV-C) is known to have the ability to render bacteria inert. We theorized that using UV-C in a continuous fashion at the room level would not only lower the amount of bacteria circulating in the air, but also lessen the amount of bacteria found on surfaces in the same space.

Methods: We set up field trials at three hospitals (Texas, Nevada, and Massachusetts) where we tested air and surface for bacteria, installed continuous UV-C products at the room level, and then tested air and surface again.

Results: In all cases, airborne bacteria was reduced between 79 and 91% over pre-installation values. Most surfaces also showed reductions in bacteria from 48 to 69%, although we report one incident of an increase of 288%.

Conclusion: The data indicate that using active air UV-C technology at the room level reduces the bioburden in the air and on surfaces, including in occupied spaces. Hospitals should consider implementing active UV-C technology to improve air quality.

KEYWORDS
Air disinfection, UV-C, airborne bacteria

INTRODUCTION

An early publication on the effectiveness of ultraviolet light on bacteria is from 1877, when two British scientists noticed that Pasteur’s solution, when placed in lead-covered test tubes, grew innumerable bacteria, while the same solution in unshielded test tubes placed in sunlight, did not (1). Since then, many studies have demonstrated that UV rays are a powerful way to render bacteria inert, beginning with Coblenz in 1922 (2) and Sharp in 1939 (3).

It has been known for decades that many diseases, such as tuberculosis and influenza, are spread via airborne and/or droplet transmission. More recently, studies have shown that pathogens thought to be spread through direct contact can also become aerosolized. Roberts et al. demonstrated that Clostridium difficile (C. diff.) spores could be disseminated through the air (4) as did Best et al. (5). Li et al. reviewed 40 studies to show a strong association between building ventilation and the transmission of airborne disease (6). Eames et al. wrote similarly, but with a tighter focus on hospital acquired infection (HAI), including meticillin-resistant Staphylococcus aureus (MRSA) (7). Nazaroff’s discussion of indoor bioaerosol dynamics lays out how the airflow in a space moves particulate matter, including microbes (8).

Knowing that disease could be spread through the air, and that short-wave ultraviolet (UV-C) can render pathogens inert, it is logical that the medical community would turn to UV-C to reduce the amount of bacteria circulating in the air. Bolton and Cotton discussed how UV disinfection works in general (9) and Boyce discussed specific technologies for using UV-C in hospitals (10). Rutala et al. studied how UV-C worked at the room level to eliminate bacteria (11).

Over the decades, several approaches to UV-C were developed. These methods included using UV-C as part of the water filtration system, using it in the HVAC system, and using it as a stand-alone, mobile product. Each method has some things to recommend it, in terms of effectiveness, ease of use, and cost, but also each one has drawbacks, including these same factors and, in the case of the mobile unit, the necessity for training as well as the requirement that the space to be treated be unoccupied. Reed provided an excellent historical perspective (12) and Memarzadeh et al. concluded that ultraviolet germicidal irradiation (UVGI) is a useful addition to the disinfection toolbox (13).

The potential for surfaces to hold onto microbial contaminants despite standard cleaning methods is clear. Hoppock et al. noted that an important source of airborne materials is a result of human activity, such as entering a room, which resuspended particles from surfaces (14). Our study was designed to examine the effect of using UV-C at the room level on the amount of bacteria in the air, and whether cleaning the air would have a positive effect on surface bacteria.

Conflict of interest: Dr. Lee is employed by VidaShield, which provided the UV-C products used in this study.
METHODS

Environmental studies were conducted at an acute-care hospital in Massachusetts (Hospital A), an acute-care children’s hospital in Texas (Hospital B), and an acute-care hospital in Nevada (Hospital C). In each case, the study materials and methodology were the same. Baseline air and surface samples were taken, UV-C units were installed, and several weeks after that, air and surface sampling were repeated, and before-and-after results compared.

