Annals of Clinical Microbiology
www.acm.or.kr

Mini review

Roles of clinical microbiology in hospital environmental cleaning and disinfection: a narrative review

Young Ah Kim
Department of Laboratory Medicine, National Health Insurance Service Ilsan Hospital, Goyang, Korea

Abstract

Purpose: This narrative review examines the pivotal role of clinical microbiology in environmental cleaning and disinfection within healthcare facilities. With an increasing focus on infection control, particularly regarding multidrug-resistant organisms (MDROs), the review explores disinfection strategies, monitoring methods, and best practices, including recent recommendations from the Korea Disease Control and Prevention Agency.

Current content: MDROs such as methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, and carbapenem-resistant gram-negative bacteria are significant contributors to healthcare-associated infections (HAIs). These organisms persist on hospital surfaces, posing a risk of transmission. There are various disinfection modalities for non-critical surfaces (e.g., bedrails, floors) detailing the advantages and limitations of common disinfectants, including quaternary ammonium compounds, hydrogen peroxide, and sodium hypochlorite. It is efficient to use self-disinfecting surfaces coated with heavy metals and no-touch disinfection technologies, such as ultraviolet (UV)-C light and vaporized hydrogen peroxide. Clinical microbiologists are responsible for monitoring methods, including swab cultures, Replicate Organism Detection and Counting plates, and adenosine triphosphate assays, to assess the microbial load on hospital surfaces. Comprehensive monitoring is needed, which also includes visual inspection, UV-visible markers, and fluorescent tracers for quality control and performance feedback.

Conclusion: Environmental cleaning and disinfection are essential in reducing HAIs linked to MDROs. Effective implementation of evidence-based disinfection practices, adherence to guidelines, and collaboration between clinical staff are critical components of successful infection control. The clinical microbiologist's role is vital in evaluating cleaning efficacy and ensuring optimal infection prevention strategies through regular feedback and microbial surveillance.

Keywords: Bacterial multiple drug resistance, Carbapenems, Cross infection, Disinfection, Vancomycin-resistant enterococci

OPEN ACCESS
pISSN : 2288-0585
eISSN : 2288-6850

Ann Clin Microbiol 2024 September, 27(3):171-177
https://doi.org/10.5145/ACM.2024.27.3.3

Corresponding to
Young Ah Kim
E-mail: yakim@nhimc.or.kr

Received: August 28, 2024
Revised: August 28, 2024
Accepted: August 29, 2024

Introduction

Background

Recently, the importance of environmental management in healthcare facilities has been emphasized as a part of infection control [1,2]. Multidrug-resistant organisms (MDROs), such as methicillin-resistant

Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), and carbapenem-resistant gram-negative bacilli (*Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacterales*), are long-term environmental survivors [3]. MRSA and VRE have been reported to survive for 4 weeks-7 months and 5 days-4 months in the environment, respectively [3].

Environmental reservoirs of MDROs result in the spread of microorganisms and an increase in the prevalence of healthcare-associated infections (HAIs) [4,5]. Colonized or infected patients contaminate environmental surfaces and non-critical equipment, the pathways of which can be broken by environmental cleaning [6]. Adequate strategies for cleaning, disinfection, and monitoring are important for managing hospital environments [6].

Objectives

This review provides an overview of general environmental cleaning/disinfection and monitoring modalities, including clinical microbiology. The recommendations provided by the Korea Disease Control and Prevention Agency (KDCA), will also be summarized briefly.

Environmental cleaning/disinfection modalities

Healthcare environment requires disinfection of non-critical items according to Spaulding categories [7]. Examples of non-critical items are bedpans, bedrails, floors, and other high-touch surfaces [8]. Some disinfectants that can be used for low-level disinfection of non-critical items are alcohol, sodium hypochlorite, hydrogen peroxide, phenolics, quaternary ammonium compounds, and peracetic acid. These disinfectants are usually applied in many forms-based on the targeted microorganisms. Each type of disinfectant has its advantages and disadvantages, including the type of surface, characteristics of the specific disinfectant, cost, ease of use, and safety. Therefore, the selection of specific disinfectants typically involves input of multiple stakeholders. It should be used in a hospital environment with sufficient contact time, temperature, and concentration. It is necessary to establish dwell times in a laboratory setting because of the pressure to turn the rooms around quickly.

Quaternary ammoniums are widely used healthcare disinfectants and US Environmental Protection Agency approved. It is a cheap, persistently active, and surface-compatible agent with wide action rages (bactericidal, viricidal against enveloped viruses and fungicidal). It is frequently used for routine cleaning and disinfection of noncritical environmental surfaces. But it is not sporicidal and ineffective against mycobacterium or nonenveloped viruses. Cotton towels and cloths can diminish microbicidal activity and organic matter affect its activity. Advantages and disadvantages of other disinfectants are summarized in Table 1.

