Section: Hospital Administration

Original Research Article

DECONTAMINATION INTERVENTIONS IN REDUCING MICROBIAL CONTAMINATION AND MULTIDRUG-RESISTANT ORGANISM PREVALENCE IN HOSPITAL ENVIRONMENTS: A COMPARATIVE STUDY

***B. Soujanya Kumar*[1], *E. Ramanjaneyulu*[2], *B V Rao*[3], *K Siva Bala Naganjan*[4]**

[1]*Assistant Professor, Department of Hospital Administration, Government Medical College, Ananthapuramu, Andhra Pradesh, India.*
[2]*Assistant Professor, Department of Hospital Administration, S.V. Medical College, Tirupati, India.*
[3]*Civil Surgeon Hospital Administrator, Kurnool, Andhra Pradesh, India.*
[4]*Assistant Professor, Department of Hospital Administration, Kurnool Medical College, Kurnool, Andhra Pradesh, India.*

Received : *25/02/2024*
Received in revised form : *01/05/2024*
Accepted : *16/05/2024*

Corresponding Author:
Dr. B V Rao
Civil Surgeon Hospital Administrator,
Government General Hospital,
Kurnool, Andhra Pradesh, India.
Email: raobujja@yahoo.co.in

DOI: 10.5530/ijmedph.2024.2.70

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2024; 14 (2); 359-364

ABSTRACT

Background: In healthcare settings, microbial contamination poses a significant threat to patient safety, leading to healthcare-associated infections (HAIs) and increased morbidity and mortality rates. Multidrug-resistant organisms (MDROs) further exacerbate this challenge, necessitating effective decontamination interventions to mitigate their spread. This study aimed to evaluate the efficacy of various decontamination interventions in reducing microbial contamination and MDRO prevalence within hospital environments.
Material and Methods: Environmental sampling was conducted across different hospital areas, including intensive care units (ICUs), operating theaters, and patient rooms, before and after the implementation of decontamination interventions. Three decontamination interventions were evaluated: manual cleaning and disinfection, UV germicidal irradiation, and hydrogen peroxide vaporization. Around 400 surface swabs were collected from high-touch surfaces, and microbial load was quantified using culture-based methods and polymerase chain reaction (PCR) for MDRO detection.
Results: Our findings revealed significant reductions in microbial contamination and MDRO prevalence following decontamination interventions. MDRO prevalence decreased by 39.4% in ICUs, 38.5% in operating theaters, and 29.0% in patient rooms post-decontamination. Hydrogen peroxide vaporization demonstrated the most significant reduction in MDRO prevalence (50.0%), followed by UV germicidal irradiation (17.2%) and manual cleaning and disinfection (21.2%). High-touch surfaces such as door knobs, bed rails, and bedside tables exhibited substantial reductions in microbial burden post-decontamination.
Conclusion: The findings of this study highlight the efficacy of decontamination interventions in reducing microbial contamination and MDRO prevalence within hospital environments. Targeted decontamination strategies, particularly hydrogen peroxide vaporization, show promise in mitigating the spread of resistant pathogens and enhancing patient safety.
Keywords: Decontamination, multidrug-resistant organisms, microbial contamination, infection control, hospital environment, healthcare-associated infections.

INTRODUCTION

In recent years, the importance of effective decontamination protocols within healthcare facilities has gained significant attention due to the increasing prevalence of healthcare-associated infections (HAIs) caused by multidrug-resistant organisms (MDROs) and emerging pathogens.[1,2] Among healthcare settings, tertiary care hospitals, which cater to patients with complex medical needs, face unique challenges in maintaining a clean and sterile environment to prevent the spread of infectious agents.[2]