Baseline microbiologic sampling for the studies was accomplished by collecting air samples onto trypticase soy agar with blood (TSA) plates (Hardy Diagnostics, Santa Maria, CA). The sampler works by pulling air in through a perforated cover. The air impacts the agar plates, which are coated with blood. The cells that land on the plates start to reproduce and form colonies. These colonies are counted (raw CFU). This number is adjusted using a standard method for the probability that more than one viable particle was pulled though a single sampling hole and merged with other particles on the plate to produce a single colony. This adjustment is the correction hole factor.

Multiple samples were taken from each location. Representative areas sampled included next to the bed, at the window, near the linen cart, at the nightstand and near the window.

Air samples were collected with SAS 180 samplers (BioScience International, Rockville, MD). All air samples were run at 1000L (approximately five and a half minutes), and air was collected onto 90 mm sampling plates. As plates were collected, they were packed in coolers with gel packs, then packaged with gel packs and shipped overnight to an independent laboratory (Antimicrobial Test Laboratories (now Microchem Laboratories), Round Rock, TX).

Surface samples of 25 cm² were collected directly onto the Rodac sampling plates, using a straight downward motion to insure the sampling plate contacted the surface with sufficient pressure to collect the sample. Plates were then refrigerated and prepared for overnight shipping to the lab. For surface bacterial sampling, TSA with Lecithin and Tween plates were used.

Multiple samples were taken from each location. Representative areas sampled included the bed rails, the over-bed table, keyboards and chair arms. All plates were refrigerated and prepared for overnight shipping to the same independent lab. At the lab, all plates were incubated at 30 ± 2° C for 5-7 days, after which they were evaluated. Total colony forming units (CFUs) were recorded for each specimen.

In each study location, after pre-installation sampling was complete, UV-C units (VidaShield™; American Green Technology, South Bend, IN) were installed. Each unit contained a fully shielded UV-C bulb housed atop a standard 2 x 4 ceiling light fixture. A 59 watt shielded UV lamp produced 15 watts of high output ultraviolet-C energy at a wavelength of 253.7 nanometers. Because the radiation chamber where the UV lamp is housed is enclosed and the air passes through the chamber, there is little to no distance from the lamp to the air that passes directly over the lamp. At its furthest point, the span is 6 inches. Each unit holds four small fans (similar to those in a desktop...
computer) that create differential pressure to continuously draw air into the system at 50 cubic feet per minute. On the way to the irradiation chamber, the air passes through a MERV 6 filter to remove dust and large particulates and then, once treated, the cleaned air is pushed back into the room. The intake and exhaust baffles are set at a 30-degree angle, which moves the air in a pattern that avoids repeatedly recirculating the same air. The fans draw air into the unit at a rate of 50 CFM. When operating continuously, the unit theoretically will treat a volume of air equivalent to an 8' x 10' x 10' (800 cubic feet) room four times per hour. The UV-C portion of the units run continuously, 24/7 whether the overhead room light is on or off. The units available for test were with no downlight, fluorescent/LED downlights and LED array downlights. Units were installed following each facility’s infection control risk assessment (ICRA). Once the units were operational all areas were reopened for normal use. The product used in this study is requires only minimal maintenance (an annual bulb and filter change), easily performed by existing facilities services staff.

For a variety of hospital operational reasons, after intervals of 228, 35, and 70 days (for Hospitals A, B, and C), the sampling was repeated. The same materials were used and the same methodology was followed. The same lab performed all testing. The intervals were counted from the day of the first unit installation. Room availability dictated the speed of installation and post-installation testing.

RESULTS
It is well established that UV-C is effective at treating the air. Therefore, results showing that airborne bacteria counts would be lower at the room level post-installation were expected. Because the air would be cleaner after UV-C treatment, we also anticipated a reduction in bacteria on surfaces, which we found in most cases.