Self-disinfecting surfaces are coated with heavy metals for protection from bacterial contamination. Many surfaces are coated with copper for this purpose, and the reaction mechanism involves the generation of reactive oxygen species that damage nucleic acids, proteins, and lipids [9]. A 99.99% reduction in *Escherichia coli* and *S. aureus* was reported on surfaces coated with 48% copper over a 24-hour incubation time [9]. Light-activated antimicrobial coatings are self-disinfecting surfaces that irradiate certain compounds with visible or ultraviolet light to produce reactive radicals [10]. They are less toxic than chemical disinfectants, and are broadly microbicidal in nature. However, a constant source of photoactivation is required and it is unclear whether these surfaces are sporicidal.

No-touch modalities disinfect through various mechanisms. For example, ultraviolet (UV)-C (200–280 nm) and UV-B (280–320 nm) radiation disrupt DNA or RNA replication, resulting in cell rupture at high intensities [11]. Vaporous hydrogen peroxide systems generate free radicals that exhibit toxicity toward bacteria and spores by coating their surfaces with hydrogen peroxide [11].

Table 1. Advantages and disadvantages of low-level disinfectants

Disinfectants	Advantages	Disadvantages
Alcohol	Kills bacteria, mycobacterium, fungus, virus Fast, no corrosion, no stain, easy to use, nontoxic	Not sporicidal and slow to norovirus Affected by organic material Damage to rubber and deteriorate glue Flammable and evaporate rapidly Not EPA registered
Sodium hypoc hlorite	Kills bacteria, mycobacterium, fungus, virus, and spore Fast, cheap, nonflammable, relatively stable, unaffected by water hardness (water treatment) EPA-registered	Leave salt residue, stain, and discolor Corrosion of metals and odor Unstable (ready to use product) Affected by organic matter
Hydrogen peroxide	Kills bacteria, mycobacterium, fungus, virus. Fast, easy to use, safe (lowest EPA toxicity), no stain, not flammable, surface compatible EPA-registered	Not sporicidal at low concentration
Iodophors	Kills bacteria, mycobacterium, and virus. Nonflammable	Not sporicidal and prolonged contact time for virus (mainly for antiseptic use) Stain and silicone degradation Not EPA registered
Phenolics	Kills bacteria, mycobacterium, fungus, virus. Cheap, no stain, nonflammable EPA-registered	Not sporicidal Absorbed by porous material Irritation of tissue and depigmentation of skin
Quaternary ammonium compounds	Kills bacteria, fungus, and enveloped virus Surface compatible, cheap, persistently active EPA-registered	Not sporicidal, tuberculocidal and virucidal (nonenveloped virus) High water hardness Affected by organic matter Absorbed by cotton and some wipes
Peracetic acid	Kills bacteria, fungus, virus, and spore Unaffected by organic material Surface compatible EPA-registered	No stain Odor and mucous irritation Brass or copper incompatibility

Abbreviation: EPA, US Environmental Protection Agency.

Monitoring modalities

Microbial contamination of environmental surfaces can be evaluated more accurately using microbiological methods. Swab cultures are commonly used because they are easy to perform and can be used to sample irregular surfaces and hands [12]. Moistened sterile swabs were applied to the sample surfaces and inoculated onto agar, often with enrichment broth. Specific pathogens can be identified during an outbreak using the information obtained about the pathogens from swab cultures.

Replicate Organism Detection and Counting (RODAC) contact plates are small Petri plates filled with agar that can acquire samples by direct application on the surface. These are easy to use and standardized for quantitative measurement (colony forming units/cm^2). However, high costs, limited sampling, and reduced sensitivity are disadvantages of the RODAC contact plate [12].

Agar slide cultures are used to sample flat and hard surfaces, often in conjunction with aerobic colony counts (ACC). The limitations of the ACC method include lack of accepted criteria for defining a surface as "clean," cost of processing, delay in results, and small sample area per swab or slide [13]. Microbiological methods are very useful for providing precleaning levels of microbial contamination for each object or surface, but their sensitivity depends on many factors, such as the type of surface being sampled, specific pathogens, and user technique. Therefore, quality control assessments are essential and should be supervised by certified environmental microbiology laboratories.

Environmental cultures are highly sensitive and specific in providing a direct indication of the presence of specific pathogens. Culture methods are useful for identifying sources of outbreaks and environmental reservoirs. The disadvantages of culture methods are that they are not suitable for routine use, are expensive, and lack a defined threshold for determining the level or status of cleanliness. It also requires prolonged time to obtain results (> 48 h) and access to laboratory resources and trained personnel for interpreting results.

