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# Robotic Systems for Disinfecting Surfaces in Hospital Rooms and Other Health Care Environments


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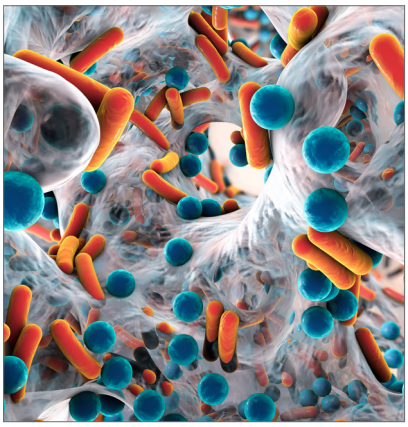

*iStock Photo: Biofilm of antibiotic resistant bacteria*

In 2017, CADTH's horizon scanning service reviewed a portable pulsed-xenon ultraviolet (UV) light system, a then-emerging technology to supplement existing cleaning and disinfection processes in hospital rooms.[1] Since then, robotic UV light disinfection systems have been subject to health technology assessment[2] and automated devices that use hydrogen peroxide vapour (vaporous hydrogen peroxide [VHP]) to disinfect surfaces have emerged.[3] In light of the COVID-19 pandemic, questions about the potential role of robotic disinfection systems in this context have been raised.[4]

## How it Works

A supplement to existing manual cleaning and disinfection practices, robotic disinfection systems are automated portable devices intended for use in unoccupied rooms to reduce health care acquired infections (HAIs).[2,3,5] Following placement and set-up by a trained operator, the devices are activated (on delay or remotely) and automatically complete a treatment cycle before being repositioned (to ensure complete room coverage) or removed.[2,3,5] This article discusses two approaches to robotic disinfection in health care settings: UV germicidal irradiation (UVGI) or VHP also called hydrogen peroxide fogging.

### Ultraviolet Germicidal Irradiation

UVGI robots work by emitting UV-C light (200 nm to 280 nm wavelength) or UV-B (280 nm to 320 nm). The light emitted by the robots destroys DNA in bacteria, viruses, and other harmful microorganisms preventing their ability to replicate and infect humans.[2,5] There are two type of UVGI robots, those that disinfect using continuous UV-C light produced by mercury bulbs and those that disinfect using pulses of UV-C and UV-B light produced by xenon bulbs.[2,5] The duration of a treatment cycle varies by device, typically between 10 and 45 minutes.[2,5] Depending on the device, set-up and positioning may also vary.[2,5] Some devices use a single robot in a single location for the entire treatment cycle, while others use multiple devices placed around the room or a single device that is moved periodically to ensure coverage.[2,5]

### Hydrogen Peroxide Vapour

VHP robots generally work by releasing one of two forms of vapour into a sealed room until it covers all surfaces, killing bacteria, viruses, and other microorganisms.[3] Condensed hydrogen peroxide (or "wet") systems heat 30% to 35% hydrogen peroxide until it becomes a vapour.[3] Aerosolization (or "dry mist" or "dry gas") systems use pressurization or nebulization to distribute 6% hydrogen peroxide throughout the enclosed space.[3] The devices are usually activated from outside the room and VHP sensors are used to detect any leakage and ensure VHP has decreased to a safe level before people re-enter the room.[3] In a case study of one VHP robot, the reported treatment time for one VHP device was two hours.[6]

## Who Might Benefit?

In Canada, 8,000 people die from HAIs and another 220,000 are infected each year.[7] Infections caused by organisms such as *Clostridium difficile (C. difficile),* methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) are of particular concern in Canadian health care settings[7] and their prevention is the focus of much of the research into using robotic UVGI and VHP robots to supplement disinfection practices.[2,8,9] COVID-19 may also be transmitted in health care facilities putting patients, health care workers, and the public at risk.[10] The current understanding of COVID-19 indicates that the disease may spread through contaminated surfaces.[11]

## Availability in Canada

In Canada, UVGI disinfection systems do not require a medical device licence from Health Canada, but the manufacturer must ensure that their products comply with the *Radiation Emitting Devices Act and Radiation Emitting Devices* Regulations.[1] Information regarding the regulation of VHP disinfection systems in Canada was not identified. Several devices are currently available in Canada. These include, but are not limited to:

- Pulsed-xenon UV light systems
  - Lightstrike Germ-Zapping Robot (Xenex Disinfection Systems, San Antonio, TX).[12]
- Continuous UV-C light systems
  - UVD Robot (UVD Robots, Odense, Denmark)[13]
  - Tru-D SmartUVC (Tru-D SmartUVC, Memphis, TN).[14]
- VHP systems
  - Bioquell BQ-50 (PharmaMedSci , St. Laurent, QC)[15]
  - Bioquell BQ-EMS (PharmaMedSci, St. Laurent, QC)[15]
  - Nocospray Disinfection System (AMG Medical Inc., Montreal)[16]
  - VHP Victory Biodecontamination Unit (STERIS, Mentor, Ohio).[17]

## What Does it Cost?

The costs of implementing UVGI robots were estimated by Ontario Health (Quality) (then, Health Quality Ontario) in a 2018 health technology assessment.[2] The authors estimated costs to owning pulsed-xenon and continuous UV-C robots as:

- Pulsed-xenon UV light systems
  - Purchase price, CA$142,325 (four-year warranty).
- Continuous UV-C light systems
  - Purchase price, CA$124,517 (one-year warranty)
  - Leasing price, CA$53,424.