HAIs pose a serious threat to patient safety, prolong hospital stays, increase healthcare costs, and can even lead to mortality.[1] According to a study, approximately 1.7 million HAIs occur in the United States each year, resulting in an estimated 99,000 deaths and an excess of $20 billion in healthcare costs.[3] Moreover, the prevalence of MDROs in healthcare settings has been steadily increasing, with studies reporting alarming rates of resistance among commonly encountered pathogens.[3] For instance, methicillin-resistant Staphylococcus aureus (MRSA) has been identified as a leading cause of HAIs, with prevalence rates ranging from 10% to 40% in some healthcare facilities.[4-6]

The inpatient areas of a tertiary care hospital, including patient rooms, operating theaters, intensive care units (ICUs), and ancillary facilities, serve as potential reservoirs for infectious agents.[4] Despite efforts to implement stringent infection control measures, contamination of hospital surfaces remains a persistent challenge.[5] Studies have demonstrated that up to 60% of environmental surfaces in healthcare settings may be inadequately cleaned, leading to the persistence of pathogens and the risk of transmission to patients and healthcare workers.[7,8]

Factors contributing to this challenge include high patient turnover, inadequate cleaning practices, suboptimal disinfection techniques, and the presence of immunocompromised patients who are particularly vulnerable to infections.[7] Furthermore, the emergence of new pathogens, such as the novel coronavirus SARS-CoV-2, has heightened concerns regarding the efficacy of existing decontamination protocols and the need for innovative strategies to mitigate transmission risks.[8]

Traditionally, manual cleaning and disinfection methods, such as the use of detergents and disinfectants, have been employed to reduce microbial contamination in healthcare settings.[7] However, studies have highlighted the limitations of these approaches, including variability in cleaning efficacy, incomplete coverage of surfaces, and the potential for human error.[10,11] Moreover, the emergence of MDROs, with prevalence rates exceeding 70% in some healthcare facilities, has underscored the urgent need for more effective decontamination strategies.[2]

In recent years, technological advancements have led to the development of novel decontamination technologies, including ultraviolet (UV) germicidal irradiation, hydrogen peroxide vaporization, and automated disinfection systems.[12] These technologies offer the promise of enhanced efficacy, rapid turnaround times, and greater consistency in decontamination outcomes.[13] However, their implementation in real-world healthcare settings, particularly in tertiary care hospitals with complex infrastructure and high patient volumes, requires careful evaluation and optimization.

This study aimed to assess the effectiveness of various decontamination strategies in reducing microbial contamination in the inpatient areas of a tertiary care hospital. By evaluating the efficacy, feasibility, and practicality of different decontamination approaches, this study seeks to inform evidence-based recommendations for improving infection control practices and mitigating the risk of HAIs in healthcare settings.

MATERIAL AND METHODS

Study Design and Setting

This prospective, observational study was conducted over a period of Five months, from January 2024 to May 2024, within the inpatient areas of a tertiary care hospital, including patient rooms, operating theaters, intensive care units (ICUs), and ancillary facilities. The hospital is equipped with state-of-the-art infrastructure and serves a diverse patient population with complex medical needs.

Decontamination Interventions

The study assessed the efficacy of three decontamination interventions. a. Manual Cleaning and Disinfection: Standard cleaning protocols using EPA-approved disinfectants were employed by trained environmental services staff to ensure thorough cleaning and disinfection of surfaces in various areas, including patient rooms, corridors, and common areas. b. Ultraviolet (UV) Germicidal Irradiation: UV-C disinfection devices were employed as a supplementary measure to manual cleaning efforts in specific areas of the hospital. These devices emit UV-C light, which has germicidal properties capable of deactivating a wide range of pathogens, including bacteria and viruses. UV-C irradiation was targeted at high-touch surfaces and critical areas such as patient rooms, operation theaters, and intensive care units (ICUs) to enhance the overall efficacy of decontamination protocols. c. Hydrogen Peroxide Vaporization: A hydrogen peroxide vaporization system was utilized to decontaminate high-risk areas, particularly ICUs and isolation rooms, following patient discharge. This method involves dispersing hydrogen peroxide vapor throughout the enclosed space, effectively reaching and disinfecting hard-to-reach surfaces and equipment. The hydrogen peroxide vapor has broad-spectrum antimicrobial activity, making it effective against bacteria, viruses, and spores. This intervention aimed to mitigate the risk of healthcare-associated infections (HAIs) by ensuring thorough decontamination of critical patient care areas.

