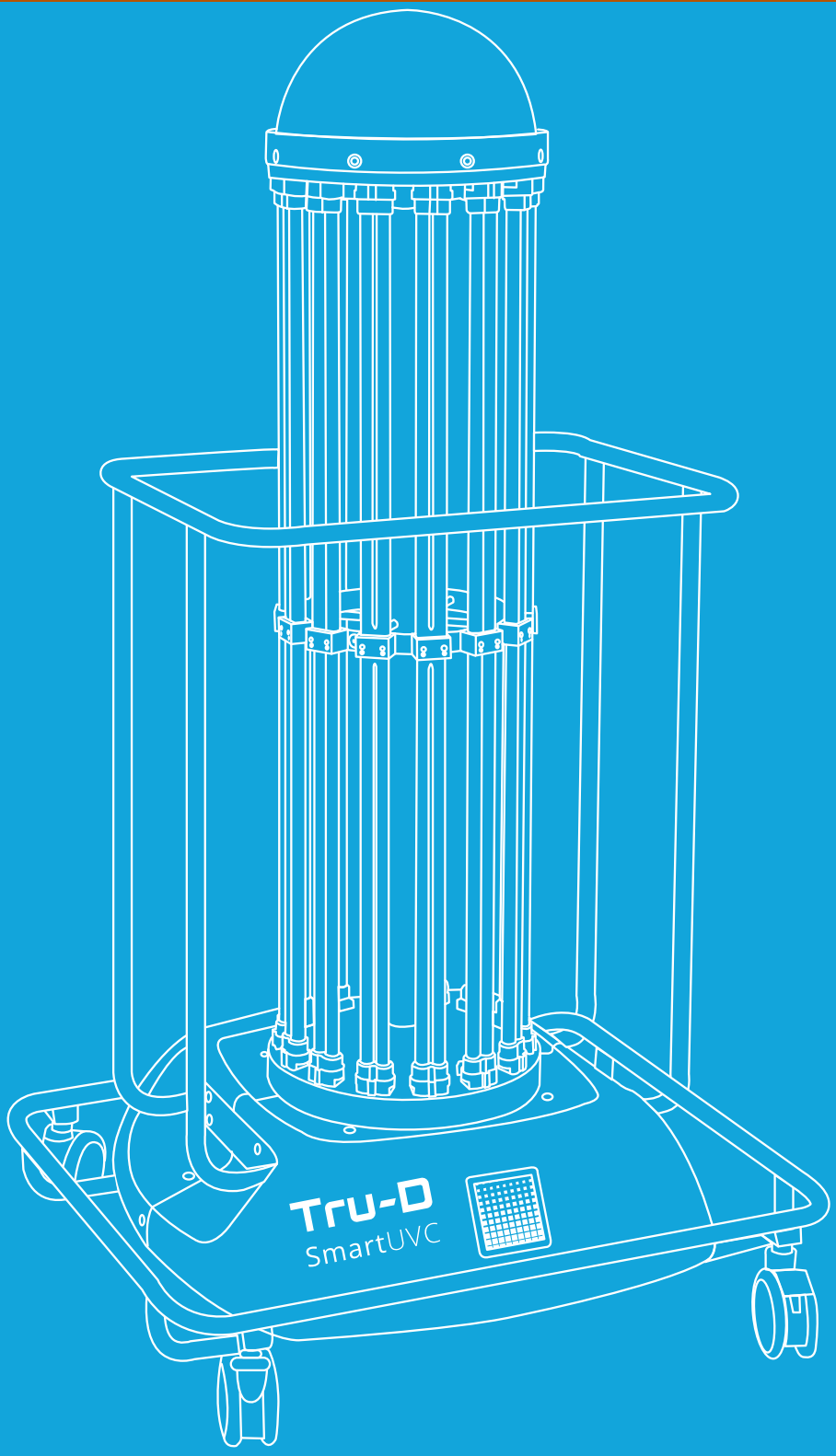

CASE STUDY

‘NO TOUCH’ TECHNOLOGIES FOR ENVIRONMENTAL DECONTAMINATION: FOCUS ON ULTRAVIOLET DEVICES

‘No touch’ technologies for environmental decontamination: focus on ultraviolet devices and hydrogen peroxide systems

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Purpose of review
This article reviews ‘no touch’ methods for disinfection of the contaminated surface environment of hospitalized patients’ rooms. The focus is on studies that assessed the effectiveness of ultraviolet (UV) light devices, hydrogen peroxide systems, and self-disinfecting surfaces to reduce healthcare-associated infections (HAIs).