By trialing continuous UV-C air purification technology in geographically distinct areas we hoped to discover its efficacy when implemented at the room level. In every case, the amount of airborne bacteria was greatly reduced, and in most cases, surface bacteria was also reduced.

Hospitals reported that healthcare-associated odors were diminished considerably. This was especially evident at Hospital C, where foul odors had been a constant in the closed unit psychiatric holding area, but also mentioned at Hospital A. We believe that cleaning the air with active UV-C technology not only reduced the number of CFUs present, but also resolved odors. This may be due, at least in part, to the UV-C acting on the biological nature of the odors.

DISCUSSION
Hospodsky et al. documented human occupancy as the major source of indoor airborne bacteria but observed that the skin, nasal and hair that is shed becomes not only airborne but also settles on surfaces (14). Huang et al. explored the likelihood that a hospital patient could acquire antibiotic-resistant bacteria from someone who had been in the room before (15). Mitchell et al. expanded by performing a meta-analysis on the same topic. They noted the use of UV-C lighting fixtures as a way to reduce the likelihood of a future patient acquiring infection from a prior room occupant (16). King et al. studied surface contamination as a result of airborne disposition of bacteria. They found that small particle bioaerosols are spread with no correlation between surface area of contaminants and distance from the source (17).

Schabrun and Chipchase identified healthcare equipment as a significant source of nosocomial infections (18). Otter et al. agreed that contaminated surfaces are implicated in transmission of pathogens, and further called out UV-C as a disinfection technique with improved efficacy over conventional methods (19). Dumford identified portable hospital equipment

<p>| TABLE 1: Mean airborne bacteria correction hole factor CFUs pre- and post-installation |
|-----------------------------------------------|-----------------------------------------------|---------------------------------|------------------|------------------|</p>
<table>
<thead>
<tr>
<th>Study location</th>
<th>Mean CFUs pre-installation</th>
<th>Mean CFUs post-installation</th>
<th>Change</th>
<th>Student’s t-test, one-tailed p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital A ICU</td>
<td>167</td>
<td>37</td>
<td>-79%</td>
<td>0.0305</td>
</tr>
<tr>
<td>Hosp. A OR Breakroom</td>
<td>472</td>
<td>92</td>
<td>-81%</td>
<td>0.0264</td>
</tr>
<tr>
<td>Hospital B patient room</td>
<td>599</td>
<td>55</td>
<td>-91%</td>
<td>0.0002</td>
</tr>
<tr>
<td>Hospital C 6 bed psych unit</td>
<td>439</td>
<td>88</td>
<td>-80%</td>
<td>0.0234</td>
</tr>
</tbody>
</table>

All facilities had significant reductions in airborne bacteria with 24/7 operation of the shielded UV-C ceiling unit.

<p>| TABLE 2: Mean surface bacteria correction hole factor CFUs pre- and post-installation |
|-----------------------------------------------|-----------------------------------------------|---------------------------------|------------------|------------------|</p>
<table>
<thead>
<tr>
<th>Study location</th>
<th>Mean CFUs pre-installation</th>
<th>Mean CFUs post-installation</th>
<th>Change</th>
<th>Student’s t-test, one-tailed p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital A ICU</td>
<td>45</td>
<td>19</td>
<td>-57%</td>
<td>0.0049</td>
</tr>
<tr>
<td>Hosp. A OR Breakroom</td>
<td>120</td>
<td>62</td>
<td>-48%</td>
<td>0.2922*</td>
</tr>
<tr>
<td>Hospital B patient room</td>
<td>25</td>
<td>97</td>
<td>+288%</td>
<td>0.0104</td>
</tr>
<tr>
<td>Hospital C 6 bed psych unit</td>
<td>115</td>
<td>36</td>
<td>-69%</td>
<td>0.0288</td>
</tr>
</tbody>
</table>

*This p value due to small sample size

Most facilities had significant reductions in surface bacteria after implementing UV-C at the room level.
as holding reservoirs of *C. diff.* (20) and Stiefel et al. investigated surfaces as a source of MRSA contamination (21). Shiomori et al. demonstrated that making the bed of a patient with MRSA dispersed MRSA into the air in significant amounts for at least fifteen minutes (22).