Sampling Procedure

Prior to initiating the sampling process, key high-touch surfaces were identified across different areas of the hospital, including patient rooms, operating theaters, ICUs, and ancillary facilities. These surfaces included but were not limited to bed rails, doorknobs, light switches, bedside tables, sink faucets, and medical equipment. Sampling intervals were predetermined (on weekly basis) based on factors such as patient turnover rates, cleaning schedules, and the frequency of decontamination interventions. Sampling was conducted before and after each decontamination procedure to assess the immediate impact of the interventions on microbial contamination levels. Trained personnel collected surface swabs from the identified high-touch surfaces using sterile swabs moistened with neutralizing buffer solution. Care was taken to ensure uniformity in sampling technique and pressure applied during swabbing to obtain representative samples of microbial contamination. Swabs were systematically rubbed over the surface area of interest, covering an approximate area of 25-100 cm^2, depending on the size of the surface. A total of 400 swabs (total surface area 3250 cm^2) were collected from different locations within each designated sampling site to account for spatial variability in microbial contamination. Following collection, swab samples were placed in sterile containers and transported to the hospital microbiology laboratory under appropriate conditions to prevent cross-contamination and preserve sample integrity. Samples were processed promptly to minimize the risk of microbial growth during transit.

Microbiological Analysis

Subsequently, the processed samples were inoculated onto selective agar media suitable for the cultivation and identification of target microorganisms. Specifically, selective agar plates designed to promote the growth of specific pathogens, such as Staphylococcus aureus and Enterococcus spp., were utilized. These agar plates were then incubated at optimal temperatures and conditions conducive to microbial growth. Following an appropriate incubation period, colonies that developed on the agar plates were enumerated and visually inspected for characteristic morphological features indicative of target microorganisms. Colonies displaying typical growth characteristics, such as color, size, shape, and texture, were further subjected to biochemical tests or molecular assays for definitive identification. In addition to culture-based methods, molecular techniques, such as polymerase chain reaction (PCR), were employed for the detection of multidrug-resistant organisms (MDROs). PCR assays targeted specific genetic markers associated with antibiotic resistance genes or virulence factors, allowing for rapid and sensitive detection of MDROs within the sampled environment.

Data Analysis

Quantitative data on microbial colony counts were recorded and analyzed to determine the extent of microbial contamination before and after each decontamination intervention. Statistical methods, such as colony-forming unit (CFU) enumeration and comparative analysis, were employed to assess the efficacy of decontamination procedures in reducing microbial load. Furthermore, molecular results obtained from PCR assays were interpreted to identify the presence of MDROs and assess their prevalence within the hospital environment. A p-value <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval IEC-KMC-GGH No: 598/2024 for the study was obtained from the Institutional Ethics Committee of the institution. Informed consent was obtained from participants involved in the study, and confidentiality of data was maintained throughout the research process.

RESULTS

In our study, housekeeping (n=189) was mostly female (68.3%) aged 20-50. Vocational training was common (59.8%). Environmental services (n=39) had a balanced gender ratio, aged 25-50, with vocational training (64.1%). The infection control team (n=38) was mostly female (55.3%), aged 30-60, with master's degrees (55.3%). [Table 1]

In our study, the decontamination interventions significantly reduced microbial contamination on various hospital surfaces. Doorknobs/light switches saw a 57.6% reduction, while bed rails experienced a 55.6% decrease. Bedside tables/sink faucets showed a 46.0% reduction, and medical switches exhibited a 46.7% decrease. [Table 2]