Recent findings
The contaminated surface environment in hospitals plays an important role in the transmission of several key nosocomial pathogens including methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus* spp., *Clostridium difficile*, *Acinetobacter* spp., and norovirus. Multiple clinical trials have now demonstrated the effectiveness of UV light devices and hydrogen peroxide systems to reduce HAIs. A limited number of studies have suggested that ‘self-disinfecting’ surfaces may also decrease HAIs.

Summary
Many studies have demonstrated that terminal cleaning and disinfection with germicides is often inadequate and leaves environmental surfaces contaminated with important nosocomial pathogens. ‘No touch’ methods of room decontamination (i.e., UV devices and hydrogen peroxide systems) have been demonstrated to reduce key nosocomial pathogens on inoculated test surfaces and on environmental surfaces in actual patient rooms. Further UV devices and hydrogen peroxide systems have been demonstrated to reduce HAI. A validated ‘no touch’ device or system should be used for terminal room disinfection following discharge of patients on contact precautions. The use of a ‘self-disinfecting’ surface to reduce HAI has not been convincingly demonstrated.

Keywords
healthcare-associated infections, hydrogen peroxide systems, room decontamination, surface environment, UV devices

INTRODUCTION

Healthcare-associated infections (HAIs) remain an important source of patient morbidity and mortality. Based on a large sample of U.S. acute care hospitals, ~4% of patients on any given day has at least one HAI [1]. Based on this study, it was estimated that 722 000 HAIs occurred in 2011 in U.S. acute care hospitals which resulted in ~75 000 deaths. The total annual costs for the five major HAIs have been estimated to be $9.8 billion (2012 US dollars) [2]. Dr Weinstein 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 healthcare personnel (HCP), 20–40%; antibiotic-driven changes in flora, 20–25%; and other (including contamination of the environment), 20% [3]. Further, contamination of the hands of HCP could result directly from patient contact or indirectly from touching contaminated environmental surfaces [4]. 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 [5,6].

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Curr Opin Infect Dis 2016, 29:000–000
DOI:10.1097/QCO.0000000000000284

KEY POINTS

- The contaminated surface environment in patient rooms has been linked to transmission of several important nosocomial pathogens including MRSA, VRE, *C. difficile*, *Acinetobacter* spp., and norovirus.
- Multiple studies have demonstrated that a substantial number of room surfaces are not adequately cleaned following patient discharge. Admittance to a room previously occupied by a patient colonized or infected with a multidrug-resistant pathogen (e.g., MRSA, VRE, *Acinetobacter*) results in the newly admitted patient having an increased risk of acquiring that pathogen by 39–353%.
- Because room surfaces are frequently not clean/disinfected during terminal cleaning, multiple 'no touch' methodologies have been invented for terminal room disinfection. The most studied technologies are UV devices and hydrogen peroxide systems.
- UV devices and hydrogen peroxide systems have been shown to eliminate clinically relevant numbers of important nosocomial pathogens from inoculated test objects and from actual room surfaces.
- Multiple clinical trials have now demonstrated that UV devices and hydrogen peroxide systems decrease HAIs due to multidrug-resistant pathogens. Although many of the studies are of low quality, the consistency of the studies and the few well designed studies lead one to conclude that 'no touch' technologies are an effective method for enhancing terminal room disinfection and reducing the incidence of HAIs.

This article will briefly review the following: first, data demonstrating that the contaminated surface environment in a hospitalized patent's room plays an important role in the transmission of several key healthcare-associated pathogens; second, the rationale for the development and use of 'no-touch' methods of room decontamination; and third, the evidence supporting the effectiveness from room decontamination of ultraviolet (UV) light devices and hydrogen peroxide systems. This review will focus on the recent studies demonstrating the effectiveness of 'no-touch' methods to decrease HAIs, and update and expand a recent paper that reviewed the ability of UV devices and hydrogen peroxide systems to decrease HAI [7▪].