Kramer, Schwebke and Kampf looked at how long pathogens can survive on surfaces (23). Acinetobacter spp. survived up to five months, *C. diff.* pathogens can survive on surfaces (23). Acinetobacter spp. survived up to five months, *Escherichia coli* up to five months, *Staphylococcus aureus* including MRSA, up to seven months. Jawad et al. pointed out that the relative humidity in a space impacts the survival of Acinetobacter spp. and concluded that the bacteria can be transferred from surfaces not only by moist vectors but also by dry ones (24).

It is clear from the literature that bacteria in the air and on surfaces poses a risk to patients, visitors, and staff. Our study showed that using UV-C at the room level reduced the bio burden of the air, and, in most cases, of that on surfaces.

In our study, Hospital B had a very large percentage increase (+288%) in surface bacteria post-installation although the actual numbers weren’t extreme (25, 97). We attribute this to the fact that the study room had been terminally cleaned before pre-installation samples were taken. The pre-installation samples were taken in a cleaned, unoccupied and closed room. The post-installation samples were taken in the room after a patient on isolation had occupied the room and had not been terminally cleaned at the time post-installation samples were taken. This result demonstrates the importance and efficacy of surface cleaning as part of the entire infection control process.

Limitations: A limitation of this study is the location of study sites in fully functioning operational facilities. We had no control over people opening and closing doors thereby affecting airflow into and out of the room, how and how often surfaces were cleaned, as well as the consistent cleaning procedures and the number and types of patients who occupied the spaces. Room furnishings were not identical, nor were layouts. Most patient rooms tested were occupied by patients or work areas were functioning as intended and in use by staff. These variables may have affected the results. A second limitation is the decision to study total bacteria CFUs, and not specific pathogens, fungi, or viruses. Because the study was in live environments, and not in a lab, we had no control over the number and types of pathogens that might be present. Because the hospital environment is dynamic and we did not seed the environment with any given pathogen we used total bacteria load as a surrogate for all pathogens. This approach might be seen as similar to using a biological indicator in a steam sterilizer to ensure hospital equipment and supplies are properly sterilized for use on patients. When the equipment is cleaned and wrapped and sterilized it would be hard to test every potential pathogen, but an indicator helps provide a level of assurance that the equipment is ready for use.

CONCLUSIONS
The data clearly demonstrate that using active air UV-C technology at the room level reduces the bioburden in the air and improves indoor air quality. In addition, the majority of the facilities had reduced surface bacteria in areas where continuous UV-C air purification at the room level was operational. Hospitals should consider adding active air UV-C technology at the room level to decrease airborne and surface microorganisms and improve indoor air quality.

REFERENCES


What Can IPAC Canada Do for You?  
Supporting Surveillance Activities in Canadian Acute and Long-Term Care Settings

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Communicable diseases are a public health concern in Canada and early detection of communicable diseases can assist in implementation of measures aimed at minimizing and preventing further transmission, hence their surveillance is critical [1,2]. Surveillance is generally defined as the systematic collection, analysis, and interpretation of data for diseases of public health significance, including healthcare associated infections and antimicrobial resistant organisms [3]. It is closely integrated with the timely dissemination of these data to those responsible for preventing and controlling diseases [3]. Surveillance activities may be continuous in nature, or data may be gathered via point prevalence studies. Activities may be conducted at unit, facility, province, territory, national and international levels. Understanding and practice of communicable disease surveillance are core competencies of those practicing in infection prevention and control [4]. Surveillance is integral to infection prevention and control because it measures the burden of disease and so the need for interventions and the efficacy of interventions aimed at controlling the spread of communicable diseases. Surveillance data are used to establish benchmark reference points for internal and external comparison of the incidence and prevalence of disease, including detection of sentinel events, outbreaks and pandemics. Potential risk factors for acquisition and carriage of a disease can be derived from surveillance datasets. Surveillance also functions to provide timely, useful evidence to leaders and decision makers to establish priorities, and guide policies and programs.

