

## COMMENTARY

## Are Room Decontamination Units Needed to Prevent Transmission of Environmental Pathogens?

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(See the article by Boyce et al, on pages 737–742.)

Healthcare-associated infections remain an important source of morbidity and mortality, with an estimated 1.7 million infections and 99,000 deaths annually. The major source of nosocomial pathogens is thought to be patients' endogenous flora, but an estimated 20%–40% of healthcare-associated infections have been attributed to cross infection via the hands of healthcare personnel.<sup>1</sup> Contamination of the hands of healthcare personnel could in turn result directly from patient contact or indirectly from touching contaminated environmental surfaces.<sup>2</sup>

There is excellent evidence in the scientific literature that environmental contamination plays an important role in the transmission of several key healthcare-associated pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Acinetobacter*, norovirus, and *Clostridium difficile*.<sup>3–6</sup> All of these pathogens have been demonstrated to persist in the environment for hours to days (and in some cases months), to frequently contaminate the environmental surfaces in rooms of colonized or infected patients, to transiently colonize the hands of healthcare personnel, to be transmitted by healthcare personnel, and to cause outbreaks in which environmental transmission was deemed to play a role. Furthermore, admission to a room in which the previous patient had been colonized or infected with MRSA, VRE, or *C. difficile* has been shown to be a risk factor for the newly admitted patient to develop colonization or infection.<sup>7</sup>

### ADEQUACY OF ROOM CLEANING AND DISINFECTION USING CHEMICAL GERMICIDES

It has long been recommended in the United States that environmental surfaces in patient rooms be cleaned and disinfected on a regular basis (eg, daily or 3 times per week), when surfaces are visibly soiled, and after patient discharge

(terminal cleaning).<sup>6</sup> Disinfection is generally performed using an Environmental Protection Agency–registered hospital disinfectant, such as a quaternary ammonium compound. Recent studies have demonstrated that adequate environmental cleaning is frequently lacking. For example, Carling and coworkers<sup>8</sup> assessed the thoroughness of terminal cleaning in the patient's immediate environment in 23 acute care hospitals (1,119 patient rooms) by using a transparent, easily cleaned, stable solution that fluoresces when exposed to hand-held UV light. The overall thoroughness of cleaning, expressed as a percentage of surfaces evaluated, was 49% (range for all hospitals, 35%–81%). Using a similar design, Carling and associates<sup>9</sup> assessed environmental cleaning in intensive care unit rooms in 16 hospitals (2,320 objects) and demonstrated that only 57.1% of sites were cleaned after discharge of the room's occupant. A recent study by Havill et al<sup>10</sup> using adenosine triphosphate (ATP) bioluminescence assays and aerobic cultures demonstrated that medical equipment frequently had not been disinfected according to protocol.

### IMPROVING ROOM CLEANING AND DISINFECTION AND DEMONSTRATING THE EFFECTIVENESS OF SURFACE DECONTAMINATION IN REDUCING HEALTHCARE-ASSOCIATED INFECTIONS

Several investigators have reported that intervention programs aimed at environmental services workers resulted in significant improvement in cleaning practices.<sup>11–13</sup> Such interventions have generally included multiple activities: improved education, monitoring the thoroughness of cleaning (eg, by use of ATP assays or fluorescent dyes) with feedback of performance to the environmental service workers, and/or use of cleaning checklists. We have found that assignment of cleaning responsibility (eg, medical equipment to be cleaned by nursing or

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TABLE 1. Comparison of Room Decontamination Systems That Use UV Irradiation and Hydrogen Peroxide (HP)