Warranty costs covering replacement bulbs, parts, and technical support ranged from CA$11,500 to C$13,356 annually. Other operating costs estimated in the report included CA$60,000 per year for a device operator. The authors also conducted a budget impact analysis concluding the five-year costs of owning two devices to be CA$586,023 for pulsed-xenon robots and CA$634,255 for continuous UV-C robots in Ontario hospitals.

Two conference abstracts estimated the costs of implementing UVGI systems technologies in Canadian settings.[18,19] The authors concluded that UVGI systems may deliver value for money[18] and may save money by reducing HAIs.[19]

No information about the costs of implementing VHP robots was identified.

## Current Practice

Best practices for environmental cleaning and disinfection of health care environments involve the physical removal of visible and invisible material such as dirt, blood, and microorganisms (cleaning) and killing disease-causing microorganisms (disinfection).[20] Cleaning and disinfecting complex health care environments requires careful selection of equipment and materials, establishing practices for hand hygiene, and use of personal protective equipment.[20]

In the context of COVID-19, WHO recommends cleaning and disinfection practices that clearly delineate roles for staff, pay particular attention to high-touch services, and help health care workers avoid contaminating hands and equipment during patient care.[21] The organization also recommends the careful selection of disinfectants to ensure they are appropriate for clinically relevant pathogens in addition to SARS-CoV-2.[21]

## What is the Evidence?

Our literature search focused on publications about robotic disinfection systems published after CADTH's 2017 horizon scan.[1]

### Ultraviolet Germicidal Irradiation

UVGI robots were evaluated in a 2018 health technology assessment by Ontario Health (Quality).[2] The report assessed the available evidence for pulsed xenon- and mercury-based devices to prevent HAIs. The authors were "unable to make a firm conclusion about the effectiveness of this technology on [hospital-acquired infections] given the very low to low quality of evidence." In 2019, a CADTH rapid review of the clinical effectiveness and guidelines of UVGI robots made similar conclusions.[22]

A 2020 evaluation of UVGI robots by ECRI found limited evidence that the devices reduce HAIs.[5]

A 2019 systematic review and meta-analysis examined the effectiveness of pulsed-xenon UV light systems to reduce HAIs.[8] The authors concluded that, based on evidence from before-and-after studies, the devices may help reduce some HAIs (i.e., *C. difficile* infections and MRSA) but not VRE.[8] In a 2018 systematic review and meta-analysis on the effectiveness of UVGI and VHP to reduce multi-drug resistant HAIs the authors concluded that UVGI may help reduce infections caused by *C. difficile* and VRE, but not MRSA infections.[9]

### Vaporous Hydrogen Peroxide

In a 2020 assessment of the clinical effectiveness of VHP robots for reducing health care acquired infection,[3] ECRI found inconclusive evidence and a need for further study of the technology based on the findings of one systematic review and meta-analysis[9] of low-quality studies.

### Disinfection Robots and COVID-19

Reports and studies of UVGI to prevent the spread of COVID-19 appear to be limited. In guidance from ECRI on the role of UVGI to prevent the spread of COVID-19, the authors note that the SARS-CoV-2 virus is expected to be susceptible to UV light.[4] Recommendations for improved patient safety in operating rooms suggests that higher-risk locations (e.g., anesthesia work areas) in "at-risk" rooms be treated with UV-C to reduce the risk of perioperative infections, including COVID-19.[23] A retrospective multi-centre study of infection control precautions to prevent the spread of COVID-19 in endoscopy centres in China reported widespread use of UV light disinfection, but did not evaluate its effectiveness.[24]

No reports or studies using VHP to prevent the spread of COVID-19 were identified.

## Safety

Exposure of patients, staff, and visitors to UV-C radiation produced by UVGI robots is the primary safety concern related to their use.[5] Safety precautions such as motion sensors to stop treatment cycles and signage to deter entry into spaces being cleaned by UVGI robots are typically used.[5] Blackout curtains may also be used to prevent UV light from escaping spaces being treated.[1]

Similarly, exposure to VHP appears to be the primary safety concern when using these devices.[3] When treating a room with VHP, the space is hermetically sealed to prevent leakage and sensors are used to detect leakage and determine when it is safe to re-enter the room.[3]

## Issues to Consider

Using UVGI robots to supplement existing cleaning and disinfection practices requires training staff and changes to existing workflows to accommodate the added time needed for appropriate use.[1,2,5,8] The need for empty rooms may not be practical in hospitals with multi-patient rooms.[2,8] Similar issues may need to be considered should UVGI be used in the context of COVID-19.[4]

Direct exposure to UV light is necessary for UVGI robots to be effective. Incomplete cleaning that leaves visible dirt, shadows caused by improper placement of the device, closed doors, and the like may all impact the robot's ability to disinfect contaminated areas.[5] UV light can damage and degrade materials, such as plastics, over time.[5] It may be necessary to remove or protect important equipment before treating a room with UVGI.[5]

No literature discussing the implementation of VHP robots was identified.

## Related Developments

A limitation of UVGI and VHP robots is that rooms need to be empty so that they can be used. Technologies that continuously disinfect the air or surfaces in health care environments while rooms are occupied are emerging or in development.[25-39]

One approach to continuous disinfection forces air to pass through a UV light filter installed in the ventilation system before it enters the room.[25-35] A similar approach has also been proposed to disinfect the air in ambulances.[36] Using UV-A lighting fixtures to continuously disinfect surfaces has also been proposed.[37] Another approach uses diluted hydrogen peroxide produced from air in concentrations below human safety thresholds to continuously disinfect health care environments while they are in use.[38,39]

## Looking Ahead

The role of automated disinfection systems in preventing HAIs and COVID-19 is unclear. There is a need for more research comparing automated devices,[5] and evaluating their clinical and cost-effectiveness for preventing HAIs.[9]

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