ROLE OF THE CONTAMINATED SURFACE ENVIRONMENT IN TRANSMISSIN OF HEALTHCARE-ASSOCIATED PATHOGENS

Over the past decade, substantial scientific evidence has accumulated that contamination of environmental surfaces in hospital rooms plays an important role in the transmission of several key healthcare-associated pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* spp. (VRE), *Clostridium difficile*, *Acinetobacter* spp., and norovirus [8–11,12▪]. In general, all these pathogens share the following characteristics: ability to survive for prolonged periods of time 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 healthcare-associated pathogens is summarized as follows:

(1) The surface environment in rooms of colonized or infected patients is frequently contaminated with the pathogen.
(2) The pathogen is capable of surviving on hospital room surfaces and medical equipment for a prolonged period of time.
(3) Contact with hospital room surfaces or medical equipment by HCP frequently leads to contamination of hands and/or gloves.
(4) The frequency with which room surfaces are contaminated correlates with the frequency of hand and/or glove contamination of HCP.
(5) Daily use of a disinfectant instead of a detergent reduces HAI rates.
(6) The patient admitted to a room previously occupied by a patient colonized or infected with a pathogen (e.g., MRSA, VRE, *C. difficile*, *Acinetobacter*) has an increased likelihood of developing colonization or infection with that pathogen.
(7) Daily disinfection of room surfaces (versus clean only if soiled) reduces acquisition of pathogens on hands of HCP after contact with surfaces or patients.
(8) Improved terminal cleaning of rooms leads to a decreased rate of individual patient colonization and/or infections.
(9) Improved terminal cleaning of rooms leads to a decreased facility-wide rate of colonization and/or infection.
(10) Improved terminal disinfection with a 'no-touch' method leads to a decreased rate of infection in patients subsequently admitted to a room in which the prior occupant was colonized or infected.

(11) Improved terminal disinfection with a 'no-touch' method leads to a decreased rate of facility-wide colonization and/or infection.

Importantly, admission to a room wherein the previous occupant was colonized or infected with a multidrug-resistant pathogen (e.g., MRSA, VRE, *Acinetobacter* spp.) has been shown to increase the risk of acquiring that pathogen by 39–353% [9,13▪▪].

Recent studies have extended the findings on the role of the environment in the transmission of nosocomial pathogens. A variety of medically important viruses have been found to be able to survive for an epidemiologically important duration as well as contaminate environmental surfaces including influenza viruses, severe acute respiratory disease-coronavirus and Middle East respiratory syndrome-coronavirus [14▪,15]. Carbapenem-resistant *Enterobacteriaceae* (CRE) have been demonstrated to contaminate the environmental surfaces near colonized patients [16]. However, CRE strains do not survive for prolonged periods on environmental surfaces decreasing the risk that subsequent patients would acquire the pathogen [17]. As noted above the surface environment in rooms of colonized or infected patients is frequently contaminated. Recently, environmental contamination has been demonstrated in the rooms of *C. difficile* excretors without diarrhea or active infection [18–20]. Several recent papers have demonstrated the presence of medically important nosocomial pathogens (e.g., MRSA, VRE, *C. difficile*) on the surfaces in rooms of patients not colonized or infected with the pathogen thus emphasizing the need for appropriate terminal disinfection of all hospital rooms [21,22].

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 (i.e., visibly clean, ATP bioluminescence, fluorescent dye, aerobic plate counts), several studies have demonstrated that less than 50% of room surfaces were properly cleaned [23,24]. Improved cleaning has been demonstrated to lead to reductions in HAIs [25]. However, it has been reported that there is a paucity of high-quality studies demonstrating that improved cleaning/disinfection reduces HAIs [26]. Importantly, the studies that have assessed interventions to improve cleaning have reported that following the intervention, 5 to ~30% of surfaces remain potentially contaminated [24].

'NO TOUCH' METHODS FOR DECONTAMINATING HOSPITAL ROOM SURFACES

As noted above, multiple studies have demonstrated that environmental surfaces and objects in rooms are frequently improperly cleaned/disinfected and these surfaces may be important in transmission of healthcare-associated pathogens. Further, although interventions aimed at improving cleaning thoroughness have demonstrated effectiveness, many surfaces remain inadequately cleaned and therefore, potentially contaminated. For this reason, multiple new methodologies have been developed to decontaminate environmental surfaces (i.e., 'no touch' methods) (Table 1) [7▪,27,28,29▪▪,30▪▪,31▪]. In addition, new technologies have been developed to inhibit the growth of microbes on environmental surfaces (i.e., 'self-disinfecting surfaces') (Table 1) [32,33,34▪▪].

