OPEN

Environmental Cleaning and Decontamination to Prevent *Clostridioides difficile* Infection in Health Care Settings: A Systematic Review

Elizabeth Schoyer, MPH and Kendall Hall, MD

Objective: The aim of this systematic review was to examine the most effective and feasible methods for environmental cleaning and decontamination to prevent *Clostridioides difficile* infection (CDI) in health care settings.

Methods: A systematic search of the databases CINAHL and MEDLINE was conducted from 2008 to 2018 for English language articles with search terms including "*Clostridium difficile*," and related medical subject headings, in combination with terms like "disinfection," "decontamination," and "no-touch decontamination."

Results: Twelve studies and 2 systematic reviews were selected for inclusion in this review. The studies were primarily in hospitals (10/12) and used a before-after approach. The studied interventions included cleaning and decontamination with a chlorine-based agent (i.e., bleach; 2 studies), standard cleaning plus the use of hydrogen peroxide decontamination (3 studies), and standard bleach cleaning plus the use of ultraviolet light decontamination (6 studies), and there was 1 study about launderable bed covers. The interventions ranged in frequency, duration, and the area selected for cleaning and decontamination (e.g., all patient rooms versus only CDI patients' rooms). Studies showed significant reductions in CDI associated with use of bleach (versus quaternary ammonium compound) and hydrogen peroxide decontamination after standard bleach cleaning (versus bleach cleaning alone). Four of 6 studies found significant reductions in CDI after the implementation of ultraviolet light decontamination after standard bleach cleaning.

Conclusions: The studied practices for environmental cleaning and decontamination were associated with significant decreases in facility-level CDI rates in most of the reviewed studies; however, study quality was low. Implementation challenges are worthy of further examination.

Key Words: *Clostridioides difficile*, *Clostridium difficile*, health care–associated infections, environmental cleaning, disinfection, decontamination, patient safety, HAIs, colitis, hospital, long-term care facility, nursing home

(*J Patient Saf* 2020;16: S12–S15)

Preventing *Clostridioides difficile* (*C. difficile*) infection (CDI) in health care settings is an important U.S. public health priority. There are an estimated half a million incident CDIs per year and around 30,000 deaths per year as a result of CDI.[1] The financial cost of CDI is also high; in recent years, CDI has resulted in approximately $5 billion a year in health care costs in the United States.[2–4] A 2017 meta-analyses of 9 pooled study results found that cost incurred by a facility for an inpatient CDI case was $17, 260 (95% confidence interval [CI], $9341–$25,180).[5]

The health care environment is recognized as one of the primary sources of *C. difficile* transmission.[6] In recent estimates, more than half of CDI cases are classified as health care associated (versus community associated).[7] A review of multiple CDI prevention practices found that environmental cleaning and decontamination was the most cost-effective strategy.[8] The *C. difficile* organism is spread through the feces of infected and colonized patients. Patients with contaminated hands may spread *C. difficile* through touching surfaces in the health care environment, and transmission can occur when other patients, health care staff, or visitors touch contaminated surfaces and ingest the organism (e.g., while eating).[7] If a patient is taking antimicrobials, they are more susceptible to colonization or infection with *C. difficile* because antimicrobials alter gastrointestinal tract flora, destroying the bacteria that help to protect against *C. difficile.* Both symptomatic and asymptomatic *C. difficile* carriers have the potential to contaminate the environment.[9,10]

Eliminating *C. difficile* from surfaces in the health care environment requires specialized practices. *C. difficile* produces spores that are especially robust and may remain viable for more than 7 days.[11] Furthermore, the spores are resistant to alcohol and many hospital disinfectants.[12] Among cleaning and decontamination agents for washing surfaces by hand, chlorine-releasing solutions (e.g., bleach), at sufficient concentration and with appropriate exposure time (at least 10 minutes), demonstrate the best evidence for killing *C. difficile*.[13] Terminal (upon discharge) cleaning with a sporicidal agent is the currently recommended standard practice for *C. difficile*.[13]

