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Major article

Effectiveness of ultraviolet devices and hydrogen peroxide systems for terminal room decontamination: Focus on clinical trials

David J. Weber MD, MPH [a,b,*], William A. Rutala PhD, MPH [a,b], Deverick J. Anderson MD, MPH [c], Luke F. Chen MBBS, MPH [c], Emily E. Sickbert-Bennett PhD, MS [a,b], John M. Boyce MD [d]

[a] Department of Hospital Epidemiology, University of North Carolina Health Care, Chapel Hill, NC
[b] Division of Infectious Diseases, University of North Carolina School of Medicine, Chapel Hill, NC
[c] Division of Infectious Diseases, Duke University Medical School, Durham, NC
[d] Division of Infectious Diseases, Yale School of Medicine, New Haven, CT

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Over the last decade, substantial scientific evidence has accumulated that indicates contamination of environmental surfaces in hospital rooms plays an important role in the transmission of key health care–associated pathogens (eg, methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, *Clostridium difficile*, *Acinetobacter* spp). For example, a patient admitted to a room previously occupied by a patient colonized or infected with one of these pathogens has a higher risk for acquiring one of these pathogens than a patient admitted to a room whose previous occupant was not colonized or infected. This risk is not surprising because multiple studies have demonstrated that surfaces in hospital rooms are poorly cleaned during terminal cleaning. To reduce surface contamination after terminal cleaning, no touch methods of room disinfection have been developed. This article will review the no touch methods, ultraviolet light devices, and hydrogen peroxide systems, with a focus on clinical trials which have used patient colonization or infection as an outcome.

Multiple studies have demonstrated that ultraviolet light devices and hydrogen peroxide systems have been shown to inactivate microbes experimentally plated on carrier materials and placed in hospital rooms and to decontaminate surfaces in hospital rooms naturally contaminated with multidrug-resistant pathogens. A growing number of clinical studies have demonstrated that ultraviolet devices and hydrogen peroxide systems when used for terminal disinfection can reduce colonization or health care–associated infections in patients admitted to these hospital rooms.

Health care–associated infections (HAIs) remain an important source of patient morbidity and mortality. Based on a large sample of U.S. acute care hospitals, approximately 4% of patients on any given day have at least 1 HAI.[1] Overall, there were an estimated 722,000 HAIs in U.S. acute care hospitals in 2011; approximately 75,000 hospital patients with an HAI died during their hospitalization. It has been estimated that the source of pathogens causing an HAI in the intensive care unit was the patients' endogenous flora (40%-60%); cross-infection via the hands of health care personnel (HCP; 20%-40%); antibiotic-driven changes in flora (20%-25%); and other (including contamination of the environment; 20%).[2] Further, contamination of the hands of HCP could result directly from patient contact or indirectly from touching contaminated environmental surfaces.[3] It has been shown that the gloves or hands of HCP are just as likely to become contaminated from touching a patient as touching an environmental surface in a patient's room.[4,5]

Over the last decade, substantial scientific evidence has accumulated that contamination of environmental surfaces in hospital rooms plays an important role in the transmission of several key health care–associated pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Clostridium difficile*, *Acinetobacter* spp, and norovirus.[6-11] In general, all of these pathogens share the following characteristics:

* Address correspondence to David J. Weber, MD, MPH, 2163 Bioinformatics, CB #7030, Chapel Hill, NC 27599-7030.
E-mail address: dweber@unch.unc.edu (D.J. Weber).
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ability to survive for prolonged periods of times on environmental surfaces, ability to remain virulent after environmental exposure, frequent contamination of the hospital environment, ability to colonize patients, ability to transiently colonize the hands of HCP, and transmission via the contaminated hands of HCP.[8] Norovirus and *C difficile* also are noted for a small inoculating dose and relative resistance to antiseptics and disinfectants used on environmental surfaces. Evidence supporting the role of the contaminated surface environment in the transmission of several key health care–associated pathogens is summarized as follows:

- The surface environment in rooms of colonized or infected patients is frequently contaminated with the pathogen.
- The pathogen is capable of surviving on hospital room surfaces and medical equipment for a prolonged period of time.
- Contact with hospital room surfaces or medical equipment by HCP frequently leads to contamination of hands or gloves.
- The frequency with which room surfaces are contaminated correlates with the frequency of hand or glove contamination of HCP.
- The patient admitted to a room previously occupied by a patient colonized or infected with a pathogen (eg, MRSA, VRE, *C difficile*, *Acinetobacter* spp) has an increased likelihood of developing colonization or infection with that pathogen.
- Improved terminal cleaning of rooms leads to a decreased rate of individual patient colonization and infection.
- Improved terminal cleaning of rooms leads to a decreased facility-wide rate of colonization and infection.
- Improved terminal disinfection with a no touch method leads to a decreased rate of infection in patients subsequently admitted to a room where the prior occupant was colonized or infected.
- Improved terminal disinfection with a no touch method leads to a decreased rate of facility-wide colonization and infection.