	Sterinis	Steris	Bioquell	Tru-D
Abbreviation	DMHP (dry mist HP)	VHP (vaporized HP)	HPV (HP vapor)	UV-C
Active agent	Stenusul (5% HP, <50 ppm silver cations)	Vaprox (35% HP)	35% HP	UV-C irradiation at 254 nm
Application	Aerosol of active solution	Vapor, noncondensing	Vapor, condensing	UV irradiation, direct and reflected
Aeration (removal of active agent from enclosure)	Passive decomposition	Active catalytic conversion	Active catalytic conversion	Not necessary
Sporicidal efficacy	Single cycle does not inactivate <i>Bacillus atrophaeus</i> BIs; ~4-log <sub>10</sub> reduction in <i>Clostridium difficile</i> <sup>a</sup> and incomplete inactivation in situ	Inactivation of <i>Geobacillus stearothermophilus</i> BIs	Inactivation of <i>G. stearothermophilus</i> BIs; >6-log <sub>10</sub> reduction in <i>C. difficile</i> <sup>a</sup> in vitro and complete inactivation in situ	1.7–4-log <sub>10</sub> reduction in <i>C. difficile</i> <sup>a</sup> in situ
Evidence of clinical impact	None published	None published	Significant reduction in the incidence of <i>C. difficile</i>	None published

NOTE. Adapted from Otter and Yezli.<sup>18</sup> BIs, biological indicators; VRE, vancomycin-resistant *Enterococcus*.

<sup>a</sup> All *C. difficile* experiments were done with *C. difficile* spores.

environmental surfaces to be cleaned by environmental service) is also important to ensure that all objects and surfaces are decontaminated, especially the surfaces of medical equipment (eg, cardiac monitors). Improved environmental cleaning has been demonstrated to reduce environmental contamination with VRE,<sup>14–16</sup> MRSA,<sup>15</sup> and *C. difficile*.<sup>16</sup> Importantly, no study has reported proper cleaning of more than 85% of objects in the postintervention period. Furthermore, all studies have focused improvement on only a limited number of “high-risk” objects. At the University of North Carolina Health Care, we were also able to achieve substantial improvements in the thoroughness of cleaning (as demonstrated by removal of fluorescent dye spots), yet when we altered the location of these dye spots on high-risk objects to include other objects we demonstrated that the appropriate cleaning of objects dropped from 90% to approximately 60% of spotted objects (W.A.R., L. Osborne, unpublished observations). Thus, a concern of published studies is that they have only demonstrated improved cleaning of a limited number of high-risk objects (or “targeted” objects), not an improvement in the overall thoroughness of room decontamination.

#### “NO-TOUCH” METHODS FOR ROOM DISINFECTION

As noted above, multiple studies have demonstrated that environmental surfaces and objects in rooms are frequently not properly cleaned. Furthermore, while interventions aimed at improving cleaning thoroughness have demonstrated effectiveness, many surfaces remain inadequately cleaned and therefore potentially contaminated. For this reason, several manufacturers have developed room disinfection units that can decontaminate environmental surfaces and objects. These systems use one of 2 methods—either UV light<sup>17,18</sup> or hy-

drogen peroxide<sup>17</sup> (HP; Table 1). These technologies supplement but do not replace standard cleaning and disinfection because surfaces must be physically cleaned of dirt and debris.

#### UV LIGHT FOR ROOM DECONTAMINATION

UV irradiation has been used for the control of pathogenic microorganisms in a variety of applications, such as control of legionellosis, as well as disinfection of air, surfaces, and instruments.<sup>6,19</sup> At certain wavelengths, UV light will break the molecular bonds in DNA, thereby destroying the organism. UV-C has a characteristic wavelength of 200–270 nm (eg, 254 nm), which lies in the germicidally active portion of the electromagnetic spectrum of 200–320 nm. The efficacy of UV irradiation is a function of many different parameters, such as intensity, exposure time, lamp placement, and air movement patterns.