There are now substantial data demonstrating the effectiveness of 'no touch' methodologies for terminal room disinfection. These methodologies fall into two broad classes; devices that use UV light and systems that generate hydrogen peroxide

Table 1. 'No touch' methodologies for decontamination of hospital room surfaces

Room decontamination methodologies for terminal room decontamination
Ultraviolet light devices
UV-C
UV-pulsed xenon
Hydrogen peroxide systems
Hydrogen peroxide vapor (30–35% H_2O_2)
Aerosolized hydrogen peroxide systems (5–6% H_2O_2 plus silver)
Room decontamination methodologies for continuous decontamination
High-intensive narrow-spectrum light
Low dose continuous hydrogen peroxide
Spot surface decontamination methodologies
Handheld UV devices
Steam cleaning
'Self-disinfecting' surfaces
Antimicrobial coatings
Copper
Silver
Triclosan
Polycationic and light-activated antimicrobial surfaces
Bacteriophage-modified surfaces
Altered topography [e.g., shark skin-like surfaces such as Sharklet AF (Sharklet Technologies, Alachua, Florida)]

[7▪,27,28,29▪▪,30▪▪,31▪]. Ultraviolet light – C (UV-C) devices use specifically designated wavelengths (254 nm range) and deliver targeted doses for vegetative bacteria (e.g., 12 000 μW s/cm^2) or for spores (22 000–36,000 μW s/cm^2) on surfaces, while the UV pulsed xenon devices emit broad spectrum UV in short pulses [28]. There are currently two major hydrogen peroxide systems [27]. First, H_2O_2 vapor systems that deliver a heat-generated vapor of 30–35% (w/w) aqueous H_2O_2 through a high-velocity air stream to achieve homogeneous distribution throughout an enclosed area. Second, aerosolized H_2O_2 systems deliver a pressure-generated aerosol [27]. The systems employed most frequently in healthcare use a solution containing 5–6% H_2O_2 and less than 50 ppm silver. Aerosolized droplets are introduced into an enclosure via a unidirectional nozzle.

Ultraviolet light devices

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 [7▪,29▪▪,30▪▪]. In general, the inoculating doses were more than 4-log$_{10}$ in order to fully assess the level of inactivation. The most commonly tested organisms were epidemiologically important healthcare-associated pathogens and included MRSA, VRE, *C. difficile*, and *Acinetobacter* spp. From these studies one can conclude that more than 3-log$_{10}$ vegetative organisms can be killed in 5–25 min by UV, but it requires greater time and energy to kill a spore-forming organism such as *C. difficile*. All studies have reported reduced killing via indirect versus direct line of sight from the UV device. 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 [35,36]. In addition, multiple studies have assessed the effectiveness of UV devices to decontaminate actual hospital rooms following discharge of a patient colonized or infected with a multidrug-resistant pathogen [7▪,29▪▪,30▪▪]. Pathogens evaluated included MRSA, VRE, *Acinetobacter*, and *C. difficile*. Cycle times for vegetative bacteria ranged from 10 to 25 min and for *C. difficile* from 10 to 45 min. In all cases the frequency of positive surface sites post-treatment was less than 11% and in many cases was less than 1%. The reported log$_{10}$ reductions were always greater than 2. It is important to understand that the bioburden on contaminated surfaces in hospital rooms is relatively low and therefore the reduction in frequency of positive surface sites is a better measure of UV effectiveness than the log$_{10}$ reduction.

Hydrogen peroxide systems

The effectiveness of H_2O_2 vapor systems has been well studied [7▪,27,37]. Multiple studies have demonstrated the ability of H_2O_2 vapor systems to inactivate viruses and bacteria inoculated onto test surfaces. H_2O_2 vapor systems are capable of inactivating nonenveloped viruses, mycobacteria, and even high numbers of bacterial spores. Further, multiple studies have demonstrated the ability of hydrogen peroxide systems to reduce multidrug-resistant organisms (MDROs) contaminating surfaces in hospital rooms [7▪,27,29▪▪,30▪▪]. In the majority of studies, the number of contaminated surfaces was reduced to 0% and in all cases to less than 5%. Of note, none of the studies described the log$_{10}$ reduction in pathogens. It is important to realize that there are key differences in the manner in which the various H_2O_2-based room disinfection systems generate and deliver their active agent. H_2O_2 vapor systems use heat to generate hydrogen peroxide vapor (HPV) from 30 to 35% H_2O_2, while aerosolized H_2O_2 systems use pressure or ultrasonic nebulization to generate H_2O_2 from 5 to 6%. These systems have fundamental differences which result in the H_2O_2 vapor systems having an increased level of efficacy, homogeneous distribution, and shorter cycle times [27,37,38].

