

Review of the Efficacy of Ultraviolet C for Surface Decontamination

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Abstract

Evidence has shown that the state of the patient care environment has a direct impact on heightening the risks of hospital-acquired infections among patients admitted in hospitals. Moreover in view of the suboptimal standard of cleanings by housekeeping staff, there has been the quest for a better approach to reliably disinfect environmental surfaces in health-care facilities. The ultraviolet light has been known for its antimicrobial property and has been used in water treatment, food processing, and in-duct cleaning of ventilations. A recent introduction of its use for surface decontamination has raised interest among health-care facilities. However, studies have shown that, in spite of its relative success in other applications, there is doubt in its efficacy in decontaminating shadowed areas of the room, and therefore, may not be seen as justifying its capital intensiveness.

Keywords: Environmental disinfection, surface decontamination, ultraviolet C, ultraviolet light technology

INTRODUCTION

The ultraviolet (UV) light is conventionally known for the effectiveness of its antimicrobial activity, but there is significant doubt about its relative effectiveness in surface disinfection. Currently, there is convincing evidence that contaminated surfaces in hospital settings increase the risk of the transmitting hospital-acquired infections to other patients. The old argument that the environment does not contribute to the transmission of infection is fast losing credence as the plethora of evidence are abound suggesting that a new patient stands the risk of inheriting the pathogens left behind in a room by the previous occupant.^[1] Hence, existing studies imply that improved environmental surface cleaning and decontamination can lower the rates of healthcare-associated infections.^[2-4]

However, evidence have also shown that housekeeping practices of cleaning and disinfection of the environmental surfaces of even the best hospitals are suboptimal, and thereby missing out on nearly half of the high-risk environmental surfaces.^[5] Therefore, the quality environmental cleaning depends on the operator, and there is evidence that manual cleaning can spread bacteria on surfaces.^[6] This is more so as many hospitals outsource their housekeeping tasks of environmental surface disinfection to private companies which raises the question of whether they meet the acceptable standards. The local Saudi

Arabian MERS-CoV guideline (which is the only one that dwelt on the use of UVC and hydrogen peroxide (H₂O₂) for surface decontamination) recommend using either of the two as a mandatory part of terminal cleaning.^[7] It did not make a distinction between the two in terms of preference.

A quest for a better solution for environmental decontamination has led to the application of an old concept, the UV light, for decontamination of environmental surfaces. The UV light was well known for its antimicrobial effects and had been hitherto used for disinfection of water, food, and air ducts. Several UV light technology products are available in the market with even sporicidal label claim. Consequently, there is an increasing interest in novel and more efficient technological tools which can consistently decontaminate hospital's environmental surfaces.^[8] This article reviews the efficacy of UVC in surface decontamination and compares it with H₂O₂ with a view to proffering a practical and more efficient disinfectant for hospital environmental surfaces.

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ROLE OF ULTRAVIOLET LIGHT IN DECONTAMINATION OF THE ENVIRONMENT

UV light is electromagnetic radiation containing 265-nm wavelengths that are not long enough to be visible to the eyes. At this wavelengths, UV is capable of inducing mutation to bacteria, viruses, and other microorganisms due to its effects on the molecular structures of the pathogens. Its action results in destroying the structural bonds in the DNA of the pathogens, with a resultant rendering of the pathogens harmless or thereby inducing a bacteriostatic action on the pathogens.^[9]

UV light is conventionally used for both air disinfection and water purifications,^[10] and recently, to inactivate microorganisms on surfaces. The novel application of UV gamma irradiation is the use of UV light technologies to disinfect environmental surfaces in vacant rooms. These technologies come as moveable or fixed units to disinfect an entire vacant room.^[9]

Some studies^[8,11,12] have evaluated the effectiveness of using UV technologies for disinfecting patient rooms in hospitals [Table 1]. All of these studies cited have variously

reported that UV light can, significantly, decrease the bio-burden of common multidrug-resistant as well as spore-forming pathogens including MRSA, *Acinetobacter* spp.,^[20] VRE, *Mycobacteria*, Ebola virus,^[21] and *Clostridium difficile*.^[22] on contaminated environmental surfaces in the health-care settings by up to 4 log.^[6]

THE PITFALLS OF ULTRAVIOLET TECHNOLOGIES FOR ENVIRONMENTAL SURFACE DISINFECTIONS

Studies^[19,20] have shown that the UV light can reduce the microbial load on environmental surfaces, and can potentially contribute to reducing infection rates, in conjunction with other infection control measures like improved housekeeping practices. However, UV light is not without its own drawbacks when applied for environmental surface decontamination. For instance, concerns have been raised about its effectiveness in shadowed areas. In some of the models evaluated in the studies, items that are not in direct line of the light have a lower inactivation rate as compared to those in direct line of the light. That necessitates multiple-position or multiple-machine decontamination process. A study has suggested that using