An automated mobile UV-C unit (Tru-D; Lumalier) has been shown to eliminate more than 3-log<sub>10</sub> vegetative bacteria (MRSA, VRE, and *Acinetobacter baumannii*) and more than 2.4-log<sub>10</sub> *C. difficile* seeded onto Formica surfaces in experimentally contaminated patient rooms.<sup>20</sup> In this issue of the journal, Boyce et al<sup>21</sup> report the results of assessing the effectiveness of the same UV-C unit (Tru-D) in reducing environmental contamination with vegetative bacteria (measured using aerobic colony counts) and *C. difficile* inoculated onto stainless steel carrier disks. Room decontamination with the UV system resulted in significant reductions in aerobic bacteria on 5 high-touch surfaces. Mean *C. difficile* log<sub>10</sub> reductions ranged from 1.8 to 2.9 when cycle times of 34.2–100.1 minutes were used. Surfaces in direct line of sight were significantly more likely to yield negative culture results after UV decontamination than before decontamination. There are now 3 studies that have demonstrated that this UV-

TABLE 2. Advantages and Disadvantages of Room Decontamination Using UV Irradiation and Hydrogen Peroxide (HP)

## UV irradiation

## Advantages

- Reliable biocidal activity against a wide range of healthcare-associated pathogens
- Room surfaces and equipment decontaminated
- Room decontamination is rapid (~15 minutes) for vegetative bacteria
- Effective against *Clostridium difficile*, although longer exposure is required (~50 minutes)
- HVAC system does not need to be disabled, and the room does not need to be sealed
- UV light is residual-free and does not give rise to health or safety concerns
- No consumable products so costs include only capital equipment and staff time
- Good distribution in the room of UV energy via an automated monitoring system

## Disadvantages

- All patients and staff must be removed from the room before decontamination
- Decontamination can be accomplished only at terminal disinfection (ie, cannot be used for daily disinfection) because the room must be emptied of people
- Capital equipment costs are substantial
- Does not remove dust and stains, which are important to patients and visitors; hence, cleaning must precede UV decontamination
- Sensitive to use parameters (eg, wavelength, UV dose delivered)
- Requires that equipment and furniture be moved away from walls
- Studies have not been conducted to demonstrate whether use of UV room decontamination decreases the incidence of healthcare-associated infections

## HP systems

## Advantages

- Reliable biocidal activity against a wide range of healthcare-associated pathogens
- Room surfaces and equipment decontaminated
- Effective against *C. difficile*
- Useful for disinfecting complex equipment and furniture
- Does not require that furniture and equipment be moved away from the walls
- HP is residual-free and does not give rise to health or safety concerns (aeration unit converts HP into oxygen and water)
- Uniform distribution in the room via an automated dispersal system
- Demonstrated to reduce healthcare-associated infections (ie, *C. difficile*)

## Disadvantages

- All patients and staff must be removed from the room before decontamination
- HVAC system must be disabled to prevent unwanted dilution of HP during use, and doors must be closed with gaps sealed by tape
- Decontamination can be accomplished only as terminal disinfection (ie, cannot be used for daily disinfection) because the room must be emptied of people
- Capital equipment costs are substantial
- Decontamination requires ~3–5 hours
- Does not remove dust and stains, which are important to patients and visitors; hence, cleaning must precede HP decontamination
- Sensitive to use parameters (eg, HP concentration)

NOTE. HVAC, heating, ventilation, and air conditioning.

C system is capable of reducing vegetative bacteria inoculated on a carrier by 3–4 log<sub>10</sub> in 15–20 minutes and *C. difficile* by 1.7–4 log<sub>10</sub> in 35–100 minutes.<sup>20–22</sup> The studies also demonstrated reduced effectiveness when surfaces were not in direct line of sight.

