A Manual Disinfection Enhancement Method utilizing a Pulsed-Xenon Ultraviolet Device in Accordance with the Effect on the Contamination Levels of Vancomycin-Resistant Enterococci (VRE) and Methicillin-Resistant Staphylococcus Aureus (MRSA)

Saeed Hussein Alhmoud
Department of Interior Design, Faculty of Art and Design, Applied Science Private University, Amman, Jordan
s_alhmoud@asu.edu.jo (corresponding author)

Khitam Alsaqer
Community and Mental Health Department, Faculty of Nursing, Zarqa University, Zarqa, Jordan

Received: 23 September 2024 | Revised: 8 October 2024 and 12 October 2024 | Accepted: 14 October 2024

 DOI: https://doi.org/10.48084/etasr.9082

ABSTRACT

In hospitals, Ultraviolet (UV) disinfection lowers the rates of nosocomial infections; surface decontamination systems using Pulsed Xenon Ultraviolet light (PPX-UV) may be useful in lowering the microbiological load. This study aims to evaluate and compare Methicillin-Resistant Staphylococcus aureus (MRSA) and Vancomycin Resistant Enterococci (VRE) using manual plus PPX-UV disinfection technology versus standard manual room cleaning. Samples of high-touch surfaces from 20 rooms were taken both before and after both group the manual cleaning alone and the manual plus PPX-UV. Post-cleaning results showed a notable reduction in colony counts for both VRE (99%) and MRSA (98%) when comparing manual cleaning to manual plus PPX-UV treatment. The manual method showed higher colony counts for both bacteria compared to the manual plus PPX-UV method, with statistically significant differences in incidence rate ratios observed ($p < .05$). The study findings demonstrate that while manual cleaning methods can reduce microbial load, the manual plus PPX-UV method is notably more effective in achieving lower colony counts post-cleaning. This study underscores the importance of employing effective disinfection strategies in healthcare environments.

Keywords-hospital associated infections; Ultraviolet (UV); environmental quality improvement; Vancomycin Resistant Enterococci (VRE); Methicillin-Resistant Staphylococcus Aureus (MRSA); Healthcare-Acquired Infections (HAIs)

I. INTRODUCTION

Environmental cleaning is important for reducing microbial contamination of surfaces and subsequent risk for Healthcare-Acquired Infections (HAIs) [1-3]. Vancomycin-Resistant Enterococci (VRE) and Methicillin-Resistant Staphylococcus Aureus (MRSA) are important pathogens that cause HAIs. The hospital environment is a major source of bacterial pathogens that can survive on high-touch surfaces in a hospital room for extended periods, so it has an important role in their transmission [4, 5]. It causes infections that negatively affect patient outcomes, including length of hospital stay and mortality [6, 7].

MRSA is a significant public health concern in Jordan, particularly in healthcare facilities. Studies have shown varying prevalence rates, with hospital-acquired MRSA being more common than community-acquired strains. Authors in [8] report that the prevalence of MRSA among clinical isolates in Jordanian hospitals ranged from 30% to 50%. Factors contributing to the spread of MRSA include overuse of antibiotics, inadequate infection control practices, and close patient contact in healthcare facilities [9].

VRE has been increasingly recognized in Jordan, especially in Intensive Care Units (ICUs) and among patients with prolonged hospital stay. In [10] is reported that the prevalence of VRE in certain hospitals was around 10% to 20% among enterococcal isolates. Similar to MRSA, the emergence of VRE is linked to antibiotic misuse and particularly of vancomycin [11].

Portable Pulsed Xenon Ultraviolet (PPX-UV) technology uses high-intensity broad-spectrum UV irradiation in the 200–320 nm range technology, have not been compared with other techniques [12]. Also, manual cleaning which is the standard cleaning procedure used in most hospitals [13], may be inadequate if not carried out correctly and this requires supervision with constant reinforcement and education of Environmental Management Service (EMS) staff to maintain effectiveness.

The effectiveness of manual debridement plus PPX-UV in hospitals compared to manual debridement alone has not been tested [14]. Therefore, the present study compares the adoption of manual plus PPX-UV technology to provide a systematic overview of the environmental cleaning of hospital room surfaces to prevent HAIs. Moreover it evaluates a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of VRE and MRSA.