Recent studies assessing the use parameters and effectiveness of ultraviolet devices and hydrogen peroxide systems

Hydrogen peroxide vapor has been demonstrated to inactivate key pathogens (i.e., MRSA, VRE, *Acinetobacter*) on both porous and nonporous surfaces [39].

Several recent studies have assessed the effect of use parameters on the effectiveness of UV devices. Boyce *et al.* [40] studied the impact of distance and orientation using inoculated (MRSA, VRE, *C. difficile*) test objects on the effectiveness of a single UV-C device. They concluded that UV-C irradiance, dosage, and antimicrobial effect received from a mobile UV-C device varied substantially based on location in a room relative to the UV-C device. Cadnum *et al.* [41] compared UV-C devices and concluded that variations in test methods can significantly impact measured reductions in pathogens by UV-C devices during experimental testing. Specifically, they reported that the following factors affected pathogen killing: spreading the inoculum over a larger surface area enhanced killing, orientation of the carriers in parallel rather than perpendicular enhanced killing, and different types of organic load affecting killing. However, type of carrier, variation in carrier height, and interrupted cycles had no effect on killing.

Few studies have directly compared the effectiveness of different 'no touch' methods. Nerandzic *et al.* [42] compared a UV-C device with a UV light – pulsed xenon (UV-PX) device at manufacturer recommended exposure times and demonstrated that the UV-C device had superior killing of MRSA, VRE, and *C. difficile*. Increasing distance from the UV-PX device dramatically reduce killing efficacy whereas pathogen concentration, organic load, and shading did not. Wong *et al.* [43] compared two different UV-C devices. Both were effective in killing MRSA and VRE up to concentrations of 10^6 CFU/ml when suspended in a isotonic saline. However, one device was approximately seven times more effective in killing MRSA and VRE when they were suspended in a protein solution.

CLINICAL TRIALS USING 'NO TOUCH' ROOM DECONTAMINATION METHODS

Multiple clinical trials have assessed the efficacy of a UV device or hydrogen peroxide system for terminal room decontamination to reduce HAIs from multidrug-resistant pathogens (Table 2). Thirteen studies have now demonstrated that the use of a 'no touch' device or system reduces the incidence or prevalence of selected MDROs. However, overall the quality of these studies, in general, is poor for the following three reasons: first, most of the studies used a before–after design which is more likely subject to bias than cross-over studies or randomized clinical trials (however, the use of controls as was done in some studies can reduce the possibility of bias); second, almost all of the studies did not provide a prespecified statistically valid measure of success with a prestudy sample size calculation; and third, most of the studies did not assess potential confounding that could explain the decrease in multidrug-resistant pathogens such as hand hygiene compliance and compliance with appropriate surface cleaning prior to decontamination. Another limitation to assessing the relative effectiveness of different 'no touch' methods is that no study compared two different methods. However, the multitude of positive studies suggests that 'no touch' technologies do indeed decrease HAIs. Further, some studies described below were well designed and assessed potential confounders. Along with the studies listed in Table 2, one before–after study used a UV-PX device nightly in the operating rooms and reported a decrease in surgical site infections for class 1 procedures [57]. The mechanism for this reduction is unclear because the surface environment is not felt to have a substantial impact on the likelihood of surgical site infections.

Several studies warrant detailed discussion, including the studies by Passaretti *et al.* [53], by Pegues *et al.* [47], and by Anderson *et al.* [46]. Passaretti *et al.* [53] performed a 30-month prospective cohort (before–after study that was strengthened by the use of concurrent controls) intervention using a HPV device on six high-risk units in a 994-bed

Table 2. Clinical trials of 'no touch' methods: UV devices and hydrogen peroxide systems