Table 1: Studies on the effectiveness of ultraviolet C

Study	Method	Findings
Andersen <i>et al.</i> , 2006 ^[11]	Compared the antimicrobial properties of effect UVC light and chemical disinfectants on surfaces of isolation units	UVC was not effective in shadowed areas of the rooms, necessitating further disinfection with chemicals
Weber <i>et al.</i> , 2016 ^[13]	To test the capabilities of UV light technologies to decrease the microbial contamination on environmental surfaces in patient care areas ^[8]	Shadowed areas are more likely to be unaffected by the UV disinfection
Memarzadeh <i>et al.</i> , 2010 ^[14]	Reviews the significance of UV light technologies in air decontamination in health-care settings	UV technologies cannot, yet, be used as a stand-alone intervention to inactivate or destroy pathogens, but may be used as an adjunct the conventional interventions for terminal cleaning
Health Protection Scotland ^[9]	Reviewed the scientific evidence for the efficacy of UV light decontamination systems	Their efficacy is dependent on the organic load and pathogen, the intensity and dose of the UV light, the distance from the device and the exposure time, as well as whether the surface to be cleaned is within direct line-of-sight
Havill <i>et al.</i> , 2012 ^[15]	Prospective observational study to compare between HPVs and UVC to decrease microbial contamination inpatient care rooms	In the shadowed areas, HPV is significantly more effective than the UV technologies
Barbut <i>et al.</i> , 2009 ^[16]	The prospective, randomized, before-after trial, using hydrogen peroxide sprays and sodium hypochlorite solution for eradicating bacterial spores	The hydrogen peroxide sprays have shown significant superiority over sodium hypochlorite solution at eliminating <i>C. difficile</i> spores. The latter stands the chance of being a promising option eradicating <i>C. difficile</i> in the room of infected or colonized patients
Weber <i>et al.</i> , 2016 ^[13]	Compared the efficacy of UV technologies and hydrogen peroxide sprays in decreasing contamination on environmental surfaces postterminal cleaning	Unlike the UVC, H ₂ O ₂ has shown demonstrable capability to decrease healthcare-associated <i>Clostridium difficile</i> infections
Holmdahl <i>et al.</i> , 2011 ^[17]	The tests compared the effectiveness of hydrogen peroxide and sodium hypochlorite, on biological indicators	Hydrogen peroxide vapor generator was faster in action and more effective than sodium hypochlorite machines on <i>G. Stearothermophilus</i> biological indicators
Mosci <i>et al.</i> , 2017 ^[18]	A comparison of the effectiveness of manual decontamination with sodium hypochlorite solution 0.5% and an automated spray system <8% H ₂ O ₂ + silver ion	Both are effective against <i>C. difficile</i> and mesophilic microbes, though the hydrogen peroxide and silver ions disinfection is preferable because, it is faster, and its effectiveness is not operator-dependent., as compared to the hypochlorite
Fu <i>et al.</i> , 2012 ^[6]	A comparison of the effectiveness, and safety profile of H ₂ O ₂ sprays and aerosolized hydrogen peroxide, on <i>G. Stearothermophilus</i> biological indicators with discs containing MRSA, <i>C. Difficile</i> and <i>Acinetobacterbaumannii</i>	The H ₂ O ₂ vapor system has shown better safety profile, fast action and added effectiveness in bacterial inactivation
Haas <i>et al.</i> ^[19]	A retrospective study of the effectiveness of UV light environmental disinfection as an adjunct to an improved terminal cleaning of rooms previously occupied by isolated patients, by comparing the rates of hospital-acquired MDROs before and during the UVD use	Despite the missing about a quarter of the opportunities to decontaminate the rooms, there was a significant reduction in the rates of hospital-acquired MDRO rates was noticed during the period of UVD use as compared with the period before. UV technologies appeared, in this study, to have some beneficial effect

UVC: Ultraviolet C, H₂O₂: Hydrogen peroxide, MRSA: *Methicillin-Resistant Staphylococcus aureus*, MDROs: Multidrug-resistant organisms, UVD: Ultraviolet disinfection, HPV: Hydrogen peroxide vapor, *G. Stearothermophilus*: *Geobacillus stearothermophilus*, HVAC: Heating, ventilation and air condition

a reflective coated wall could reduce the time limit by about 50%, but it did not further increase its log reduction capability.^[23]