Manual cleaning under time pressures can result in failure to decontaminate all necessary surfaces.[14,15] Automated no-touch methods have been developed and implemented to eliminate *C. difficile* and other pathogens that cause health care–associated infections. The 2 most commonly studied no-touch methods for *C. difficile* decontamination are hydrogen peroxide decontamination (HPD) and ultraviolet light decontamination (UVD). In controlled laboratory studies, both methods have shown effectiveness in almost entirely eliminating *C. difficile*. It is generally recommended that surfaces are precleaned before use of UVD or HPD, as organic matter is thought to reduce the efficacy of these methods.[16]

METHODS

The question of interest for this review is as follows: What are the most effective and feasible environmental cleaning and decontamination practices to prevent CDI? To answer this question, we searched the databases CINAHL and MEDLINE from 2008 to 2018 for "*Clostridium difficile*," and related medical subject headings terms and synonyms in combination with terms like "disinfection," "decontamination," and "no-touch decontamination." The search string also included a variety of health care settings, including "hospitals," "long-term care," and "transitional care." The initial search yielded 121 original results. We excluded laboratory

From the IMPAQ International, LLC, Oakland, California.
Correspondence: Elizabeth Schoyer, IMPAQ International, LLC, 1333 Broadway, Suite 300, Oakland, CA 94612 (e-mail: eschoyer@impaqint.com).
Address for reprints: Same as for the corresponding author.
This work was funded by the Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services (contract numbers HHSP233201500013I and HHSP23337002T).
The authors disclose no conflict of interest.

studies, articles with insufficient study design or irrelevant outcomes, and studies in which environmental cleaning and decontamination was implemented with other CDI prevention interventions. Of these, 45 full-text articles were retrieved and screened. Reference lists of articles were also screened to ensure thoroughness, and 5 studies were retrieved by these means. A total of 12 studies and 2 systematic reviews were selected. (During the writing of this report, the Centers for Disease Control and Prevention transitioned from use of the name *Clostridium difficile* to *Clostridioides difficile*; for the purposes of this report, they are synonymous.)

RESULTS

Most studies (10/12) showed statistically significant reductions in CDI after the implementation of an environmental cleaning and decontamination intervention; however, study quality was low and studies were difficult to compare. These findings are similar to those of Louh et al[8] in their examination of CDI prevention studies in acute care hospitals from 2009 to 2015. In another review, Khanafer et al[17] cited mostly positive outcomes in a review that included 9 studies on environmental cleaning for CDI prevention published from 1982 to December 2013. Khanafer et al[17] concluded that environmental cleaning with a 10:1 bleach solution is both practical and effective.

In this review, the cleaning and decontamination interventions fall into 4 categories: use of a chlorine-based (e.g., bleach) agent, use of HPD after standard cleaning, use of UVD after standard bleach cleaning, and 1 study about launderable bed covers. Within these categories there were different variables, such as the frequency of cleaning (e.g., daily or at discharge) and the area of cleaning (e.g., CDI patient rooms, all patient rooms, or patient rooms and communal spaces). The studies reviewed were primarily quasiexperimental with a before-after approach. One exception was a study by Anderson et al,[18] which was the only randomized trial. Also of note, 2 of the studies on HPD no-touch decontamination methods received some financial support from the makers of the products, in the form of free use of equipment[19] and reduced cost to use the products.[18] Two UVD studies had more than one author who was an employee of Xenex, the company that sells the machines that were studied in the intervention.[19–21]

Studies: Cleaning With Bleach

Two studies examined patient outcomes after a period in which patient rooms were cleaned with bleach.[22,23] In one of these studies, Hacek et al[22] evaluated a cleaning intervention at 3 hospitals with a total of approximately 850 beds in which terminal cleaning of the rooms occupied by CDI patients was conducted with a bleach solution (5000 ppm) as a replacement for quaternary ammonium compound. In addition, walls were added to a checklist of surfaces to clean after patient discharge there were periodic unannounced cleaning assessments by supervisory staff. After 2 years of the new procedures, the average number of CDI patients per 1000 patient days decreased from 0.85 to 0.45. There was a 48% reduction in the prevalence density of CDI (95% CI, 36%–58%; $P < 0.0001$) when compared with the 10 months prior. The researchers report that that there were no other significant infection prevention practice changes during the cleaning intervention implementation period.