II. METHODS

A comparative study was conducted between May 10th and July 18th, 2024 in standard manual cleaning to the prevalence of staphylococcus aureus transmission and infection in Acute Care Hospitals (ACHs). Seventeen high-touch surfaces in a care unit room (bed rails/controls, tray table, IV pole (grab area), call box/button, telephone, bedside table handle, chair, room sink, room light switch, room inner doorknob, bathroom, inner doorknob/plate, bathroom light switch, bathroom handrails by toilet, bathroom sink, toilet seat, toilet flush handle, toilet bedpan cleaner) were collected using Rodac plates that can be used for microbiological control of all surfaces [15]. Additionally, a prospective study was conducted to evaluate the use of a new hospital room disinfection protocol and ultraviolet (UV) disinfection protocol devices in the healthcare setting. 20 rooms were cleaned using standard procedures, which included manual cleaning of visible dirt followed by soaking and wiping with DispatchW disinfection solution. This solution is ready to use and has strength comparable to the 1:10 bleach solution recommended by the CDC for effective disinfection [16-18]. Then half of the rooms were cleaned using the PPX-UV. The PPX-UV device was deployed according to the manufacturer's protocol, involving four cycles of five minutes each. Post-cleaning samples were then collected for analysis.

Transmission-Based Precautions (TBP) are required for patients who exhibit symptoms consistent with colonization or infection with a communicable condition; these samples are tested for MRSA by Polymerase Chain Reaction (PCR) (on admission to the health facility) or culture (as a routine process of care according to institutional policy) [14, 19].

The portable pulsed xenon ultraviolet light device being used in this study measures approximately 76.2 × 50.8 × 96.6 cm [7], features a user-friendly touch interface, an integrated cooling system, and a reflector system to focus ultraviolet light on high-touch surfaces. Moreover, there are numerous safety features, including special glass to reduce visual light intensity and ultrasonic sensors to terminate pulsing, if movement is detected in the room. PPX-UV light is absorbed by and fuses with the microorganism DNA, resulting in its deactivation. A new ultraviolet (UV) disinfection protocol device was developed to provide a more effective and convenient tool for disinfecting hospital rooms. The device is a hands-free box, equipped with lamps and uses a five-minute cycle.

In this study, these devices were operated by EMS personnel, who received extensive training and supervision, and were used in empty patient rooms during cleaning to avoid accidental UV exposure to the patient. The device was used in the central patient room area for 5 minutes per cycle, meaning a total disinfection time approximately 20 minutes per room (Figure 1).

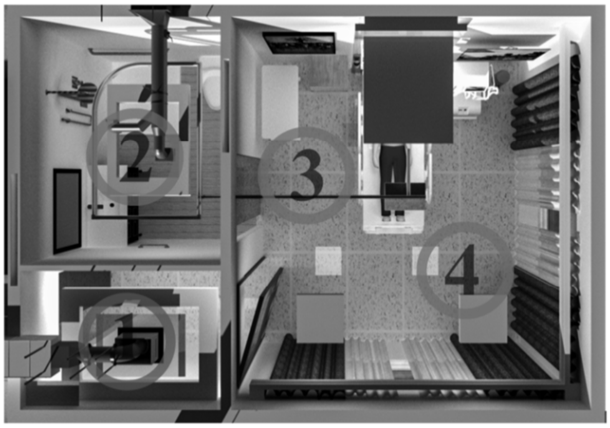

Fig. 1. Schematic ultraviolet disinfection device location.

III. RESULTS

Post-cleaning results showed an average of 50 colonies for VRE and 10 colonies for MRSA in the rooms where used the manual cleaning method meaning 80% and 92% reduction, respectively. Also showed 5 colonies for VRE and 2 colonies for MRSA in the rooms where used the manual plus PPX-UV cleaning method meaning 99% and 98% reduction, respectively. The VRE count for the manual cleaning method was significantly higher than that for the manual plus PPX-UV method. Likewise, the MRSA count was also significantly higher in the manual cleaning group compared to the manual plus PPX-UV group (Table I).

