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Review of the Efficacy of UVC for Surface Decontamination

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Abstract:

Evidence has shown that the state of the patient care environment has a direct impact in heightening the risks of hospital acquired infections among patients admitted in hospitals. And in view of the sub-optimal standard of cleanings by housekeeping staff, the quest for a better approach to reliably disinfect environmental surfaces in healthcare facilities.

The ultraviolet light has been known for its antimicrobial property, and have 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 hospitals.

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, would not be seen as justifying its capital intensiveness.

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Introduction:

The ultraviolet light is traditionally 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 increases 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 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], [3], [4]

However, evidence have also shown that housekeeping practices of cleaning and disinfection of the environmental surfaces of even the best hospitals are sub-optimal, 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 out-source 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 for surface decontamination) recommend using either of the two as a mandatory part of terminal cleaning.[7] It did not make 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 Ultra violet (UV) light, for decontamination of environmental surfaces. 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 hospitals' environmental surfaces.[8] This article reviews the efficacy of UVC in surface decontamination, and compare it with hydrogen peroxide with a view to proffering a practical and more efficient disinfectant for hospital environmental surfaces.

Role of Ultraviolet light (UV) Light in Decontamination of the Environment

Ultraviolet light is an 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 traditionally used for both air disinfection and water purifications,[10] and recently, to inactivate microorganisms on surfaces. The novel application of Ultra violet 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. [11]

Some studies [12], [13], [14], [15] have evaluated the effectiveness of using UV technologies for disinfecting patient rooms in hospitals (See 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.,[16] VRE, *Mycobacteria*, Ebola virus,[17] and *Clostridium Difficile*[18] on contaminated environmental surfaces in the healthcare settings by up to 4 log^{10}.

Table 1. Studies on the Effectiveness of UVC

Study	Method	Findings
1. Andersen, Bånrud, Bøe, Bjordal, &Drangsholt, 2006[19]	Compared the antimicrobial properties of effect UV C light and chemical disinfectants on surfaces of isolation units,	UVC was not effective in shadowed areas of the rooms, necessitating further disinfection with chemicals.
2. Weber et al., 2016[20]	To test the capabilities of UV light technologies to decrease the microbial contamination on environmental surfaces in patient care areas.[21]	Shadowed areas are more likely to unaffected by the UV disinfection

3. Memarzadeh, Olmsted, & Bartley, 2010[22]	Reviews the significance of UV light technologies in air decontamination in healthcare 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 [23]	Reviewed the scientific evidence for efficacy of UV light decontamination systems	Their efficacy is dependent upon 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.
4. Havill, Moore, & Boyce, 2012 [24]	Prospective observational study to compare between Hydrogen Peroxide Vapors and UVC to decrease microbial contamination in patient care rooms.	***In the shadowed areas, HPV is significantly more effective than the UV technologies***.
5. Barbut, Menuet, Verachten, &Girou, 2009 [25]	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 colonised patients.
6. Rutala& Weber, 2013 [26]	Compared the efficacy of UV technologies and hydrogen peroxide sprays in decreasing contamination on environmental surfaces post terminal cleaning.	Unlike the UVC, H_2O_2 has shown demonstrable capability to decrease health care-associated Clostridium difficile infections
7. Holmdahl, Lanbeck, Wullt, &Walder, 2011[27]	The tests compared the effectiveness of Hydrogen Peroxide and Sodium Hypochlorite, on biological indicators.	Hydrogen Peroxide vapour generator was faster in action, and more effective than sodium hypochlorite machines on G. Stearothermophilus biological indicators.
8. Mosci et al., 2017 [28]	A comparison of the effectiveness of manual decontamination with sodium hypochlorite solution 0.5% and an automated spray system <8% H2O2 + 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-dependant., as compared to the hypochlorite.
9. Fu, Gent, Kumar, & Child, 2012 [29]	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 vapour system has shown better safety profile, fast action and added effectiveness in bacterial inactivation
10. Haas, Menz, Dusza, &Montecalvo [30]	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.

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The Pitfalls of UV Technologies for Environmental Surface Disinfections

Studies[31], [32] 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 ~~have~~ suggested that using a reflective coated wall could reduce the time limit by about 50%, but it did not further increase its log reduction capability [33].