#### HP SYSTEMS FOR ROOM DECONTAMINATION

Several systems that produce HP (eg, HP vapor, aerosolized dry mist HP, and vaporized HP) have been studied for their ability to decontaminate environmental surfaces and objects

in hospital rooms (Table 1). A system using HP vapor has been demonstrated to completely inactivate >10<sup>6</sup> *Geobacillus stearothermophilus* spores contained in biological indicators hung in patient rooms and almost eliminate all MRSA surface contamination.<sup>23</sup> Other studies have also demonstrated the ability of HP to almost eliminate MRSA, VRE, and drug-resistant gram-negative bacilli.<sup>24</sup> Importantly, Boyce and co-workers,<sup>25</sup> using a before-after design, have shown that use of the HP systems was associated with a significant reduction in the incidence of *C. difficile* infection on 5 high-incidence wards. However, HP system decontamination was shown to

take more than 4 times longer to complete than conventional cleaning, thus resulting in prolonged bed turnover time.<sup>26</sup>

#### COMPARISON OF UV IRRADIATION AND HP FOR ROOM DECONTAMINATION

The UV-C system studied by Boyce et al<sup>21</sup> and the systems that use HP have their own advantages and disadvantages (Table 2). The main advantage of both units is their ability to achieve substantial reductions in vegetative bacteria. As noted above, manual cleaning has been demonstrated to be suboptimal because many environmental surfaces are not cleaned. Another advantage is their ability to substantially reduce *C. difficile*, given that low-level disinfectants (such as quaternary ammonium compounds) have limited or no measurable activity against spore-forming bacteria.<sup>5</sup> Both systems are residual-free, and they decontaminate all exposed surfaces and equipment in the room.

The major disadvantages of both decontamination systems are the substantial capital equipment costs; the need to remove personnel and patients from the room, thus limiting their use to terminal room disinfection (must prevent or minimize exposure to UV light and HP); the staff time needed to transport the system to rooms to be decontaminated and monitor its use; the need to physically clean the room of dust and debris; and the sensitivity to use parameters. There are several important differences between the 2 systems. The UV-C system offers faster decontamination, which reduces the "down time" of the room before another patient can be admitted. The HP systems have been demonstrated to be more effective in eliminating spore-forming organisms. Whether this improved sporicidal activity is clinically important is unclear, given that studies have demonstrated that although environmental contamination is common in the rooms of patients with *C. difficile* infection, the level of contamination is relatively low (this is also true for MRSA and VRE). Finally, the HP systems were demonstrated to reduce *C. difficile* incidence in a clinical study,<sup>25</sup> whereas similar studies with the UV-C system have not been published.

#### CONCLUSIONS

Ample evidence exists that environmental contamination with important healthcare-associated pathogens (MRSA, VRE, *Acinetobacter*, norovirus, and *C. difficile*) poses a risk for patient-to-patient transmission of these organisms. Multiple studies have demonstrated that environmental service workers frequently fail to decontaminate high-risk objects. Importantly, a recent study by Stiefel et al<sup>27</sup> demonstrated that contact with the environment was just as likely to contaminate the hands of healthcare workers as was direct contact with the patient.

Although an intervention bundle can improve cleaning by environmental service workers, it remains suboptimal, with many objects and surfaces not cleaned. Furthermore, the ability to achieve high rates of cleaning long term has not been

demonstrated. While no-touch room decontamination systems might aid in reducing or eliminating environmental contamination after terminal room disinfection, we still need to develop new practices or technologies to improve the thoroughness of daily room cleaning (eg, tinted germicides that color surfaces when applied, but the color disappears once it dries).

There is now ample evidence that no-touch systems such as UV-C light or HP can reduce environmental contamination with healthcare-associated pathogens. However, each specific system should be studied and its efficacy demonstrated (similar to systems in Table 1) before being introduced into healthcare facilities. Importantly, only a single study using a before-after design has been published that demonstrated that such a system can reduce healthcare-associated infections. Additional studies assessing the effectiveness of no-touch room decontamination systems are needed to further assess the benefits of these technologies. In addition, cost-effectiveness studies would be useful in aiding selection among the different room decontamination technologies and specific systems. Last, if additional studies continue to demonstrate a benefit, then widespread adoption of these technologies (eg, as a supplemental intervention during outbreaks, after discharge of patients under contact precautions, and on a regular basis in special rooms [eg, operating rooms]) should be considered for terminal room disinfection in healthcare facilities.

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