Furthermore, the presence of organic matter on the environmental surface can decrease the lethal effect of the UV radiation on pathogens.^[24] Accordingly, none of the studies or reviews suggests that UV light technology can be used as a stand-alone measure, but perhaps, as a supplement to the existing housekeeping practices. This requires that the surface must be physically cleaned before applying the UV light as an adjunct. This is in addition to its other disadvantage that the room must be vacated before using the technology because of its effects on, among others, the skin of humans (cutaneous inflammation),^[25] of some adverse inflammatory responses, including the creation of inflammatory mediators, and changes to vascular responses.^[26] The UV light also has effects on the eyes and visual systems,^[27] including potential changes to the cornea, pterygium, and acute photokeratitis (snow blindness), among others.^[28]

DISCUSSION: ULTRAVIOLET C VERSUS HYDROGEN PEROXIDE

An alternative surface disinfectant with similar antimicrobial action, including sporicidal property, is the vaporized H₂O₂ that destroys pathogens, including spores by degrading the bacterial cell.^[29] H₂O₂, which is commercially available in a range of concentrations from 3% to 90%, is also considered eco-friendly, as it can quickly disintegrate into harmless by-products: water and oxygen.^[30] Published literature have attributed good antimicrobial activity to H₂O₂ and have confirmed its biocidal activity against a wide range of pathogens, including bacteria, yeasts, fungi, viruses, and spores.^[5] It also has an additional advantage of overcoming the drawbacks arising from the use of UVC; The ability to reach all nooks and corners of the room, including part of the air vents when the air conditioners are not operating.^[31]

When compared to its peers, for example, glutaraldehyde, peracetic acid, and orthophthaldehyde, it has far better favorable chemical characteristics, including its use as a sterilant (at the concentration of 6%–25%, and a contact time of 6 h), and has a high level of disinfection claim (sporicidal). In addition, it has a longer reuse life (2 days), a long shelf life (2 years), it does not require activation, and has a good materials compatibility.^[5]

Furthermore, a study, in which a new activated H₂O₂ wipe disinfectant was used to disinfect high-touch surfaces in patient rooms has demonstrated that 99% of surfaces yielded <2.5 colony-forming units/cm, 75% yielded no growth.^[32]

Analyzing Table 2, it could be deduced that both the UV and the H₂O₂ technologies can be used for room surfaces and equipment decontamination because of their broad-spectrum antimicrobial activity against pathogens, including *C. difficile* for. Furthermore, in both cases, the

room must be vacant prior to decontamination, they do not remove dust and stains, and hence, proper cleaning must be completed before the disinfection as part of a terminal cleaning (as the room should remain vacant prior using the UV technology).

However, H₂O₂ is a relatively better choice for the following reasons:

1. There is no prospective (known to authors) clinical study to show that UV light decontamination can decrease the rates of hospital-acquired infections. Clinical trials have shown that using the H₂O₂ for surface disinfection can decrease the rates of hospital-acquired infections
2. No reported study that suggests that UVC is effective in shadowed areas, even when the room contents have been moved away from the walls. H₂O₂ can be conveniently used for disinfecting room with complex equipment and furniture without necessarily moving the contents away around
3. H₂O₂ has no harmful residue. Hydrogen Peroxide is converted into oxygen and water with conducive environmental impact
4. The automated dispersal system ensures uniform distribution in the room, including all corners, crannies, and openings, including even air vents
5. At the concentration of 3%, it can be safely and effectively used as an intermediate level surface and semi-critical items disinfectant.

RECOMMENDATIONS

1. Making a choice
 - a. As can be seen in this review, a better alternative to UVC for surface decontamination is the vaporized H₂O₂ in the concentration of 3%–6% which can permeate its sporicidal property in all areas of the room, including shadows and ventilation ducts
 - b. Apart from using it for decontaminating inanimate environmental surfaces, H₂O₂ vapors can be effectively used for high-level disinfection of medical devices such as soft contact lenses, ventilators, and endoscopes. Furthermore, it can also be used for spot-disinfecting fabrics in patients' rooms^[5]
 - c. Manual terminal cleaning of patient rooms using neutral detergent according to the standard hospital protocol should always precede the use of H₂O₂
 - d. Apply the H₂O₂ vapor according to the manufacturer's recommendations.
2. If the choice is for UVC, then follow these steps^[9]
 - a. UV light systems can be used as an additional measure when performing terminal room decontamination
 - b. The use of UV light systems for environmental decontamination should only be undertaken following completion of a manual clean as residual dirt can reduce efficacy

Table 2: Comparing the merits and demerits of ultraviolet light and hydrogen peroxide for surface disinfection

