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## Brief Report

## Evaluation of an automated room decontamination device using aerosolized peracetic acid

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Decontamination  
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Because manual cleaning is often suboptimal, there is increasing interest in use of automated devices for room decontamination. We demonstrated that an ultrasonic room fogging system that generates sub-micron droplets of peracetic acid and hydrogen peroxide eliminated *Clostridium difficile* spores and vegetative pathogens from exposed carriers in hospital rooms and adjacent bathrooms.

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Environmental surfaces play an important role in transmission of health care-associated pathogens.<sup>1</sup> Because manual cleaning is often suboptimal, there is increasing interest in use of automated devices for room decontamination. Ultraviolet-C (UV-C) radiation devices are commonly used because of their efficacy, safety, and ease of use.<sup>2-6</sup> However, the effectiveness of UV-C is reduced as distance from the device increases and in shaded areas, and residual pathogen contamination is not uncommon on surfaces after UV-C exposure.<sup>2-6</sup> Hydrogen peroxide vapor devices are more effective, but have not been widely used because of factors such as increased time of operation.<sup>7</sup>

The Altapure ultrasonic room fogging system (Altapure, South Bend, IN) generates submicron droplets of peracetic acid and hydrogen peroxide with activity against a wide range of pathogens including spores. The fogging system is used in multiple hospitals in the United States, but there are no published data on its efficacy or safety. Safety is a particular concern because both peracetic acid and hydrogen peroxide are strong oxidizing agents that have

the potential to cause serious eye, skin, and respiratory tract irritation.<sup>8,9</sup> Here, we examined the efficacy of the device in killing pathogens and obtained information on real-world experience from hospitals that have used the fogging system routinely for patient room disinfection.

## METHODS

The Altapure ultrasonic room fogging system includes an ultrasonic fogging device (length: 106.7 cm, width: 50.8 cm, and height: 81.3 cm) and an air scrubber device with the same dimensions. The 2 devices are on wheels and attached so they can be moved together by 1 user. An optional automatic vent cover can be attached to the devices. The system is placed in the center of the room and plugged into a standard electrical outlet. After closing the vents and sealing under the door, the device is activated from outside the room using a handheld control. Signage is placed on the door to indicate that no one should enter; the operator is not required to stay during operation. On activation, the ultrasonic fogging device converts a concentrated disinfectant solution (22% hydrogen peroxide and 4.5% peracetic acid) into submicron droplets containing 0.88% hydrogen peroxide and 0.18% peracetic acid that disseminate throughout the room. The complete operation cycle requires 40 minutes for a 90 m cubed room, including 10 minutes of fogging, 10 minutes of dwell time, and 20 minutes of dehumidification in which the air scrubber removes peracetic acid and hydrogen peroxide. Peracetic acid decomposes to acetic acid and oxygen, resulting in a vinegar-like odor after cycle completion.

We examined the efficacy of the device for reduction of 5-6 log<sub>10</sub> colony forming units of pathogens in 5% fetal calf serum dried onto

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glass slides. The test organisms included spores of *Clostridium difficile* VA17, a North American pulsed field gel electrophoresis type 1 strain, a clinical isolate of pulsed field gel electrophoresis type USA300 methicillin-resistant *Staphylococcus aureus* (MRSA), and C68, a VanB-type vancomycin-resistant *Enterococcus* strain. The slides were placed in 10 locations in hospital rooms, including 3 sites near the device (ie, within 1.2 m), 3 sites far from the device (3.0–3.7 m), 3 sites not in direct line of sight of the device (under a bedside table, inside a drawer left fully open, and inside a drawer left only partially open with a 5 cm opening space), and on the toilet seat in the adjacent bathroom. The height of the slides varied from floor level to 1.8 m above the floor. After operation, cultures were processed as previously described.<sup>2</sup> Log reductions were calculated in comparison with untreated control slides. Testing was completed in 7 hospital rooms.

To obtain information on real-world experience using the fogging system, we requested telephone interviews with environmental services (EVS) directors from 5 hospital systems where the system has been used routinely for patient room disinfection for at least 6 months. The interview included questions on how often and where the devices are used, who operates the devices, monitoring methods, time required for operation, measures taken to ensure safety of personnel, and any safety concerns related to use of the fogging system.

## RESULTS

For each of the 7 rooms, the device eliminated all pathogens from near and far locations, from the inside of fully opened drawers, and from under the table ( $\geq 5$  log reduction). Inside partially opened drawers, the device eliminated all of the pathogens in 5 of 7 rooms; MRSA persisted in 2 partially open drawers but was reduced by  $>4$  log, and *C difficile* spores persisted in 1 partially open drawer but was reduced by 1.35 log. No harmful effects on surfaces were observed, and there was no evidence of a residue on surfaces after operation.