Colony counts in 20 rooms before cleaning differed based on the cleaning method used. For VRE, the manual cleaning method had a mean of 300 and a median of 290, with a first-quartile to the third-quartile range of 150–320, while the manual plus PPX-UV method had a mean of 500 and a median of 400, with a range of 350–600. In the case of MRSA, the manual cleaning method had a mean of 140, a median of 30, and a range of 40–150, compared to the manual plus PPX-UV method, which showed a mean of 100, a median of 120, and a range of 20–200. These initial plate counts were not equivalent and did not follow a normal distribution.

TABLE I. COLONY COUNTS BEFORE AND AFTER CLEANING

Parameter	Cleaning Method	Mean Count	Median Count	Range	Post-Cleaning Count	Reduction	CI 95%	sig
VRE (Before Cleaning)	Manual	300	290	150 - 320	50	80%	14.5 (4.0 - 50.0)	0.01
	Manual + PPX-UV	500	400	350 - 600	5	99%		
MRSA (Before Cleaning)	Manual	140	30	40 - 150	10	92%	8.0 (1.5 - 45.0)	0.02
	Manual + PPX-UV	100	120	20 - 200	2	98%		

IV. DISCUSSION

The findings of this study highlight the significant differences in contamination levels of VRE and MRSA between manual cleaning methods and the use PPX-UV disinfection device after the manual cleaning. According to previous studies, there was a statistically significant decrease in organisms like VRE and C. diff spores even in pre-cleaning absence [20, 21]. Moreover, researchers in [22, 23] demonstrated that the organic material from the hospital rooms had a negligible impact on UV spore killing. The results demonstrate that while both cleaning methods can reduce microbial load, the manual plus PPX-UV method is notably more effective in achieving lower colony counts post-cleaning. After manual cleaning, samples taken from seventeen high-touch surfaces showed high residual MRSA colony counts.

Previous researches have consistently shown that traditional cleaning methods often leave residual pathogens in healthcare environments. In [24] the authors have found that manual cleaning alone resulted in variable efficacy against VRE and MRSA, with average reductions of only 50-70% in contaminated surfaces. This aligns with our findings where the manual cleaning method resulted in a mean of 50 colonies for VRE, indicating that while some reduction was achieved, it was far from complete.

In contrast, the manual plus PPX-UV method demonstrated a remarkable 99% reduction in VRE counts, which is consistent with findings in [12], where reported that UV disinfection can achieve up to 99.9% reduction in various pathogens, including MRSA and VRE. This study contributes to the body of research on the application of a pulsed-xenon ultraviolet (PPX-UV) disinfection device for surface disinfection in the hospital setting [25]. The superior efficacy of UV light as a disinfection strategy can be attributed to its ability to penetrate biofilms and disrupt microbial DNA, leading to cell death.

The statistical analysis further supports the superiority of the manual plus PPX-UV method over just manual cleaning. The Incidence Rate Ratios (IRR) for both VRE (IRR = 14.5) and MRSA (IRR = 8.0) indicate that manual cleaning significantly increases the expected colony counts compared to the manual plus PPX-UV method. This finding underscores the critical need for advanced disinfection technologies in healthcare settings, particularly as antibiotic-resistant organisms continue to pose a major threat to patient safety.

The integration of pulsed-xenon ultraviolet (PPX-UV) technology into hospital cleaning protocols offers both benefits and challenges. It has shown effectiveness in reducing contamination from pathogens like VRE and MRSA. While the initial costs for PPX-UV devices are high, studies indicate that long-term savings from decreased HAIs could justify the investment [26]. Hospitals that adopted UV disinfection reported significant reductions in HAIs, leading to fewer patient readmissions and lower costs [27]. The economic feasibility of this technology must be assessed in relation to hospital budgets and potential improvements in patient outcomes. The time needed for PPX-UV disinfection cycles ranges from 5 to 10 minutes per room, which can extend overall cleaning times in busy hospitals [14]. However, research shows that when effectively integrated into current cleaning protocols, this time impact can be minimized [28]. A streamlined approach that combines manual cleaning with PPX-UV treatment allows for timely room readiness without sacrificing safety. Evacuating rooms during UV disinfection presents logistical challenges, as guidelines require all personnel and patients to leave to avoid UV exposure [29]. This necessitates careful planning in healthcare facilities to ensure safety and minimize disruptions. Some hospitals have adopted staggered room evacuations to efficiently use PPX-UV technology while maintaining patient flow [30].