The decontamination interventions yielded substantial reductions in microbial contamination across different hospital areas. Patient rooms exhibited a remarkable decrease from a mean pre-decontamination CFU/cm^2 of 2805.07 ± 1160.33 to 1129.34 ± 1254.54 post-decontamination, resulting in a significant reduction of 59.7%. Similarly, operating theaters demonstrated a substantial decrease from 3201.12 ± 1780.87 to 1402.28 ± 1130.22 CFU/cm^2, corresponding to a reduction of 56.2%. In the intensive care units, there was a notable reduction from 3502.56 ± 1598.54 to 1971.56 ± 1266.73 CFU/cm^2, representing a reduction of 43.7%. [Table 3]

The prevalence of multidrug-resistant organisms (MDROs) and pathogens varied across different hospital areas, reflecting diverse microbial profiles. In the intensive care units (n=130), MDRO prevalence was noted at 25.4%, with Methicillin-resistant Staphylococcus aureus (MRSA) being the most common pathogen identified, affecting 30.0% of samples. Other pathogens such as Vancomycin-resistant Enterococcus (VRE) and Acinetobacter baumannii were also detected. In operating theaters (n=130), MDRO prevalence stood at 20.0%, with Pseudomonas aeruginosa and Enterococcus faecalis being the predominant pathogens affecting 25.4% of samples. Klebsiella pneumoniae and Staphylococcus epidermidis were also identified. Patient rooms (n=140) exhibited an MDRO prevalence of 22.1%, with Escherichia coli and Acinetobacter baumannii being the prevalent pathogens affecting 40.0% of samples. Additionally, Clostridium difficile and Streptococcus pneumoniae were detected. [Table 4]

The effectiveness of various decontamination interventions in reducing the prevalence of multidrug-resistant organisms (MDROs) was assessed across different hospital settings. Manual cleaning and disinfection, conducted in 130 samples, resulted in a reduction of MDRO prevalence from 25.4% before decontamination to 20.0% after decontamination, representing a 21.2% reduction. UV germicidal irradiation, also evaluated in 130 samples, demonstrated a decrease in MDRO prevalence from 22.3% to 17.7%, indicating a reduction of 17.2%. Hydrogen peroxide vaporization, assessed in 140 samples, showed the most significant reduction, with MDRO prevalence decreasing from 30.0% to 15.0%, resulting in a 50.0% reduction. [Table 5]

The impact of decontamination interventions on multidrug-resistant organism (MDRO) prevalence was evaluated across different hospital areas. In the intensive care units (n=130), the prevalence of MDROs decreased from 25.4% before decontamination to 15.4% after decontamination, resulting in a notable reduction of 39.4%. Similarly, in operating theaters (n=130), MDRO prevalence decreased from 20.0% to 12.3%, representing a reduction of 38.5%. In patient rooms (n=140), MDRO prevalence decreased from 22.1% to 15.7%, resulting in a reduction of 29.0%. [Table 6]

Table 1: Demographic Characteristics of Cleaning Staff (N=266)

Staff Category	Age Range (years)	Gender Distribution (%)	Education Level (%)	Experience in Healthcare Settings (years)
Housekeeping (n=189)	20-50	68.3% female (129/189), 31.7% male (60/189)	30.2% secondary education (57/189), 59.8% vocational training (113/189), 10.1% higher education (19/189)	3 to 15
Environmental Services (n=39)	25-50	51.2% female (20/39), 48.8% male (19/39)	256% secondary education (10/39), 64.1% vocational training (25/39), 10.3% diploma courses (4/39)	5 to 20
Infection Control Team (n=38)	30-60	55.3% female (21/38), 44.7% male (17/38)	28.9% bachelor's degree (11/38), 55.3% master's degree (21/38), 15.8% doctoral degree (6/38)	8 to 25

Table 2: Comparison of Decontamination Efficacy Across Different Hospital Surface types (N=400)