This article will review no touch methods for terminal room disinfection, specifically ultraviolet (UV) light devices or hydrogen peroxide systems, with a focus on studies that have assessed whether use of these technologies has been demonstrated to reduce HAIs.

RATIONALE FOR USING A NO TOUCH METHOD FOR TERMINAL ROOM DISINFECTION

Multiple studies have demonstrated that surfaces in hospital rooms are poorly cleaned during terminal cleaning. Although methods of assessing the adequacy of cleaning varied (ie, visibly clean, adenosine triphosphate bioluminescence, fluorescent dye, aerobic plate counts), several studies have demonstrated that <50% of room surfaces were properly cleaned.[12-18] Several reviews have concluded that improved cleaning leads to reductions in HAI.[11,19] However, there is a paucity of high-quality studies demonstrating that improved cleaning and disinfection reduces HAIs.[20,21] Importantly, the studies that have assessed interventions to improve cleaning have reported that after the intervention, approximately 5%-30% of surfaces remain potentially contaminated.[12-18]

Because of the demonstrated failure of interventions to achieve consistent and high rates of cleaning and disinfection of room surfaces, new no touch methods of room disinfection have been developed. The most promising no touch methods use either UV light devices or hydrogen peroxide systems.[22-24]

UV LIGHT DEVICES FOR TERMINAL ROOM DECONTAMINATION

Background

UV irradiation has been used for control of pathogenic microorganisms in a variety of applications, such as control of legionellosis, and disinfection of air, surfaces, and instruments.[22] At certain wavelengths, UV light will break the molecular bonds in DNA, thereby destroying the organism. Most UV room disinfection devices use UV-C irradiation which has a characteristic wavelength of 200-270 nm (eg, 254 nm) that lies in the germicidal active portion of the electromagnetic spectrum of 200-320 nm. Another UV device uses pulsed-xenon radiation, which produces UV light in the 200- to 320-nm range.

The efficacy of UV irradiation devices used for hospital room disinfection is a function of many parameters, including organic load, pathogen, intensity, dose, distance from the device, exposure time, direct line of sight from device or shaded exposure, lamp placement, room size and shape, and surface. Few studies have systematically investigated how these parameters affect the effectiveness of UV irradiation. Nerandzic et al studied 2 UV room disinfection devices (Tru-D [Tru-D SmartUVC, Memphis, TN] and PATHOGON® [STERIS, Mentor, OH]) and reported the following: (1) pathogen concentration did not significantly impact the killing efficacy of the devices; (2) both a heavy and light organic load had a significant negative impact on the killing efficacy of the devices; and (3) increasing the distance to ~3.05 m from the devices reduced the killing efficacy to ≤3 $\log_{10}$ colony forming units/cm^2 for MRSA and VRE and <2 $\log_{10}$ colony forming units/cm^2 for *C difficile* spores.[25] Cadnum et al studied how various parameters affected the effectiveness of a UV-C device (Optimum-UV™, Clorox, Oakland, CA) and reported the following: (1) spreading the inoculum over a greater surface area significantly enhanced killing of MRSA and *C difficile*; (2) orientation of the carrier disks in parallel rather than perpendicular with the UV-C enhanced killing; (3) presence of an organic load also impacted the measured efficacy of UV-C under certain test conditions; (4) use of plastic, formica, and glass slides resulted in similar killing when compared with steel carrier disks, provided manual spreading was used; and (5) heights from floor level to 6 ft did not affect killing at 1.83 m using Optimum.[26]

UV device effectiveness to reduce intentionally contaminated sites

Multiple studies have assessed the effectiveness of UV devices to inactivate microbes inoculated onto various test surfaces which are then placed in a typical hospital room (Table 1).[27-33] In general, the inoculating doses were >4 $\log_{10}$ in order to fully assess the level of bacterial inactivation. The most commonly tested organisms were epidemiologic important health care–associated pathogens and included MRSA, VRE, *C difficile*, and *Acinetobacter* spp.

One can conclude the following from the reported results: (1) > 3 $\log_{10}$ vegetative organisms can be killed in 5-25 minutes by UV-C; (2) it requires greater time and energy to kill a spore-forming organism, such as *C difficile*; (3) the level of inactivation of pulsed xenon may be less than for UV-C; however, this is based on a limited number of published results; and (4) the level of inactivation on surfaces in direct line of sight of the UV device may be up to 2 $\log_{10}$ greater than for *C difficile* not in the direct line of sight. There appears to be substantial consistency across many studies regarding the effectiveness of UV-C; however, most studies have used the same device (ie, Tru-D), and only a few of the UV devices commercially available have actually been studied. The time needed to inactivate pathogens has been demonstrated to be shortened by use of UV reflective wall paint for multiple different UV-C devices.[30,32]

UV device effectiveness to reduce actual contaminated sites

Multiple studies have assessed the effectiveness of UV devices to decontaminate actual hospital rooms after discharge of a patient colonized or infected with a multidrug-resistant pathogen (Table 2).[27,33-37] Pathogens evaluated included MRSA, VRE, *Acinetobacter* spp, and *C difficile*. Cycle times for vegetative