A. Implications for Infection Control Practices

The substantial reductions in colony counts achieved by the manual plus PPX-UV suggest that integrating advanced disinfection technologies could lead to lower rates of HAIs. A systematic review in [31] emphasized that improved cleaning protocols, including UV disinfection, are essential in combating the rise of multidrug-resistant organisms in hospital settings.

Furthermore, the current study highlights the importance of assessing baseline contamination levels when evaluating cleaning efficacy. As the results prove, the initial contamination levels significantly influence post-cleaning outcomes. This suggests that hospitals should routinely monitor environmental contamination to adjust their cleaning protocols effectively.

B. Limitations and Future Directions

The sample size of 20 rooms may limit the generalization of the findings. Future studies should aim to include larger sample sizes and diverse healthcare settings to validate these results. Additionally, longitudinal studies assessing the long-term impact of manual plus PPX-UV disinfection on infection rates would be beneficial.

V. CONCLUSIONS

This study underscores the importance of employing effective disinfection strategies in healthcare environments. The manual plus Portable Pulsed Xenon Ultraviolet (PPX-UV) method not only significantly reduces contamination levels of Vancomycin-resistant Enterococci (VRE) and Methicillin-resistant Staphylococcus aureus (MRSA) compared to manual cleaning but also represents a promising tool in the ongoing battle against antibiotic-resistant pathogens. As healthcare facilities continue to face challenges coming by Healthcare-acquired Infections (HAIs), integrating advanced technologies like PPX-UV into routine cleaning protocols could be pivotal in enhancing patient safety and outcomes.

REFERENCES

[1] S. M. A. Abdelmalek, M. W. Qinna, R. Al-Ejielat, and P. J. Collier, "Methicillin-Resistant Staphylococci (MRS): Carriage and Antibiotic Resistance Patterns in College Students," *Journal of Community Health*, vol. 47, no. 3, pp. 416–424, Jun. 2022, https://doi.org/10.1007/s10900-022-01065-9.

[2] D. J. Anderson *et al.*, "Decontamination of Targeted Pathogens from Patient Rooms Using an Automated Ultraviolet-C-Emitting Device," *Infection Control & Hospital Epidemiology*, vol. 34, no. 5, pp. 466–471, May 2013, https://doi.org/10.1086/670215.

[3] S. H. Alhmoud, C. Cagnan, and E. F. Arcan, "Improving Interior Environmental Quality Using Sustainable Design in Jordanian Hospital Bedrooms," *European Journal of Sustainable Development*, vol. 9, no. 3, pp. 443–443, Oct. 2020, https://doi.org/10.14207/ejsd.2020.v9n3p443.

[4] J. M. Boyce, "A review of wipes used to disinfect hard surfaces in health care facilities," *American Journal of Infection Control*, vol. 49, no. 1, pp. 104–114, Jan. 2021, https://doi.org/10.1016/j.ajic.2020.06.183.

[5] S. H. Alhmoud, S. B. Denerel, Ç. Çağnan, and H. H. Alhmoud, "Enhancing the Environmental Quality of the Interior Using Sustainability in the Jordanian Hospital Bedrooms," *Annals of the Romanian Society for Cell Biology*, pp. 4015–4026, Mar. 2021.

[6] S. H. Alhmoud and Ç. Çağnan, "Adapting Hospital Interior Architecture Process to Technological Advancement in the Management of Pandemic Cases in Jordan," *Buildings*, vol. 13, no. 10, Oct. 2023, Art. no. 2602, https://doi.org/10.3390/buildings13102602.

[7] S. H. Alhmoud, "Sustainability of Development and Application of Nanomaterials in Healthcare within Hospital Settings," *International Journal of Civil Engineering*, vol. 11, Jun. 2024, https://doi.org/10.14445/23488352/IJCE-V11I6P110.