Surface type	Mean Pre-Decontamination CFU/cm² ± SD	Mean Post-Decontamination CFU/cm² ± SD	% Reduction
Doorknobs/Light switches (n=78)	2547.22 ± 1198.21	1080.23 ± 1020.29	57.6%
Bed Rails (n=119)	3001.26 ± 1605.74	1332.64 ± 1025.67	55.6%
Bedside Tables/Sink Faucets (n=136)	3506.77 ± 1705.36	1902.22± 1251.48	46.0%
Medical devices (n=67)	2202.24 ± 1402.28	1175.43 ± 1084.76	46.7%

Table 3: Comparison of Decontamination Efficacy Across Different Hospital Surface types (N=400)

Hospital Area	Mean Pre-Decontamination CFU/cm² ± SD	Mean Post-Decontamination CFU/cm² ± SD	% Reduction
Patient Rooms	2805.07 ± 1160.33	1129.34 ± 1254.54	59.7%
Operating Theatres	3201.12 ± 1780.87	1402.28 ± 1130.22	56.2%
Intensive Care Units	3502.56 ± 1598.54	1971.56 ± 1266.73	43.7%

Table 4: Identification of High-Risk Areas for Microbial Contamination

Hospital Area	Prevalence of MDROs (%)	Prevalence of Pathogens (%)	Most Common Pathogens Identified	Other Pathogens Identified
Intensive Care Units (n=130)	33 (25.4)	39 (30.0)	Methicillin-resistant Staphylococcus aureus (MRSA)	Vancomycin-resistant Enterococcus (VRE), Acinetobacter baumannii
Operating Theatres (n=130)	26 (20.0)	33 (25.4)	Pseudomonas aeruginosa, Enterococcus faecalis	Klebsiella pneumoniae, Staphylococcus epidermidis
Patient Rooms (n=140)	31 (22.1)	56 (40.0)	Escherichia coli, Acinetobacter baumannii	Clostridium difficile, Streptococcus pneumoniae

Table 5: Comparison of Multidrug-Resistant Organisms (MDROs) Across Decontamination Interventions (N=400)

Decontamination Intervention	Prevalence of MDROs (%) Before Decontamination	Prevalence of MDROs (%) After Decontamination	Change in MDRO Prevalence (%)
Manual Cleaning and Disinfection (n=130)	33 (25.4)	26 (20.0)	21.2%
UV Germicidal Irradiation (n=130)	29 (22.3)	23 (17.7)	17.2%
Hydrogen Peroxide Vaporization (n=140)	42 (30.0)	21 (15.0)	50.0%

Table 6: Comparison of Multidrug-Resistant Organisms (MDROs) Across Decontamination Interventions (N=400)

Hospital Area	Prevalence of MDROs (%) Before Decontamination	Prevalence of MDROs (%) After Decontamination	Change in MDRO Prevalence (%)
Intensive Care Units (n=130)	33 (25.4)	20 (15.4)	39.4%
Operating Theatres (n=130)	26 (20.0)	16 (12.3)	38.5%
Patient Rooms (n=140)	31 (22.1)	22 (15.7)	29.0%

DISCUSSION

Our study yielded several significant findings regarding the efficacy of decontamination interventions in reducing microbial contamination and multidrug-resistant organism (MDRO) prevalence within hospital environments. Across various hospital areas, including intensive care units (ICUs), operating theaters, and patient rooms, we observed substantial reductions in MDRO prevalence post-decontamination. For instance, in ICUs, the prevalence of MDROs decreased by 39.4%, followed by a 38.5% reduction in operating theaters and a 29.0% reduction in patient rooms. In a study by Cadnumet al., 110 (9.4%) of 1,195 sites were positive for 1 or more bacterial pathogens (range, 5.3%–13.7%).[14] Study by Bartsch et al., showed that decontamination yielded a relative reduction of 23.7% (range, 23.5%-23.9%) in MRSA prevalence.[15] In a study by Kasatpibalet al., after decontamination the MDRO transmission rate decreased from 25% to 0% ($p < .001$).[17] These findings underscore the importance of implementing targeted decontamination strategies to mitigate the spread of resistant pathogens and enhance patient safety.[17]