Furthermore, the presence of organic matter on the environmental surface can decrease the lethal effect of the UV radiation on pathogens.[34] 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 house-keeping 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),[35] of some adverse inflammatory responses, including the creation of inflammatory mediators, and changes to vascular responses.[36] The UV light also has effects on the eyes and visual systems [37] including potential changes to the cornea, pterygium, and acute photo keratitis (snow blindness), among others.[38]

Discussion: UVC versus Hydrogen Peroxide

An alternative surface disinfectant with similar antimicrobial action, including sporicidal property, is the vaporized hydrogen peroxide that destroys pathogens, including spores by degrading the bacterial cell.[39] Hydrogen peroxide, which is commercially available in a range of concentrations from 3 to 90%, is also considered eco-friendly, as it can quickly disintegrates into a harmless by-products: water and

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oxygen.[40] Published literature have attributed good antimicrobial activity to hydrogen peroxide and, have confirmed its biocidal activity against a wide range of pathogens, including bacteria, yeasts, fungi, viruses, and spores.[41] 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.[42]

When compared to its peers e.g., Glutraldehyde, peracitic acid, and orthophthaldehyde, it has far better favourable chemical characteristics including, including its use as a sterilant (at the concentration of 6% to 25%, and a contact time of 6 hours), and as a high level of disinfection claim (sporicidal). Additionally, 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.[43]

Also, a study in which a new activated hydrogen peroxide wipe disinfectant was used to disinfect high-touch surfaces in patient rooms has demonstrated that, 99% of surfaces yielded less than 2.5 colony-forming units/cm, 75% yielded no growth.[44]

Table 2. Comparing the merits and de-merits of UV Light and Hydrogen Peroxide for Surface Disinfection [45]

PRODUCT	ADVANTAGE	DISADVANTAGE
H2O2	1. Broad spectrum activity against pathogens involved in health care-associated infections 2. Can be used for disinfecting both environmental surface as well as medical devices 3. Has a sporicidal activity 4. Can be used for decontaminating complex devices and rooms 5. Does not require the manipulation of room furniture and other items in the room before decontamination. 6. Has no residual health, disposal or safety concerns (residue: oxygen and water)	1. Cannot be used in an occupied room. 2. It is labour-intensive as it requires closing the HVAC system and sealing the doors to prevent its escape 3. It cannot be routinely used, but only as part of the terminal cleaning after the patient has vacated the room. 4. Expensive 5. Time consuming: requires about 2.5 to 5 hours 6. Its effectiveness dependents on specific use parameters (e.g., concentration, contact time etc.)

	7. The system distributes the product in the room uniformly 8. There is evidence that it can reduce the rate of hospital acquired Clostridium difficile infections. 9. Can potentially reduce the environmental impact because of little or no water used, no residue and its versatility with the same result. 10. No odor or irritation issues 11. Does not coagulate blood or fix tissues to surfaces 12. Inactivates Cryptosporidium 13. May enhance removal of organic matter and organisms.[46]	
UVC	1. Broad spectrum activity against pathogens involved in health care-associated infections 2. Can be used for disinfecting both environmental surface as well as medical devices 3. Rapid contact time, e.g., 15 minutes for vegetative bacteria 4. Has a sporicidal activity after longer exposure of up to 50 minutes. 5. Plug and play: Does not require closing the HVAC system , nor sealing the room 6. Eco friendly, with no residue 7. Low recurrent running costs	1. The room must be vacated for decontamination 2. Cannot be used as a stand-alone disinfection, but as an adjunct to terminal disinfection after the patient vacates the room. 3. High capital costs 4. Proper cleaning must be done before UV decontamination 5. Its effectiveness dependents on specific use parameters (e.g., wavelength, UV dose delivered) 6. Equipment and furniture must be moved away from the walls 7. No studies that demonstrates that the use of UV light technology for decontamination reduce the ratese of health care-associated infections

Analysing the table above, it could be deduced that both the UV and the hydrogen peroxide technologies can be used for room surfaces and equipment decontamination because of their broad-spectrum antimicrobial activity against pathogens, including Clostridium 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 prior to 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 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 decreases 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. HP 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 vaporised hydrogen peroxide 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, hydrogen peroxide vapours can be effectively used for high level disinfection of medical devices like soft contact lenses, ventilators, and endoscopes. Furthermore, it can also be used for spot-disinfecting fabrics in patients' rooms. [47]
   c. Manual terminal cleaning of patient rooms using neutral detergent according to the standard hospital protocol should always precede the use of hydrogen peroxide.
   d. Apply the hydrogen peroxide vapour according to the manufacturer's recommendations.
2. If the choice is for UVC, the follow these steps:[48]

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.

c. Prior to 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 micro-organisms. This could result in 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.

Conclusions:

Although both UVC and hydrogen peroxides are broad spectrum antimicrobial agents that are used for room surfaces and equipment decontamination, for their effect against pathogens, including *Clostridium difficile*, in both cases, the room must be completely vacated prior to decontamination. However, hydrogen peroxide (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 health care-associated infections. One retrospective study showed 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 health care-associated infections. [49]

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.