[8] Y. Li *et al.*, "Comparative Analysis of Sampling Methods for Assessing Bacterial Contamination on Hospital Partition Curtains: Moistened Swabs versus RODAC Agar Plates," *Medical Science Monitor*, vol. 29, Sep. 2023, https://doi.org/10.12659/MSM.941086.

[9] A. Daher and I. Alabbadi, "Investigating the Effect of Syrian Refugees on the Pharmaceutical Sector in Jordan," *Archives of Iranian Medicine*, vol. 20, no. 8, pp. 538–546, Aug. 2017.

[10] M. Dashti, A. Dargahi, H. Sadeghi, M. Vosoughi, and S. A. Mokhtari, "Removal of Microorganisms by UVC Radiation From the Air of Hospital," *Avicenna Journal of Environmental Health Engineering*, vol. 9, no. 1, pp. 35–44, Jun. 2022, https://doi.org/10.34172/ajehe.2022.05.

[11] J. H. Han, N. Sullivan, B. F. Leas, D. A. Pegues, J. L. Kaczmarek, and C. A. Umscheid, "Cleaning Hospital Room Surfaces to Prevent Health Care–Associated Infections," *Annals of Internal Medicine*, vol. 163, no. 8, pp. 598–607, Oct. 2015, https://doi.org/10.7326/M15-1192.

[12] T. W. Huber *et al.*, "Efficacy of pulsed-xenon ultraviolet light on reduction of Mycobacterium fortuitum," *SAGE Open Medicine*, vol. 8, Jan. 2020, https://doi.org/10.1177/2050312120962372.

[13] C. Jinadatha, R. Quezada, T. W. Huber, J. B. Williams, J. E. Zeber, and L. A. Copeland, "Evaluation of a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of methicillin-resistant Staphylococcus aureus," *BMC Infectious Diseases*, vol. 14, no. 1, Apr. 2014, Art. no. 187, https://doi.org/10.1186/1471-2334-14-187.

[14] H. Kitagawa *et al.*, "Effect of pulsed xenon ultraviolet disinfection on methicillin-resistant Staphylococcus aureus contamination of high-touch surfaces in a Japanese hospital," *American Journal of Infection Control*, vol. 48, no. 2, pp. 139–142, Feb. 2020, https://doi.org/10.1016/j.ajic.2019.08.033.

[15] C. R. Kovach, Y. Taneli, T. Neiman, E. M. Dyer, A. J. A. Arzaga, and S. T. Kelber, "Evaluation of an ultraviolet room disinfection protocol to decrease nursing home microbial burden, infection and hospitalization rates," *BMC Infectious Diseases*, vol. 17, no. 1, Mar. 2017, Art. no. 186, https://doi.org/10.1186/s12879-017-2275-2.

[16] F. A. Manian *et al.*, "Isolation of Acinetobacter baumannii Complex and Methicillin-Resistant Staphylococcus aureus from Hospital Rooms Following Terminal Cleaning and Disinfection: Can We Do Better?," *Infection Control & Hospital Epidemiology*, vol. 32, no. 7, pp. 667–672, Jul. 2011, https://doi.org/10.1086/660357.

[17] S. Rashmi and R. Kumar, "Statistical Analysis of the Factors influencing the In Situ U-Value of Walls," *Engineering, Technology & Applied Science Research*, vol. 14, no. 2, pp. 13335–13340, Apr. 2024, https://doi.org/10.48084/etasr.6904.

[18] J. K. Schaffzin, A. W. Wilhite, Z. Li, D. Finney, A. L. Ankrum, and R. Moore, "Maximizing efficiency in a high occupancy setting to utilize ultraviolet disinfection for isolation rooms," *American Journal of Infection Control*, vol. 48, no. 8, pp. 903–909, Aug. 2020, https://doi.org/10.1016/j.ajic.2020.05.004.

[19] R. Scott, L. T. Joshi, and C. McGinn, "Hospital surface disinfection using ultraviolet germicidal irradiation technology: A review," *Healthcare Technology Letters*, vol. 9, no. 3, pp. 25–33, 2022, https://doi.org/10.1049/htl2.12032.