Of the 5 hospital systems that were asked for interviews, 2 made EVS directors available for telephone interviews. One of the hospital systems interviewed uses 6 Altapure fogging systems in 3 hospitals (approximately 4,500 decontaminations per year), and the other uses 2 fogging systems. Both hospital systems use each device up to 6 times daily with a total setup and operation time of 1 hour. The devices are used routinely for *C difficile* infection rooms after patient discharge and intermittently in other settings (eg, intensive care unit rooms, wards with high *C difficile* infection rates). Both facilities trained a subset of existing EVS personnel to operate the device. One of the facilities conducts monthly monitoring of the efficacy of each device by placing strips containing  $10^6$  *Geobacillus stearothermophilus* spores (Apex Biological Indicators; MesaLabs, Bozeman, MT) at 5 sites (floor by door, bedside table, toilet seat, windowsill, and opened bedside drawer). Initially, occasional windowsill indicators were positive during cold weather, and it was determined that cold air reduced fog penetration; this issue was resolved when the manufacturer added a fan that runs every 5 minutes during fogging to ensure thorough fog distribution. Subsequently, indicators have consistently been nearly 100% negative.

Measures taken to ensure safety of personnel were reviewed with the 2 EVS directors that were interviewed, and a third facility provided a formal written summary on safety testing and precautions to ensure personnel safety. Safety recommendations included providing training for the personnel using the device, wearing gloves and goggles while filling the device with the concentrated solution, and placing signage on the door to indicate that no one should enter during operation. Each of the facilities reported conducting air sampling for hydrogen peroxide and acetic acid during initial assessments of the device. One facility used badge units (Advanced

Chemical Sensors, Boca Raton, FL) worn by an operator to measure hydrogen peroxide and acetic acid exposure. The measured concentrations during filling of the device with new solution, during an 8-hour shift when the device was operated 5 times, and immediately outside rooms during the fogging process were all  $\leq 0.04$  for hydrogen peroxide and  $\leq 1.3$  for acetic acid; the Occupational Safety and Health Administration permissible exposure levels for hydrogen peroxide and acetic acid are 1 and 10 ppm as 8-hour time weighted averages, respectively. The other facilities reported measurements of  $\leq 0.5$  ppm hydrogen peroxide outside the room during operation and inside the room immediately after cycle completion.

None of the facilities reported measuring peracetic acid concentrations. However, the manufacturer provided data on peracetic acid concentrations measured in a hospital setting with a SafeCide Peracetic Acid Monitor (ChemDAQ, Pittsburgh, PA). The concentrations of peracetic acid outside the room during operation and inside the room immediately after operation were all  $< 0.16$  ppm, and 10 minutes after cycle completion the concentration was 0 ppm. The permissible exposure limit recommended by the American Conference of Governmental Industrial Hygienists for peracetic acid as a 15-minute time weighted average is 0.4 ppm.<sup>10</sup>

None of the 3 hospitals reported serious safety concerns related to use of the fogging system. However, 1 facility did report that a nursing employee developed an exacerbation of asthma after entering a room that had been disinfected. This was thought to be related to residual acetic acid odor that is present after device operation, despite measured levels that are below the permissible exposure limit. Based on this occurrence, the facility modified the signage placed outside the door to indicate that exposure has the potential to cause respiratory irritation and shortness of breath and provided education to personnel.

## DISCUSSION

We found that the Altapure ultrasonic room fogging system was effective in eliminating *C difficile* spores, MRSA, and vancomycin-resistant *Enterococcus* on carriers placed in multiple sites throughout hospital rooms. The only exception was in drawers that were left partially open. Therefore, to achieve optimal efficacy, drawers and other enclosed areas must be fully opened to allow entry of the aerosol, as is recommended by the manufacturer. The efficacy of the system is supported by the information provided by the hospital system that uses the technology routinely (ie, killing of *G stearothermophilus* spores in multiple room locations).

The fogging system has some potential advantages and disadvantages in comparison with other automated technologies. Although we did not conduct a direct comparison, data from prior studies suggest that the fogging system will be more effective than UV-C in completely eliminating contamination.<sup>7</sup> The time required to operate the fogging system is longer than the cycles recommended for some UV-C devices, but similar to the time recommended for the spore-killing cycle of the Tru-D device (Lumalier, Memphis, TN).<sup>2</sup> Moreover, the time requirement could potentially be less for the fogging system if curtains are not changed, a separate bathroom cycle is not required, and the system operates from 1 room location (cycles in 2 room locations are recommended for some UV-C devices).<sup>5</sup> Potential disadvantages of the fogging system include the cost of the solutions and the need to close the vents and seal the door to prevent leakage of the fog.

Because peracetic acid and hydrogen peroxide have the potential to cause serious eye, skin, and respiratory tract irritation, facilities using the fogging system must take precautions to ensure the safety of personnel. The information provided by the facilities using the system suggests that the risks to personnel can be minimized if standardized protocols are followed. In addition, data from the

facilities and the manufacturer suggest that the air scrubber unit is effective in reducing concentrations of peracetic acid and hydrogen peroxide safe levels.

Our study has some limitations. We only investigated killing of pathogens on carriers. Additional studies are needed to examine elimination of pathogens from surfaces in patient rooms. Studies are also needed to directly compare efficacy of the fogging system with UV-C or hydrogen peroxide vapor systems.

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