Year, author	Device/system	Study design	Setting	Selected results[a]
2016, Vianna *et al.* [44]	UV-PX	Before–after	Community hospital	Facility wide: ↓*C. difficile*, ↓all MDROs (MRSA, VRE, CDI)
2015, Horn and Otter [45]	HP vapor	Before–after	Hospital	↓CDI, ↓VRE, ↓ESBL GNB
2015, Anderson *et al.* [46]	UV-C	RCT	9 hospitals	↓All MDROs (MRSA, VRE, CDI)
2015, Pegues *et al.* [47]	UV-C	Before–after	Academic center	↓CDI
2015, Nagaraja *et al.* [48]	UV-PX	Before–after	Academic center	↓CDI
2015, Miller *et al.* [49]	UV-PX	Before–after	Nursing home	↓CDI
2014, Mitchell *et al.* [50]	Dry HP vapor	Before–after	Hospital	↓MRSA colonization and infection
2014, Haas *et al.* [51]	UV-PX	Before–after	Academic center	↓CDI, ↓MRSA, ↓VRE, ↓MDRO GNB, all MDROs
2013, Manian *et al.* [52]	HP vapor	Before–after	Community hospital	↓CDI
2013, Passaretti *et al.* [53]	HP vapor	Prospective cohort	Academic center	↓VRE, ↓all MDROs (MRSA, VRE, CDI)
2013, Levin *et al.* [54]	UV-PX	Before–after	Community hospital	↓CDI, ↓MRSA,
2011, Cooper *et al.* [55]	HP vapor	Before–after (2 cycles)	Hospitals	↓CDI (cases; incidence not significant)
2008, Boyce *et al.* [56]	HP vapor	Before–after	Community hospital	↓CDI

CDI, *Clostridium difficile* infection; ESBL, extended spectrum beta-lactamase producers; GNB, Gram negative bacteria; HP, hydrogen peroxide; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; UV-C, ultraviolet light – C; UV-PX, ultraviolet light – pulsed xenon; VRE, vancomycin-resistant *Enterococcus*.

[a]All listed results were statistically significant (see reference for more details).

tertiary care hospital. Patients admitted to rooms decontaminated using HPV were 64% less likely to acquire any multidrug-resistant pathogen [incidence rate ratio (IRR), 0.36; $P < 0.001$] and 80% less likely to acquire VRE (IRR, 0.20; $P < 0.001$). The risk of acquiring *C. difficile*, MRSA, and multidrug-resistant Gram-negative bacilli was reduced, but not significantly. The proportion of rooms environmentally contaminated with MDROs was reduced significantly on the HPV units (relative risk, 0.65; $P = 0.03$).

Pegues *et al.* [47] performed a prospective cohort (before–after study) in three haematology–oncology units to assess the efficacy of a UV-C device to reduce *C. difficile* infections (CDIs). Importantly, rooms were disinfected with bleach prior to use of the UV-C device. A significant association between UV-C use and a decline in CDI incidence was noted on study units (IRR, 0.49; 95% CI, 0.26–0.94; $P = 0.03$) but not on the nonstudy units (IRR, 0.63; 95% CI, 0.38–1.06; $P = 0.08$). Importantly, hand hygiene compliance, which was monitored by observation, and room cleaning compliance, which was monitored using ATP bioluminescence, were similar in the baseline and intervention periods (D. Pegues, personal communication).

The study by Anderson *et al.* [46] is the first randomized clinical trial to assess a 'no touch' method (UV-C, Tru-D) for terminal room disinfection. Specifically this was a prospective, multicenter, cluster-randomized, crossover trial in nine hospitals which evaluated three strategies for enhanced terminal room disinfection: standard quaternary ammonium compound plus UV-C, bleach alone, and bleach plus UV-C. Patients colonized or infected with MRSA or VRE, or with CDI were considered 'seed rooms' with 'exposed' patients being patients subsequently admitted to a 'seed room.' Exposed patients were followed for the development of an HAI due to a target pathogen. Compliance with hand hygiene and terminal room cleaning were measured and there were no differences in these potential confounders among the baseline group (quaternary ammonium compound alone) and the three intervention arms. The study showed that enhanced room decontamination strategies (i.e., bleach and/or UV-C decontamination) decreased the clinical incidence of acquisition of target MDROs (i.e., MRSA, VRE, *C. difficile*) by ~10 to 30% ($P = 0.036$).

'No-touch' room disinfection devices have been used as a component to control healthcare-associated outbreaks [7▪]. The outbreaks involved *S. aureus*, multidrug-resistant Gram-negative bacilli, *C. difficile*, and *Acinetobacter baumannii* plus MRSA. The device used in the great majority of cases was a HPV system.