[20] S. Shrestha, S. Kharel, S. Homagain, R. Aryal, and S. K. Mishra, "Prevalence of vancomycin-resistant enterococci in Asia—A systematic review and meta-analysis," *Journal of Clinical Pharmacy and Therapeutics*, vol. 46, no. 5, pp. 1226–1237, 2021, https://doi.org/10.1111/jcpt.13383.

[21] Y. Sun, Q. Wu, J. Liu, and Q. Wang, "Effectiveness of ultraviolet-C disinfection systems for reduction of multi-drug resistant organism infections in healthcare settings: A systematic review and meta-analysis," *Epidemiology & Infection*, vol. 151, Jan. 2023, Art. no. e149, https://doi.org/10.1017/S0950268823001371.

[22] E. Tacconelli and M. A. Cataldo, "Vancomycin-resistant enterococci (VRE): transmission and control," *International Journal of Antimicrobial Agents*, vol. 31, no. 2, pp. 99–106, Feb. 2008, https://doi.org/10.1016/j.ijantimicag.2007.08.026.

[23] R. E. Thomas, B. C. Thomas, J. Conly, and D. Lorenzetti, "Cleaning and disinfecting surfaces in hospitals and long-term care facilities for reducing hospital- and facility-acquired bacterial and viral infections: a systematic review," *Journal of Hospital Infection*, vol. 122, pp. 9–26, Apr. 2022, https://doi.org/10.1016/j.jhin.2021.12.017.

[24] M. Verhougstraete *et al.*, "Impact of terminal cleaning in rooms previously occupied by patients with healthcare-associated infections," *PLOS ONE*, vol. 19, no. 7, 2024, Art. no. e0305083, https://doi.org/10.1371/journal.pone.0305083.

[25] J. E. Zeber *et al.*, "Effect of pulsed xenon ultraviolet room disinfection devices on microbial counts for methicillin-resistant Staphylococcus aureus and aerobic bacterial colonies," *American Journal of Infection Control*, vol. 46, no. 6, pp. 668–673, Jun. 2018, https://doi.org/10.1016/j.ajic.2018.02.001.

[26] E. C. Christenson *et al.*, "Evidence Map and Systematic Review of Disinfection Efficacy on Environmental Surfaces in Healthcare Facilities," *International Journal of Environmental Research and Public Health*, vol. 18, no. 21, Jan. 2021, Art. no. 11100, https://doi.org/10.3390/ijerph182111100.

[27] Health Quality Ontario, "Portable Ultraviolet Light Surface-Disinfecting Devices for Prevention of Hospital-Acquired Infections: A Health

Technology Assessment," *Ontario Health Technology Assessment Series*, vol. 18, no. 1, pp. 1–73, 2018.

[28] D. L. Poster *et al.*, "Ultraviolet Radiation Technologies and Healthcare-Associated Infections: Standards and Metrology Needs," *Journal of Research of the National Institute of Standards and Technology*, vol. 126, 2021, Art. no. 126014, https://doi.org/10.6028/jres.126.014.

[29] C. C. R. Ramos *et al.*, "Use of ultraviolet-C in environmental sterilization in hospitals: A systematic review on efficacy and safety," *International Journal of Health Sciences*, vol. 14, no. 6, pp. 52–65, 2020.

[30] D. J. Anderson *et al.*, "Implementation Lessons Learned From the Benefits of Enhanced Terminal Room (BETR) Disinfection Study: Process and Perceptions of Enhanced Disinfection with Ultraviolet Disinfection Devices," *Infection Control & Hospital Epidemiology*, vol. 39, no. 2, pp. 157–163, Feb. 2018, https://doi.org/10.1017/ice.2017.268.

[31] A. Zhang, M. M. Nerandzic, S. Kundrapu, and C. J. Donskey, "Does Organic Material on Hospital Surfaces Reduce the Effectiveness of Hypochlorite and UV Radiation for Disinfection of Clostridium difficile?," *Infection Control & Hospital Epidemiology*, vol. 34, no. 10, pp. 1106–1108, Oct. 2013, https://doi.org/10.1086/673148.