Orenstein et al[23] measured CDI outcomes after a cleaning and decontamination intervention on 2 hospital wards with high baseline incidences of CDI. The intervention consisted of switching from quaternary ammonium compound to germicidal bleach wipes (5000 ppm active chlorine) for daily and terminal cleaning of all patient rooms. After a year of the new procedures, there was a reduction in hospital-acquired CDI incidence of 85%, from 24.2 to 3.6 cases per 10,000 patient days ($P < 0.001$). The researchers conclude that *daily* bleach cleaning of *all* rooms on the wards with high incidence of CDI may be more effective than only terminal only cleaning of the CDI rooms.

Studies: HPD

Three reviewed studies examined the use of HPD (as an addition to standard cleaning) for patient room decontamination.[19,24,25] Best et al[19] reported reduction in incident CDI cases in the months after a one-time deep clean with HPD. Boyce et al[24] found that, after a deep cleaning of 5 wards with HPD, then 8 months of terminal cleaning of CDI-occupied rooms with bleach and HPD, the incidence of nosocomial CDI decreased from 2.28 to 1.28 cases per 1000 patient days ($P = 0.047$). Manian et al[25] evaluated an intervention at a 900-bed community hospital, in which HPD was added to terminal cleaning of all rooms. When HPD decontamination was not possible, CDI rooms were cleaned with 4 rounds of bleach cleaning. After approximately 7 months, the rate of nosocomial CDI dropped significantly, from 0.88 cases/1000 patient days to 0.55 cases/1000 patient days (rate ratio, 0.63; 95% CI, 0.50–0.79; $P < 0.0001$). Results are ambiguous because approximately half of the CDI rooms were cleaned with 4 rounds of bleach cleaning without HPD.

Studies: Ultraviolet Environmental Disinfection

Six studies selected for this review examined the use of UVD and CDI patient outcomes. Of these, 4 studies showed statistically significant decreases in CDI after a period of UVD added to standard terminal cleaning with bleach of CDI patient rooms.[20,21,26,27] One study found borderline significant reductions in CDI,[28] and one study found no change after UVD implementation.[20] Vianna et al[20] studied the addition of UVD to terminal cleaning with bleach in a 206-bed hospital. The terminal UVD procedure was implemented for all room discharges in the intensive care unit (ICU) and for rooms occupied by patients with CDI in the rest of the hospital. After 21 months, there was a 41% decrease in CDI ($P = 0.01$). *C. difficile* infection reductions were greater in the ICU than in the rest of the hospital (61% versus 29%). The results indicate that UVD is effective when deployed to higher-risk/higher-acuity settings (e.g., the ICU) and/or when used in all room discharges (not just for patients with *C. difficile*).[23]

In a long-term acute care facility, Miller et al[21] evaluated the addition of UVD to standard procedures for patient rooms at discharge and for common areas on an approximately weekly basis. For rooms occupied by *C. difficile* patients, standard procedures also included cleaning with a bleach solution. During a 15-month period of added UVD, CDI rates decreased from 19.3 per 1000 patient days to 8.3 per 1000 patient days, a 56.9% reduction ($P = 0.02$). It is important to note that in the prior year, the facility had implemented additional infection prevention measures and it is possible that the reductions in CDI rates reflect the longer-term impact of these measures.

Less favorable results were found in a broad cluster-randomized study of 9 hospitals, in which terminal cleaning with bleach of all rooms occupied by CDI patients was compared with terminal cleaning with bleach plus UVD. In this crossover trial, Anderson et al[18] found that, comparing the strategies for 7 months each, the incidence of CDI infection among patients exposed to rooms previously occupied by patients with CDI was unchanged (n = 38 versus 36; 30.4 cases versus 31.6 cases per 10,000 exposure days; relative risk, 1.0; 95% CI, 0.57–1.75; $P = 0.997$).