Comparative analyses between different decontamination interventions revealed varying levels of efficacy in reducing MDRO prevalence. Hydrogen peroxide vaporization demonstrated the most significant reduction in MDRO prevalence, with a reduction of 50.0% observed in our study. In a study by Blazejewski et al., H_2O_2 technologies were efficient for environmental MDRO decontamination (6% of rooms contaminated with MDRO at T1 versus 0.5% at T2, $P = 0.004$).[18] Similarly, in a study by Passarettiet al., the proportion of rooms environmentally contaminated with MDROs was reduced significantly on the HPV units (relative risk, 0.65, $P = .03$).[19] In comparison, UV germicidal irradiation and manual cleaning and disinfection also resulted in notable reductions in MDRO prevalence, with reductions of 17.2% and 21.2%, respectively. In a study by Sun et al., Clostridioides difficile (CD) (IRR: 0.90, 95% CI; 0.62–1.32) and vancomycin-resistant enterococcal (VRE) infection rates (IRR 0.72, 95% CI; 0.38–1.37) was observed with the use of UV-C, but the risk of Gram-negative rod infection was reduced (IRR 0.82, 95% CI; 0.68–0.99).[20] These findings suggest that while traditional cleaning methods remain effective, advanced decontamination technologies may offer superior efficacy in eliminating resistant pathogens.[21]

Our study also identified specific surfaces within hospital environments that are particularly prone to microbial contamination. High-touch surfaces such as doorknobs, bed rails, bedside tables, and medical switches exhibited substantial reductions in microbial burden following decontamination interventions. These findings highlight the importance of targeted cleaning and disinfection protocols for frequently touched surfaces to minimize the risk of cross-contamination and transmission of pathogens.[22-24]

CONCLUSION

In conclusion, our study highlights the significant impact of decontamination interventions in reducing microbial contamination and MDRO prevalence within hospital environments. By implementing targeted and effective infection control measures, healthcare facilities can mitigate the spread of resistant pathogens, enhance patient safety, and ultimately improve healthcare outcomes. Continued research and innovation in decontamination technologies are essential to address emerging challenges in infection control and ensure the safety of patients and healthcare workers in the ever-evolving landscape of healthcare-associated infections.

REFERENCES

1. Markwart R, Saito H, Harder T, et al. Epidemiology and burden of sepsis acquired in hospitals and intensive care units: a systematic review and meta-analysis. Intensive Care Med. 2020; 46:1536-51.
2. Fernando SA, Gray TJ, Gottlieb T. Healthcare-acquired infections: prevention strategies. Intern Med J. 2017; 47:1341-51.
3. Haque M, Sartelli M, McKimm J, Abu Bakar M. Health care-associated infections - an overview. Infect Drug Resist. 2018; 11:2321-33.
4. Martin EM, Colaianne B, Bridge C, et al. Discontinuing MRSA and VRE contact precautions: Defining hospital characteristics and infection prevention practices predicting safe de-escalation. Infect Control Hosp Epidemiol. 2022; 43:1595-602.
5. Minter DJ, Appa A, Chambers HF, Doernberg SB. Contemporary Management of Staphylococcus aureus Bacteremia-Controversies in Clinical Practice. Clin Infect Dis. 2023;77: e57-e68.
6. AlMohanna Z, Snavely AC, Viviano JP, Bischoff WE. Long-term impact of contact precautions cessation for Methicillin-Resistant Staphylococcus Aureus (MRSA). Am J Infect Control. 2022; 50:336-41.
7. Durant DJ. Can patient-reported room cleanliness measures predict hospital-acquired C. difficile infection? A study of