Despite the value of communicable disease surveillance, many practicing in infection prevention and control face barriers in conducting surveillance. Common surveillance challenges include inadequate information technology resources, lack of access to health records and other key information sources because of geographic restrictions and unavailability of electronic records, a shortage of skilled staff, and competing responsibilities and budget priorities. IPAC Canada offers a number of tools to support members and non-members in their surveillance practice. All resources are available on the Surveillance and Applied Epidemiology Interest Group webpage.

1. IPAC Canada created standardized infection case definitions for use in Canadian long-term care (LTC) facilities [5]. These surveillance definitions were used to inform the LTC Surveillance Toolkit described below. These are recommended for use in Canadian LTC settings to provide a standard set of definitions that allow for benchmarking and comparison between jurisdictions across Canada.

2. IPAC Canada developed a position statement supporting surveillance in LTC settings [6]. This position statement includes a recommendation that all LTC settings in Canada routinely conduct surveillance for healthcare-associated infections at a minimum. The position statement is especially useful for those geographic jurisdictions where surveillance in LTC is not a legal mandate.

3. The IPAC Canada LTC Surveillance Toolkit, adapted from Public Health Ontario, supports the entire surveillance process. It contains tools to assess readiness to conduct surveillance, staff training and tools to support data collection and validation, using the IPAC Canada LTC case definitions, though the Toolkit can be customized for any set of definitions. The Toolkit contains a Microsoft Excel database to store data and is set up to automatically calculate rates of all infections and of those deemed to be healthcare-associated only, and to prepare tables and figures of infection rates and epidemiologic curves for reporting. The database can be used alone, or as part of the broader Toolkit. The complete IPAC Canada LTC Surveillance Toolkit, including a recorded tutorial on how to use the Toolkit, is available to IPAC Canada members and non-members alike.

Conflict of interest: None
4. The IPAC Canada Acute Care Surveillance Tracking Tool, adapted from the IPAC Canada LTC Surveillance Toolkit database tool, is a Microsoft Excel database. It is set up to automatically calculate rates of all infections and of those deemed to be healthcare-associated, as well as to prepare tables and figures of infection rates and epidemiologic curves for reporting. This Tool can be customized for use with any set of case definitions. The IPAC Canada Acute Care Surveillance Tracking Tool, and a recorded tutorial on how to use the Tool, are available to IPAC Canada members.

5. Surveillance Workshop sessions serve to provide a framework on what surveillance is, why it is important, and an overview of the six components to robust and effective surveillance system (planning and training, data collection, data cleaning and analysis, data interpretation and benchmarking, reporting and evaluation). Interactive exercises couched in acute care and LTC scenarios provide opportunities to apply some of the surveillance concepts presented, and to use some of the surveillance tools described above. Surveillance Workshop recordings and independent study materials are available to IPAC Canada members.

All IPAC Canada members are encouraged to explore each of these resources and take advantage of all that IPAC Canada has to offer to support surveillance practices.

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Apply to pre cleaned surfaces allow surface to remain wet for time indicated below. Wipe surface dry, rinse or allow to air dry.

<table>
<thead>
<tr>
<th>Bacteria/Virus</th>
<th>Contact time</th>
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<tbody>
<tr>
<td>Staphylococcus aureus (ATCC 6538)</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa (ATCC 15442)</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Human Coronavirus</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Adenovirus Type 5</td>
<td>3 minutes</td>
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This product is a broad-spectrum virucidal hard surface disinfectant that is expected to inactivate the SARS-CoV-2 (the virus that causes COVID-19).
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