Study: Launderable Bed Covers

Contaminated mattresses and bed frames are difficult to clean and have been linked to HAI transmission. To address this problem, Hooker et al[29] examined CDI rates associated with the introduction of washable bed covers at 2 long-term acute care hospitals. The cleaning intervention consisted of introducing launderable bed covers that cover both the mattress and bed deck. The launderable covers were used on all patient beds, removed after every patient discharge, and replaced with a clean cover. After 14 months of use of the bed covers, the rate of CDIs at one hospital reduced 47.8% (95% CI, 47.1%–48.6%), controlling for the rate of handwashing compliance and length of stay in days. At the second hospital, the rate of CDIs decreased by 50% (95% CI, 47.5%–52.7%), controlling for the rate of handwashing compliance and length of stay in days. Data on antimicrobial use were not available so this variable was not factored into the analyses.

Implementation Challenges

There are several implementation challenges and concerns associated with environmental decontamination for *C. difficile*.[13] Housekeepers have reported respiratory irritation when using bleach and other chlorine-based disinfectants.[30] One reason provided to support terminal cleaning versus daily cleaning of CDI patient rooms is to avoid excessive exposure of bleach for environmental services staff.[19] To address this problem, several studies have examined alternatives to bleach, including hydrogen peroxide and peracetic acid.[31–33]

Another challenge is compliance with manual cleaning procedures. Cleaning checklists can be effective,[17] and the use of adenosine triphosphate bioluminescence[26] or fluorescent markers can be useful for auditing/monitoring the thoroughness of cleaning and a basis from which to provide feedback.[34] Other guidelines from an earlier recommend frequent education for environmental service personnel in the primary language of the cleaning team.[3]

One of the challenges reported across several of the studies on HPD and UVD was being able to use the machines in all intended instances[3,25,27,28] Both touchless methods require that rooms be vacant and items be placed in a manner to allow for adequate contact with the hydrogen peroxide mist or UV light. The HPD process can take approximately 3 to 4 hours per patient room.[18] Haas et al[27] reported that the time for UVD light exposure in their study was around 6 minutes, but it took close to a half hour for setup (including setting up blackout curtains) depending on the room. Because of limited device availability, Levin et al[26] reported that only 56% of discharged contact precautions rooms received the UVD treatment. Discrepancies were attributed to limited device availability, a second room occupant who could not be moved, an urgent need for the room, and labor constraints.[28,29]

DISCUSSION

Most of the studies in this review show an association between environmental cleaning interventions and reductions in CDI. The strength of the studies was undermined by several weaknesses such as not including a control group or not controlling for important confounders such as antimicrobial use (e.g., Hooker et al[29]). Because of the heterogeneity of approaches, questions remain about whether decontamination efforts should target CDI patient rooms, all patient rooms, and/or common areas outside the patient room, and whether terminal (versus daily) cleaning and decontamination is sufficient. Comparing these variables could provide better understanding of the most effective and feasible approach. Implementation research on manual and no-touch decontamination methods could focus on the most effective approaches to implementation, in the context of resource and time limitations.

CONCLUSIONS

Environmental cleaning and decontamination interventions for *C. difficile* were associated with significant decreases in facility-level CDI rates in most of the studies in this review; however, study design was generally weak and had potential for bias. Practices with positive outcomes include daily and terminal cleaning of CDI patients' rooms with bleach solutions (typically 5000 ppm) and terminal bleach cleaning plus the use of no-touch decontamination methods such as hydrogen peroxide or UVD. Each method has implementation challenges. Touchless methods require the room or area be vacant and take time to complete.[27–29] Studies suggest that manual cleaning is optimized by standardized cleaning protocols and training and observation of environmental cleaning services staff.