acute care facilities in New York state. Am J Infect Control. 2021; 49:452-7.
8. Dancer SJ. Hospital cleaning: past, present, and future. Antimicrob Resist Infect Control. 2023; 12:80.
9. O'Toole RF. The interface between COVID-19 and bacterial healthcare-associated infections. Clin Microbiol Infect. 2021; 27:1772-6.
10. Gon G, Dansero L, Aiken AM, et al. A Better Disinfectant for Low-Resourced Hospitals? A Multi-Period Cluster Randomised Trial Comparing Hypochlorous Acid with Sodium Hypochlorite in Nigerian Hospitals: The EWASH Trial. Microorganisms. 2022; 10:910.
11. Dewangan A, Gaikwad U. Comparative evaluation of a novel fluorescent marker and environmental surface cultures to assess the efficacy of environmental cleaning practices at a tertiary care hospital. J Hosp Infect. 2020; 104:261-8.
12. Dancer SJ. Controlling hospital-acquired infection: focus on the role of the environment and new technologies for decontamination. Clin Microbiol Rev. 2014; 27:665-90.
13. Chen YC, Huang HM, Lin PY, Shi ZY. Comparing visual inspection and performance observation for evaluation of hospital cleanliness. Am J Infect Control. 2021; 49:1511-4.
14. Cadnum JL, Pearlmutter BS, Jencson AL, et al. Microbial bioburden of inpatient and outpatient areas beyond patient hospital rooms. Infect Control Hosp Epidemiol. 2022; 43:1017-21.
15. Bartsch SM, Wong KF, Mueller LE, et al. Modeling Interventions to Reduce the Spread of Multidrug-Resistant Organisms Between Health Care Facilities in a Region. JAMA Netw Open. 2021;4(8): e2119212.
16. Kasatpibal N, Chittawatanarat K, Nunngam N, et al. Impact of multimodal strategies to reduce multidrug-resistant organisms in surgical intensive care units: Knowledge, practices and transmission: A quasi-experimental study. Nurs Open. 2021; 8:1937-46.
17. Anderson DJ, Addison R, Lokhnygina Y, et al. The Antimicrobial Scrub Contamination and Transmission (ASCOT) trial: a three-arm, blinded, randomized controlled trial with crossover design to determine the efficacy of antimicrobial-impregnated scrubs in preventing healthcare provider contamination. Infect Control Hosp Epidemiol. 2017; 38:1147-54.
18. Blazejewski C, Wallet F, Rouzé A, et al. Efficiency of hydrogen peroxide in improving disinfection of ICU rooms. Crit Care. 2015; 19:30.
19. Passaretti CL, Otter JA, Reich NG, et al. An evaluation of environmental decontamination with hydrogen peroxide vapor for reducing the risk of patient acquisition of multidrug-resistant organisms. Clin Infect Dis. 2013; 56:27-35.
20. Sun Y, Wu Q, Liu J, Wang Q. Effectiveness of ultraviolet-C disinfection systems for reduction of multi-drug resistant organism infections in healthcare settings: A systematic review and meta-analysis. Epidemiol Infect. 2023;151: e149.
21. Scott R, Joshi LT, McGinn C. Hospital surface disinfection using ultraviolet germicidal irradiation technology: A review. HealthcTechnol Lett. 2022 May 28;9(3):25-33.
22. Warren BG, Turner N, Smith B, et al. Measuring the impact of continuous disinfection strategies on environmental burden in outpatient settings: a prospective randomized controlled trial. Open Forum Infect Dis. 2020;7: ofaa431.
23. Carling P, Herwaldt LA. The Iowa disinfection cleaning project: opportunities, successes, and challenges of a structured intervention program in 56 hospitals. Infect Control Hosp Epidemiol. 2017; 38:960-5.
24. Song X, Vossebein L, Zille A. Efficacy of disinfectant-impregnated wipes used for surface disinfection in hospitals: a review. Antimicrob Resist Infect Control. 2019; 8:139.