The assessment and feedback of cleaning performance are important for environmental infection control [13]. Visual inspection is a simple and basic monitoring modality that assesses the adequacy of routine cleaning and disinfection practices. Another advantage is that it allows immediate and direct feedback from individual staff. However, it is subjective, based on individual determinations, and does not assess or correlate with the bioburden.

UV-visible surface markers display the contamination of high-touch surfaces before room cleaning and disinfection to determine adequate removal [13]. A fluorescent tracer marks predetermined items and surfaces before cleaning. After cleaning, a trained observer uses UV light to determine if any tracing agent has remained. The advantages of this method are that it is rapid, inexpensive, easy to use, and objective. It requires minimal training and provides immediate feedback on performance. However, it does not assess or correlate with bioburden and labor intensiveness, as surfaces should be marked before cleaning and checked after cleaning has been completed. Additionally, some difficulties have been documented in the removal of markers from porous or rough surfaces.

Adenosine triphosphate assay detects microbial and biological materials [13]. The objects are tested before and after cleaning to determine the effectiveness of the cleaning procedure using a predetermined threshold. This method can provide immediate feedback, requires minimal training, and the results are objective. However, this method is expensive, less sensitive, less specific, and lacks a standardized threshold or benchmark for determining the cleanliness level or status. Other disadvantages include constantly changing technology and interference from bleach, microfibers, and stainless steel.

Recommendations for environmental cleaning and disinfections

The Center for Disease Control and Prevention published 'Best Practices for Environmental Cleaning in Healthcare Facilities in Resource-limited Settings,' [6] that suggests that maintaining a clean environment is as important and fundamental as hand hygiene for infection control. In addition, it is highlighted that regular environmental disinfection is essential to reduce HAIs.

Considering the importance of this topic, updated recommendations were introduced by the KDCA in 2022. These recommendations provide evidence-based medicine guidelines for hygiene and environmental management in healthcare facilities, and practical applications to prevent HAIs that stem from environmental surfaces [14]. The definitions of the level of evidence ranged from very low to high quality randomized controlled trials. According to the level of evidence, the recommendation grade is defined as category I (strongly recommended), IA (high-moderate level of evidence), and IB (low-very low level of evidence or established work). Category IA recommendations regarding the principles of environmental surface management, methods, and disinfection of diarrheagenic pathogens are summarized in Table 2.

Table 2. Guidelines for environmental disinfection, strongly recommended by KDCA with high-moderate level of evidence [14].

Title	Guideline
Principles of environmental surface management	Medical institutions periodically clean and disinfect environmental surfaces by applying consistent methods to provide a safe and hygienic environment to patients Regulations and procedures for environmental management Includes 1) Environmental management scope 2) Routine and after discharge cleaning/disinfection 3) Cleaning/disinfection of isolation room Frequent contact surfaces that are frequently touched or likely to be used are cleaned and disinfected more frequently. High-touch surfaces include bed railing, bed table, call bell, door handles, washbasin handles, and tops Clean and disinfect non-hazardous items or environmental surfaces periodically
Principles of disinfectants	No category IA recommendation
Principles of methods	Prepare procedures for cleaning and disinfecting the environment of medical institutions Clean and disinfect the environment systematically to avoid retaining infectious microbes The environmental cleaning and disinfection cycle shall be determined after considering the risk of infection to employees, patients, and visitors in relation to surface contamination. Risk assessments include the degree of contamination, frequency of contact, and vulnerability of infection of the subject Examples of daily environmental surfaces are floors, walls, and tables. They are cleaned and disinfected periodically with disinfectants certified by authorized agencies, reported, and registered, and immediately when there is visible contamination Cleaning and disinfection by route of transmission may be enhanced in frequency compared to routine cleaning and disinfection, and if necessary, the level of disinfection may be enhanced. The isolation room shall be disinfected daily using disinfectants effective against microorganisms of patient subject to isolation
Disinfection of high-touch surfaces	No category IA recommendation
Disinfection of diarrheagenic pathogen	Medical institutions comply with contact precautionary measures for cleaning and disinfection necessary for the prevention of *C. difficile*, Norovirus, Rotavirus, VRE, and CPE transmission. Establish policies and procedures for routine cleaning and disinfection of rooms for isolation ward areas in contact state and post-discharge cleaning and disinfection
Disinfection of CPE	No category IA recommendation

Abbreviations: KDCA, Korea Disease Control and Prevention Agency; VRE, vancomycin-resistant enterococci; CPE, carbapenemase-producing *Enterobacterales*.

