Review Article

Review of the Efficacy of Ultraviolet C for Surface Decontamination

Abba Amsami Elgujja, Haifa Humaidan Altalhi, Salah Ezreqat

Departments of Infection Control, King Saud University Medical City, Riyadh, Saudi Arabia

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 loosing 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 (H_2O_2) 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 H_2O_2 with a view to proffering a practical and more efficient disinfectant for hospital environmental surfaces.

Address for correspondence: Mr. Abba Amsami Elgujja,
King Saud University Medical City, Riyadh, Saudi Arabia.
E-mail: abelgujja@ksu.edu.sa

Submission: 23-04-2019 **Revision:** 28-06-2019
Acceptance: 24-07-2019 **Published:** 06-01-2020

Access this article online

Quick Response Code:

Website: www.jnsmonline.org

DOI: 10.4103/JNSM.JNSM_21_19

How to cite this article: Elgujja AA, Altalhi HH, Ezreqat S. Review of the efficacy of ultraviolet C for surface decontamination. J Nat Sci Med 2020;3:8-12.

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 *et al*., 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 *et al*., 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 unaffected by the UV disinfection
Memarzadeh *et al*., 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 *et al*., 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 *et al*., 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 C. difficile spores. The latter stands the chance of being a promising option eradicating C. difficile in the room of infected or colonized patients
Weber *et al*. 2016[13]	Compared the efficacy of UV technologies and hydrogen peroxide sprays in decreasing contamination on environmental surfaces postterminal cleaning	Unlike the UVC, H_2O_2 has shown demonstrable capability to decrease healthcare-associated *Clostridium difficile* infections
Holmdahl *et al*., 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 *G. Stearothermophilus* biological indicators
Mosci *et al*., 2017[18]	A comparison of the effectiveness of manual decontamination with sodium hypochlorite solution 0.5% and an automated spray system <8% H_2O_2 + silver ion	Both are effective against C. difficile 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 *et al*., 2012[6]	A comparison of the effectiveness, and safety profile of H_2O_2 sprays and aerosolized hydrogen peroxide, on *G. Stearothermophilus* biological indicators with discs containing MRSA, C. Difficile and Acinetobacterbaumannii	The H_2O_2 vapor system has shown better safety profile, fast action and added effectiveness in bacterial inactivation
Haas *et al*.[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, H_2O_2: 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 H_2O_2 that destroys pathogens, including spores by degrading the bacterial cell.[29] H_2O_2, 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 H_2O_2 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, glutraldehyde, 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 H_2O_2 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 H_2O_2 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, H_2O_2 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 H_2O_2 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. H_2O_2 can be conveniently used for disinfecting room with complex equipment and furniture without necessarily moving the contents away around
3. H_2O_2 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 H_2O_2 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, H_2O_2 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 H_2O_2
   d. Apply the H_2O_2 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_2O_2	Broad-spectrum activity against pathogens involved in healthcare-associated infections	Cannot be used in an occupied room
	Can be used for disinfecting both environmental surface as well as medical devices	It is labor-intensive as it requires closing the HVAC system and sealing the doors to prevent its escape
	Has a sporicidal activity	It cannot be routinely used, but only as part of the terminal cleaning after the patient has vacated the room
	Can be used for decontaminating complex devices and rooms	Expensive
	Does not require the manipulation of room furniture and other items in the room before decontamination	Time-consuming: requires about 2.5 to 5 h
	Has no residual health, disposal or safety concerns (residue: Oxygen and water)	Its effectiveness dependents on specific use parameters (e.g., concentration, contact time, etc.)
	The system distributes the product in the room uniformly	
	There is evidence that it can reduce the rate of hospital-acquired *Clostridium difficile* infections	
	Can potentially reduce the environmental impact because of little or no water used, no residue and its versatility with the same result	
	No odor or irritation issues	
	Does not coagulate blood or fix tissues to surfaces	
	Inactivates cryptosporidium	
	May enhance the removal of organic matter and organisms[5]	
UVC	Broad-spectrum activity against pathogens involved in healthcare-associated infections	The room must be vacated for decontamination
	Can be used for disinfecting both environmental surface as well as medical devices	Cannot be used as stand-alone disinfection, but as an adjunct to terminal disinfection after the patient vacates the room
	Rapid contact time, for example, 15 min for vegetative bacteria	High capital costs
	Has a sporicidal activity after longer exposure of up to 50 min	Proper cleaning must be done before UV decontamination
	Plug and play: Does not require closing the HVAC system, nor sealing the room	Its effectiveness dependents on specific use parameters (e.g., wavelength, UV dose delivered)
	Eco-friendly, with no residue	Equipment and furniture must be moved away from the walls
	Low recurrent running costs	No prospective studies that demonstrate that the use of UV light technology for decontamination reduce the rates of healthcare-associated infections