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 Jun;38(5):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 Feb 1;42(3):385–8.
3. Dancer SJ, White L, Robertson C. Monitoring environmental cleanliness on two surgical wards. Int J Environ Health Res. 2008 Oct;18(5):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. 2007;
5. Rutala WA & Weber DJ. Guideline for disinfection and sterilization in healthcare facilities, 2008.
6. TY Fu and others, ‘Efficacy, Efficiency and Safety Aspects of Hydrogen Peroxide Vapour and Aerosolized

Hydrogen Peroxide Room Disinfection Systems' (2012) 80 Journal of Hospital Infection 199.
7. Scientific Advisory Board. Infection Prevention and Control Guidelines for the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) Infection, 4th Edition. 2017;
8. Boyce JM, Havill NL, Moore BA. Terminal Decontamination of Patient Rooms Using an Automated Mobile UV Light Unit. Infect Control Hosp Epidemiol. 2011 Aug 2;32(08):737–42.
9. Scotland HP. Literature Review and Practice Recommendations: Existing and emerging technologies used for decontamination of the healthcare environment - UV light [Internet]. Health Protection Scotland. 2016 [cited 2019 Apr 20]. 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/
10. Monarca S, Feretti 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 Dec 1;34(17):4261–9.
11. Scotland HP. See 9.
12. 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 Jul 21;27(07):729–34.
13. Andersen et al. See 12.
14. Boyce et al. See 8.
15. Mahida N, Vaughan N, Boswell T. First UK evaluation of an automated ultraviolet-C room decontamination device (Tru-D^{TM}). J Hosp Infect. 2013;84:332–5.
16. 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 May 2;34(05):466–71.
17. Sagripanti J-L, Lytle CD. Sensitivity to ultraviolet radiation of Lassa, vaccinia, and Ebola viruses dried on surfaces. Arch Virol. 2011 Mar 23;156(3):489–94.
18. 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.
19. Andersen et al See 12.
20. Weber DJ, Rutala WA, Anderson DJ, Chen LF, Sickbert-Bennett EE, Boyce JM. Effectiveness of ultraviolet devices and hydrogen peroxide systems for terminal room decontamination: Focus on clinical trials. 2016
21. Boyce et al. See 8.
22. 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.
23. Scotland HP. See 9.
24. 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 May 2;33(05):507–12.
25. 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 Jun 2;30(06):507–14.
26. Weber DJ et al. See 20.
27. 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 Sep;32(9):831–6.
28. 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 Oct;97(2):175–9.
29. Fu TY, Gent P, Kumar V, Child JA. Efficacy, efficiency and safety aspects of hydrogen peroxide vapour and aerosolized hydrogen peroxide room disinfection systems. J Hosp Infect. 2012;80:199–205. 28.
30. 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 Jun 1;42(6):586–90.
31. Haas, Menz, Dusza, & Montecalvo, 2014
32. Anderson et al (2013) See 16
33. Rutala et al (2013) See 26.
34. 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. 2012.
35. Urbanski A, Schwarz T, Neuner P, Krutmann J, Kirnbauer R, Luger TA, et al. Ultraviolet Light Induces Increased Circulating Interleukin-6 in Humans. J Invest Dermatol. 1990 Jun;94(6):808–11.
36. Clydesdale GJ, Dandie GW, Muller HK. Ultraviolet light induced injury: Immunological and inflammatory effects. Immunol Cell Biol. 2001 Dec 1;79(6):547–68.
37. Stark WS, Tan KEWP. Ultraviolet Light: Photosensitivity and Other Effects on the Visual System. Photochem Photobiol. 1982 Sep 1;36(3):371–80.
38. Taylor HR. The Biological Effects of UV-B On The Eye. Photochem Photobiol. 1989 Oct 1;50(4):489–92.
39. Maris P. Modes of action of disinfectants. Vol. 14, Rev. sci. tech. Off. int. Epiz. 1995.
40. McDonnell G, Russell AD. Antiseptics and disinfectants: activity, action, and resistance. Clin Microbiol Rev. 1999 Jan 1;12(1):147–79.

41. Rutala. See 5.
42. Chan H-T, White P, Sheorey H, Cocks J, Waters M-J. Evaluation of the biological efficacy of hydrogen peroxide vapour decontamination in wards of an Australian hospital. J Hosp Infect. 2011;
43. Rutala. See 5. Table 4.
44. Boyce JM, Havill NL. Evaluation of a New Hydrogen Peroxide Wipe Disinfectant. Infect Control Hosp Epidemiol. 2013 May 2;34(5):521–3.
45. Weber and others. See 20
46. Rutala WA, Weber DJ. See 5. Table 5.
47. Rutala WA, Weber DJ. See 5.
48. Scotland HP. See 9.
49. 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 Jun 1;42(6):586–90.

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