Product	Advantage	Disadvantage
H ₂ O ₂	<p>Broad-spectrum activity against pathogens involved in healthcare-associated infections</p> <p>Can be used for disinfecting both environmental surface as well as medical devices</p> <p>Has a sporicidal activity</p> <p>Can be used for decontaminating complex devices and rooms</p> <p>Does not require the manipulation of room furniture and other items in the room before decontamination</p> <p>Has no residual health, disposal or safety concerns (residue: Oxygen and water)</p> <p>The system distributes the product in the room uniformly</p> <p>There is evidence that it can reduce the rate of hospital-acquired <i>Clostridium difficile</i> infections</p> <p>Can potentially reduce the environmental impact because of little or no water used, no residue and its versatility with the same result</p> <p>No odor or irritation issues</p> <p>Does not coagulate blood or fix tissues to surfaces</p> <p>Inactivates cryptosporidium</p> <p>May enhance the removal of organic matter and organisms^[5]</p>	<p>Cannot be used in an occupied room</p> <p>It is labor-intensive as it requires closing the HVAC system and sealing the doors to prevent its escape</p> <p>It cannot be routinely used, but only as part of the terminal cleaning after the patient has vacated the room</p> <p>Expensive</p> <p>Time-consuming: requires about 2.5 to 5 h</p> <p>Its effectiveness depends on specific use parameters (e.g., concentration, contact time, etc.)</p>
UVC	<p>Broad-spectrum activity against pathogens involved in healthcare-associated infections</p> <p>Can be used for disinfecting both environmental surface as well as medical devices</p> <p>Rapid contact time, for example, 15 min for vegetative bacteria</p> <p>Has a sporicidal activity after longer exposure of up to 50 min</p> <p>Plug and play: Does not require closing the HVAC system, nor sealing the room</p> <p>Eco-friendly, with no residue</p> <p>Low recurrent running costs</p>	<p>The room must be vacated for decontamination</p> <p>Cannot be used as stand-alone disinfection, but as an adjunct to terminal disinfection after the patient vacates the room</p> <p>High capital costs</p> <p>Proper cleaning must be done before UV decontamination</p> <p>Its effectiveness depends on specific use parameters (e.g., wavelength, UV dose delivered)</p> <p>Equipment and furniture must be moved away from the walls</p> <p>No prospective studies that demonstrate that the use of UV light technology for decontamination reduce the rates of healthcare-associated infections</p>

H₂O₂: Hydrogen peroxide, UVC: Ultraviolet C, HVAC: Heating, ventilation and air condition

- c. Before a UV light system being considered, an assessment of the area to be decontaminated must be undertaken to ensure the area can be sealed and the use of UV light made safe
- d. UV light systems must only be used in an area which has been cleared of all patients and staff. No entry to the decontamination area is allowed once the decontamination process has commenced
- e. Manufacturers' instructions for use must be followed to reduce the risk of sub-optimal UV light dosage on microorganisms. This could result in the mutation of the remaining microbes
- f. UV light systems in use must be maintained in good working order and a system of programmed maintenance in place with documented evidence
- g. A quality assurance mechanism should be in place to monitor the functionality of the UV light system using samples before and after cleaning
- h. UV light systems should not be used for routine cleaning
- i. Risk assessments should be in place for possible exposure of staff or patients to UV light
- j. Ensure appropriate time is given to the UV light decontamination process. Use of UV light systems will increase the overall decontamination time for cleaning. Additional time should be included in cleaning specification guidance [Table 2].

CONCLUSIONS

Although both UVC and H₂O₂ are broad-spectrum antimicrobial agents that are used for room surfaces and equipment decontamination, for their effect against pathogens, including *C. difficile*, in both cases, the room must be completely vacated before decontamination. However, H₂O₂ is a relatively better choice for the following reasons:

1. There is no prospective clinical study that demonstrates that UV room disinfection can reduce the rate of healthcare-associated infections.^[13] One retrospective study showed a decrease in rates, but other infection prevention measures were also implemented along with the use of UV light. Some studies have shown that the use of H₂O₂ for surface disinfection can reduce the rate of healthcare-associated infections^[19]

2. None of the studies suggest that UVC is effective in shadowed areas, even when the equipment and furniture are moved around
3. H₂O₂ can be used for disinfecting rooms that contain complex equipment and furniture without moving them around. The automated dispersal system ensures uniform distribution in the room, including all corners, crannies, and openings, including event air vents
4. H₂O₂ has no residue the HP is converted into oxygen and water with conducive environmental impact.

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Conflicts of interest

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