ACKNOWLEDGMENTS

This work was conducted under the ACTION IDIQ contract numbers HHSP233201500013I and HHSP23337002T from the Agency for Healthcare Research and Quality. We also acknowledge and thank the contributions of the Making Health Care Safer III Technical Expert Panel and Advisory Panel for their contributions to the selection of patient safety topics and review of the evidence summaries for key patient safety practices. We would specifically like to thank the reviewer for this patient safety practice: Noel Eldridge.

REFERENCES

1. Lessa FC, Mu Y, Bamberg WM, et al. Burden of *Clostridium difficile* infection in the United States. *N Engl J Med*. 2015;372:825–834.
2. Dubberke ER, Olsen MA. Burden of *Clostridium difficile* on the healthcare system. *Clin Infect Dis*. 2012;55(Suppl 2):S88–S92.
3. Dubberke E, Carling P, Carrico R, et al. Strategies to prevent *Clostridium difficile* infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol*. 2014;35:628–645.
4. Desai K, Gupta SB, Dubberke ER, et al. Epidemiological and economic burden of *Clostridium difficile* in the United States: estimates from a modeling approach. *BMC Infect Dis*. 2016;16:303.
5. Agency for Healthcare Research and Quality. *Estimating the Additional Hospital Inpatient Cost and Mortality Associated With Selected Hospital-Acquired Conditions*. Rockville, MD: Agency for Healthcare Research and Quality. Content last reviewed November 2017. Available at: https://www.ahrq.gov/hai/pfp/haccost2017-results.html#exh7.
6. Weber DJ, Rutala WA, Miller MB, et al. 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–S33.
7. Centers for Disease Control and Prevention [CDC web site]. Data summary of HAIs in the US: assessing progress 2006–2016. Last reviewed December 5, 2017 Available at: https://www.cdc.gov/hai/data/archive/data-summary-assessing-progress.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fhai%2Fsurveillance%2Fdata-reports%2Fdata-summary-assessing-progress.html. Accessed December 1, 2019.
8. Louh IK, Greendyke WG, Hermann EA, et al. *Clostridium difficile* infection in acute care hospitals: systematic review and best practices for prevention. *Infect Control Hosp Epidemiol*. 2017;38:476–482.
9. Dubberke ER, Reske KA, Noble-Wang J, et al. Prevalence of *Clostridium difficile* environmental contamination and strain variability in multiple health care facilities. *Am J Infect Control*. 2007;35:315–318.
10. Riggs MM, Sethi AK, Zabarsky TF, et al. Asymptomatic carriers are a potential source for transmission of epidemic and nonepidemic *Clostridium difficile* strains among long-term care facility residents. *Clin Infect Dis*. 2007;45:992–998.