CHOOSING A 'NO TOUCH' DEVICE OR SYSTEM

Hospitals should use a 'no touch' device or system for terminal room decontamination after discharge of patients on contact precautions. However, the multitude of commercially available devices and systems makes choosing a specific device or system difficult. UV devices may vary because of differences in UV wavelength, bulb size, energy output, ability to measure energy delivery, and cost. Similarly, hydrogen peroxide systems differ with regard to concentration, use of other microbicides, and method of injecting hydrogen peroxide into a room or space, and cost. For these reasons, infection control professionals should review the peer-reviewed literature and choose for purchase only devices with demonstrated bactericidal capability as assessed by the carrier test method and/or ability to disinfect actual patient rooms. Ultimately, one should choose only devices that have demonstrated the ability to reduce HAIs [7▪].

Further, infection control professionals should be aware of the advantages and disadvantages of both UV and hydrogen peroxide systems (Table 3). Because UV devices and hydrogen peroxide systems will not physically clean a room (e.g., remove dust or stains), room cleaning must precede disinfection. 'No touch' systems should be seen as adjunctive methods of room decontamination. A recent modeling study revealed the importance of hand hygiene to reduce HAIs and reported that a 2 : 1 improvement in terminal cleaning compared with hand hygiene was required to match an equal reduction in acquisition rates [58]. Another study implemented a three sequential tiered set of interventions: first, fluorescent markers to provide monitoring and feedback on thoroughness of cleaning; second, addition of a UV-C device for adjunctive decontamination of rooms that housed a patient with CDI; and third, enhanced standard disinfection of *C. difficile* rooms. During the baseline period 67% of the *C. difficile* rooms had positive cultures after disinfection, whereas with interventions 1, 2, and 3, the percentages of rooms with positive cultures after disinfection was reduced to 57, 35, and 7%, respectively [59].

CONCLUSIONS

'No touch' technologies have been demonstrated to kill nosocomial pathogens on inoculated test

Table 3. Comparison of UV devices and hydrogen peroxide systems for room decontamination

Similarities between UV devices and hydrogen peroxide systems
Reliable biocidal activity against healthcare-associated pathogens as assessed using inoculated test materials
Reliable biocidal activity against healthcare-associated pathogens as determined by use in contaminated patient rooms
Room surfaces and equipment decontaminated
Neither method removes dust and stains which are important to patients and visitors, and hence cleaning must precede decontamination
All patients and staff must be removed from the room prior to decontamination, thus limiting use to terminal room decontamination
Residual free and does not give rise to health or safety concerns
Substantial capital equipment costs
Demonstrated to reduce healthcare-associated infections in multiple studies
Differences between UV devices and hydrogen peroxide systems
Room decontamination more rapid for UV devices: ~5–25 min for vegetative bacteria and ~10–50 min for *C. difficile* with UV devices compared with 1.5–2.5 h for H_2O_2 systems
UV devices do not require, as do H_2O_2 systems, that the HVAC (heating, ventilation and air conditioning) system be disabled
UV devices require direct or indirect line of sight for effectiveness whereas H_2O_2 systems are effective throughout the enclosed space (e.g., a UV device run only in a patient's room would not decontaminate the bathroom unless the bathroom surfaces had direct or indirect line of sight)
H_2O_2 systems achieve higher levels of sporicidal kill (although whether this is clinically relevant has not been established)
UV devices are sensitive to use parameters (e.g., dose, distance, room configuration)
UV devices unlike H_2O_2 systems require that furniture and equipment be moved away from the walls to allow decontamination via indirect irradiation

surfaces, and on actual environmental surfaces and equipment in hospital rooms. Further, more than a dozen clinical trials have now demonstrated that use of one of these technologies can reduce HAIs. Additional well-designed studies (e.g., randomized clinical trials) should be undertaken to assess the degree to which these technologies can reduce HAIs. Studies directly comparing different technologies would be extremely useful. Finally, cost–benefit analyses should be conducted.

Because there are substantial differences between UV devices and hydrogen peroxide systems and within each technology there are multiple commercial choices, healthcare providers should rely on the peer-reviewed literature to validate specific devices and systems prior to purchase.

Acknowledgements

None.

Financial support and sponsorship

This work was supported by the Division of Adult Infectious Diseases, University of North Carolina at Chapel Hill, NC and UNC Hospitals, Chapel Hill, North Carolina.

Conflicts of interest

W.A.R. is a consultant for Clorox and has received honoraria from 3M. D.J.W. is a consultant for Clorox and Germitec. H.K. has no conflicts of interest.

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