H_2O_2: 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 H_2O_2 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, H_2O_2 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 H_2O_2 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. H_2O_2 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. H_2O_2 has no residue the HP is converted into oxygen and water with conducive environmental impact.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Weber DJ, Rutala WA, Miller MB, Huslage K, Sickbert-Bennett E. Role of hospital surfaces in the transmission of emerging health care-associated pathogens: *Norovirus*, *Clostridium difficile*, and *Acinetobacter* species. Am J Infect Control 2010;38:S25-33.
2. Carling PC, Briggs JL, Perkins J, Highlander D. Improved cleaning of patient rooms using a new targeting method. Clin Infect Dis 2006;42:385-8.
3. Dancer SJ, White L, Robertson C. Monitoring environmental cleanliness on two surgical wards. Int J Environ Health Res 2008;18:357-64.
4. Griffith CJ, Obee P, Cooper RA, Burton NF, Lewis M. The effectiveness of existing and modified cleaning regimens in a welsh hospital. J Hosp Infect 2007;66:352-9.
5. Rutala WA, William A, Weber DJ, David J. Guideline for Disinfection and Sterilization in Healthcare Facilities; 2008.
6. Fu TY, Gent P, Kumar V. Efficacy, efficiency and safety aspects of hydrogen peroxide vapour and aerosolized hydrogen peroxide room disinfection systems. J Hosp Infect 2012;80:199-205.
7. Scientific Advisory Board. Middle East Respiratory Syndrome Coronavirus; Guidelines for Healthcare Professionals. Riyadh; 2018. p. 10.
8. Boyce JM, Havill NL, Moore BA. Terminal decontamination of patient rooms using an automated mobile UV light unit. Infect Control Hosp Epidemiol 2011;32:737-42.
9. Scotland HP. Literature Review and Practice Recommendations: Existing and Emerging Technologies Used for Decontamination of the Healthcare Environment – UV Light. Health Protection Scotland; 2016. Available from: https://www.hps.scot.nhs.uk/web-resources-container/literature-review-and-practice- recommendations-existing-and-emerging-technologies-used-for-decontamination-of-the-healthcare-environment-uv-light/. [Last accessed on 2019 Apr 20].
10. Monarca S, Faretti D, Collivignarelli C, Guzzella L, Zerbini I, Bertanza G, *et al*. The Influence of Different Disinfectants on Mutagenicity and Toxicity of Urban Wastewater. Water Res 2000;34:4261.
11. Andersen BM, Bånrud H, Bøe E, Bjordal O, Drangsholt F. Comparison of UV C light and chemicals for disinfection of surfaces in hospital isolation units. Infect Control Hosp Epidemiol 2006;27:729-34.
12. Mahida N, Vaughan N, Boswell T. First UK evaluation of an automated ultraviolet-C room decontamination device (Tru-D™). J Hosp Infect 2013;84:332-5.
13. Weber DJ, Rutala WA, Anderson DJ, Chen LF, Sickbert-Bennett EE, Boyce JM, *et al.* Effectiveness of ultraviolet devices and hydrogen peroxide systems for terminal room decontamination: Focus on clinical trials. Am J Infect Control 2016;44:e77-84.
14. Memarzadeh F, Olmsted RN, Bartley JM. Applications of ultraviolet germicidal irradiation disinfection in health care facilities: Effective adjunct, but not stand-alone technology. Am J Infect Control 2010;38:S13-24.