11. Weaver L, Michels HT, Keevil CW. Survival of *Clostridium difficile* on copper and steel: futuristic options for hospital hygiene. *J Hosp Infect*. 2008;68:145–151.
12. Macleod-Glover N, Sadowski C. Efficacy of cleaning products for *C. difficile*: environmental strategies to reduce the spread of *Clostridium difficile*–associated diarrhea in geriatric rehabilitation. *Can Fam Physician*. 2010;56:417–423.
13. McDonald LC, Gerding DN, Johnson S, et al. Clinical practice guidelines for *Clostridium difficile* infection in adults and children: 2017 update by the Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA). *Clin Infect Dis*. 2018;66:e1–e48.
14. Sethi AK, Al-Nassir WN, Nerandzic MM, et al. Persistence of skin contamination and environmental shedding of *Clostridium difficile* during and after treatment of C. difficile infection. *Infect Control Hosp Epidemiol*. 2010;31:21–27.
15. Carling PC, Parry MM, Rupp ME, et al. Improving cleaning of the environment surrounding patients in 36 acute care hospitals. *Infect Control Hosp Epidemiol*. 2008;29:1035–1041.
16. Doll M, Morgan DJ, Anderson D, et al. Touchless technologies for decontamination in the hospital: a review of hydrogen peroxide and UV devices. *Curr Infect Dis Rep*. 2015;17:498.
17. Khanafer N, Voirin N, Barbut F, et al. Hospital management of *Clostridium difficile* infection: a review of the literature. *J Hosp Infect*. 2015;90:91–101.
18. Anderson DJ, Chen LF, Weber DJ, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. *Lancet*. 2017;389:805–814.
19. Best EL, Parnell P, Thirkell G, et al. Effectiveness of deep cleaning followed by hydrogen peroxide decontamination during high *Clostridium difficile* infection incidence. *J Hosp Infect*. 2014;87:25–33.
20. Vianna PG, Dale CR Jr., Simmons S, et al. Impact of pulsed xenon ultraviolet light on hospital-acquired infection rates in a community hospital. *Am J Infect Control*. 2016;44:299–303.
21. Miller R, Simmons S, Dale C, et al. Utilization and impact of a pulsed-xenon ultraviolet room disinfection system and multidisciplinary care team on *Clostridium difficile* in a long-term acute care facility. *Am J Infect Control*. 2015;43:1350–1353.
22. Hacek DM, Ogle AM, Fisher A, et al. Significant impact of terminal room cleaning with bleach on reducing nosocomial Clostridium difficile. *Am J Infect Control*. 2010;38:350–353.
23. Orenstein R, Aronhalt KC, McManus JE Jr., et al. A targeted strategy to wipe out *Clostridium difficile*. *Infect Control Hosp Epidemiol*. 2011; 32:1137–1139.
24. Boyce JM, Havill NL, Otter JA, et al. Impact of hydrogen peroxide vapor room decontamination on Clostridium difficile environmental contamination and transmission in a healthcare setting. *Infect Control Hosp Epidemiol*. 2008;29:723–729.
25. Manian FA, Griesnauer S, Bryant A. Implementation of hospital-wide enhanced terminal cleaning of targeted patient rooms and its impact on endemic *Clostridium difficile* infection rates. *Am J Infect Control*. 2013; 41:537–541.
26. Levin J, Riley LS, Parrish C, et al. The effect of portable pulsed xenon ultraviolet light after terminal cleaning on hospital-associated *Clostridium difficile* infection in a community hospital. *Am J Infect Control*. 2013; 41:746–748.
27. Haas JP, Menz J, Dusza S, et al. Implementation and impact of ultraviolet environmental disinfection in an acute care setting. *Am J Infect Control*. 2014;42:586–590.
28. Nagaraja A, Visintainer P, Haas JP, et al. *Clostridium difficile* infections before and during use of ultraviolet disinfection. *Am J Infect Control*. 2015; 43:940–945.
29. Hooker EA, Bochan M, Reiff TT, et al. Decreasing *Clostridium difficile* health care–associated infections through use of a launderable mattress cover. *Am J Infect Control*. 2015;43:1326–1330.
30. Aronhalt KC, McManus J, Orenstein R, et al. Patient and environmental service employee satisfaction of using germicidal bleach wipes for patient room cleaning. *J Healthc Qual*. 2013;35:30–36.
31. Alfa MJ, Dueck C, Olson N, et al. UV-visible marker confirms that environmental persistence of *Clostridium difficile* spores in toilets of patients with *C. difficile*–associated diarrhea is associated with lack of compliance with cleaning protocol. *BMC Infect Dis*. 2008;8:–64.
32. Doan L, Forrest H, Fakis A, et al. Clinical and cost effectiveness of eight disinfection methods for terminal disinfection of hospital isolation rooms contaminated with *Clostridium difficile* 027. *J Hosp Infect*. 2012; 82:114–121.
33. Kundrapu S, Sunkesula V, Jury LA, et al. Daily disinfection of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers' hands. *Infect Control Hosp Epidemiol*. 2012;33:1039–1042.
34. Sitzlar B, Deshpande A, Fertelli D, et al. An environmental disinfection odyssey: evaluation of sequential interventions to improve disinfection of *Clostridium difficile* isolation rooms. *Infect Control Hosp Epidemiol*. 2013; 34:459–465.