Recommendation to disinfect carbapenemase-producing *Enterobacterales*

Although there is no established strong recommendation to disinfect carbapenemase-producing *Enterobacterales* (CPE), which is a major problem in the post-COVID-19 pandemic era [15], there are some expert opinions on managing it by the KDCA [14]. To manage the CPE of a medical institution, cleaning and disinfecting the sink and shower should be considered after the CPE infected patient has been examined. If the CPE trend continues, sink drain inspection for CPE should be considered when cleaning and disinfecting the discharge water from the CPE infected patient room. Personal protective equipment, such as a gown or apron, is required in situations where contact with patient is necessary and attention should be paid for its contamination with chemicals, blood, body fluids, secretions, or excrement. If a gown or apron is to be worn, it should not become wet and should be replaced between hospital rooms and work. If gloves are used, they should be replaced between each cleaning session, such as regular cleaning of the isolated patient area and post-department cleaning of the general patient area.

Conclusions

Environmental contamination plays a role in the transmission of HAIs of MDROs, which pose a significant burden globally and disproportionately affect clinical outcomes. Environmental cleaning/disinfection is an important fundamental infection control policy, and its significance cannot be overstated. This review describes practical recommendations and guidelines for environmental management to implement effective environmental cleaning/disinfection procedures in healthcare facilities.

For the best environmental management, detailed control strategies (e.g., preparation, application, and contact time of disinfectants), adherence to best practices, proper education, defined roles for cleaning workers, and institutional collaboration are important. Feedbacks and trainings are provided based on evaluations of microbial contamination of environmental surfaces, in which clinical microbiology plays a substantial role.

Ethics statement

This was not a human population study; therefore, approval by the institutional review board and informed consent were not required.

Conflict of interest

No potential conflict of interest relevant to this article were reported.

Funding

None.

References

1. Protano C, Cammalleri V, Romano Spica V, Valeriani F, Vitali M. Hospital environment as a reservoir for cross transmission: cleaning and disinfection procedures. Ann Ig 2019;31:436-48.
2. Han Z, Pappas E, Simmons A, Fox J, Donskey CJ, Deshpande A. Environmental cleaning and disinfection of hospital rooms: a nationwide survey. Am J Infect Control 2021;49:34-9.
3. Kampf G, Kramer A. Epidemiologic background of hand hygiene and evaluation of the most important agents for scrubs and rubs. Clin Microbiol Rev 2004;17:863-93.
4. Martínez JA, Ruthazer R, Hansjosten K, Barefoot L, Snydman DR. Role of environmental contamination as a risk factor for acquisition of vancomycin-resistant enterococci in patients treated in a medical intensive care unit. Arch Intern Med 2003;163:1905-12.
5. 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.
6. Center for Disease Control and Prevention. Best Practices for Environmental Cleaning in Healthcare Facilities: in Resource-limited Settings. https://www.cdc.gov/healthcare-associated-infections/media/pdfs/environmental-cleaning-rls-508.pdf [Online] (last visited on 23 August 2024).
7. Rutala WA and Weber DJ. Disinfection and sterilization in health care facilities: an overview and current issues. Infect Dis Clin North Am 2021;35:575-607.
8. Fram DS, Medeiros EA, Ribeiro RM, Escudero DVDS, Alves JCD, Macedo B, et al. High-touch surfaces disinfection compliance in a COVID-19 intensive care unit. Am J Infect Control 2023;51:469-71.
9. Lakshminarayanan R, Ramakrishna S, Mondal DP, Srivastava AK, Dhand C. Recent advances in copper and copper-derived materials for antimicrobial resistance and infection control. Curr Opin Biomed Eng 2022;24:100408.
10. Querido MM, Aguiar L, Neves P, Pereira CC, Teixeira JP. Self-disinfecting surfaces and infection control. Colloids Surf B Biointerfaces 2019;178:8-21.
11. Tsou AY, Pavlides S, Koepfler L, Drummond C. No-touch modalities for disinfecting patient rooms in acute care settings: a rapid review. Rockville (MD): Agency for Healthcare Research and Quality (US); 2020 Oct 2. Report No.: 20(21)-EHC021.
12. Obenza A, Cruz P, Buttner M, Woodard D. Microbial contamination on ambulance surfaces: a systematic literature review. J Hosp Infect 2022;122:44-59.
13. Leas BF, Sullivan N, Han JH, Pegues DA, Kaczmarek JL, Umscheid CA. Environmental cleaning for the prevention of healthcare-associated infections. Rockville (MD): Agency for Healthcare Research and Quality (US); 2015 Aug. Report No.: 15-EHC020-EF.
14. Infection Control Consulting Network. Recommendations for cleaning and disinfection of environmental surfaces in medical institutions. https://www.iccon.or.kr/rang_board/list.html?num=1614&start=30&code=iccons_guide [Online] (last visited on 23 August 2024).
15. Abubakar U, Al-Anazi M, Alanazi Z, Rodríguez-Baño J. Impact of COVID-19 pandemic on multidrug resistant gram positive and gram-negative pathogens: a systematic review. J Infect Public Health 2023;16:320-31.