15. Havill NL, Moore BA, Boyce JM. Comparison of the microbiological efficacy of hydrogen peroxide vapor and ultraviolet light processes for room decontamination. Infect Control Hosp Epidemiol 2012;33:507-12.
16. Barbut F, Menuet D, Verachten M, Girou E. Comparison of the efficacy of a hydrogen peroxide dry-mist disinfection system and sodium hypochlorite solution for eradication of *Clostridium difficile* spores. Infect Control Hosp Epidemiol 2009;30:507-14.
17. Holmdahl T, Lanbeck P, Wullt M, Walder MH. A head-to-head comparison of hydrogen peroxide vapor and aerosol room decontamination systems. Infect Control Hosp Epidemiol 2011;32:831-6.
18. Mosci D, Marmo GW, Sciolino L, Zaccaro C, Antonellini R, Accogli L, *et al.* Automatic environmental disinfection with hydrogen peroxide and silver ions versus manual environmental disinfection with sodium hypochlorite: A multicentre randomized before-and-after trial. J Hosp Infect 2017;97:175-9.
19. Haas JP, Menz J, Dusza S, Montecalvo MA. Implementation and impact of ultraviolet environmental disinfection in an acute care setting. Am J Infect Control 2014;42:586-90.
20. Anderson DJ, Gergen MF, Smathers E, Sexton DJ, Chen LF, Weber DJ, *et al.* Decontamination of targeted pathogens from patient rooms using an automated ultraviolet-C-emitting device. Infect Control Hosp Epidemiol 2013;34:466-71.
21. Sagripanti JL, Lytle CD. Sensitivity to ultraviolet radiation of *Lassa, Vaccinia*, and *Ebola* viruses dried on surfaces. Arch Virol 2011;156:489-94.
22. Miller SL. Efficacy of ultraviolet irradiation in controlling the spread of tuberculosis; submitted to: Centers for Disease Control and Prevention National Institute for Occupational Safety and Health 2002.
23. Rutala WA, Gergen MF, Tande BM, Weber DJ. Rapid hospital room decontamination using ultraviolet (UV) light with a nanostructured UV-reflective wall coating. Infect Control Hosp Epidemiol 2013;34:527-9.
24. Nerandzic MM, Cadnum JL, Eckart KE, Donskey CJ. Evaluation of a hand-held far-ultraviolet radiation device for decontamination of Clostridium difficile and other healthcare-associated pathogens. BMC Infect Dis 2012;16:12:120.
25. Urbanski A, Schwarz T, Neuner P, Krutmann J, Kirnbauer R, Köck A, *et al.* Ultraviolet light induces increased circulating interleukin-6 in humans. J Invest Dermatol 1990;94:808-11.
26. Clydesdale GJ, Dandie GW, Muller HK. Ultraviolet light induced injury: Immunological and inflammatory effects. Immunol Cell Biol 2001;79:547-68.
27. Stark WS, Tan KE. Ultraviolet light: Photosensitivity and other effects on the visual system. Photochem Photobiol 1982;36:371-80.
28. Taylor HR. The biological effects of uv-b on the eye. Photochem Photobiol 1989;50:489.
29. Maris P. Modes of action of disinfectants. Rev Sci Tech 1995;14:47-55.
30. McDonnell G, Russell AD. Antiseptics and disinfectants: Activity, action, and resistance. Clin Microbiol Rev 1999;12:147-79.
31. Chan HT, White P, Sheorey H, Cocks J, Waters MJ. Evaluation of the biological efficacy of hydrogen peroxide vapour decontamination in wards of an australian hospital. J Hosp Infect 2011;79:125-8.
32. Boyce JM, Havill NL. Evaluation of a new hydrogen peroxide wipe disinfectant. Infect Control Hosp Epidemiol 2013;34:521-3.