Health Care Environmental Hygiene

New Insights and Centers for Disease Control and Prevention Guidance

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KEYWORDS

- Hygienic practice • Hand hygiene • Environmental hygiene
- Optimizing disinfection cleaning

KEY POINTS

- Optimizing patient-zone environmental hygiene plays a critical role in mitigating the transmission of health care-associated pathogens, particularly *Clostridioides difficile.*
- New research is clarifying the important role of asymptomatic carriers of *Clostridioides difficile* in transmission.
- The development of new hydrogen peroxide/peroxy acetic acid-based patient-zone surface disinfectants provides a potential for more effective approaches to patient-zone environmental hygiene.
- Although hand hygiene and environmental hygiene individually represent basic horizontal interventions to prevent transmission of health care-associated pathogens, there is a need for these 2 interventions to be recognized as interdependent.

INTRODUCTION

As a result of epidemiologic and microbiologic studies over the past decade, it has become increasingly evident that interventions to mitigate environmental surface pathogen contamination are an important component of health care-associated infection (HAI) prevention. During this time it has become widely appreciated that, "Cleaning of hard surfaces in hospital rooms is critical for reducing healthcare-associated infections."[1] Unfortunately, the complexity of the interrelated factors necessary to optimize the cleanliness of surfaces in the patient zone remains an evolving challenge. Despite such ongoing challenges, it is important to recognize that environmental hygiene represents a critical element of what Wenzel and Edmonds defined as

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“horizontal interventions” that are central to mitigating a wide range of HAIs.[2,3] These approaches aim to reduce the risk of infections caused by a broad range of pathogens by the implementation of standard practices that are effective regardless of patient-specific conditions.[4] In contrast to the horizontal interventions, “vertical interventions” are pathogen and/or condition specific. Vertical interventions include nasal decolonization specific to methicillin-resistant *Staphylococcus aureus* (MRSA) and transmission-based isolation precautions. These interventions are narrowly focused on preventing transmission of specific pathogens.

These interventions remain important in defined settings and become most cost effective when the indications for their use are most clearly defined. Although vertical and horizontal approaches are not mutually exclusive, there is evolving evidence that horizontal interventions in endemic situations may represent the best use of HAI prevention resources.[4]

To facilitate discussion of the many elements necessary to optimize health care hygienic cleaning, it is useful to put these interventions into a defined construct of HAI prevention activities. As noted in **Fig. 1**, hygienic cleaning and hand hygiene as well as interventions related to instrument reprocessing, air quality, water quality, and physical setting design are all horizontal interventions. All these horizontal interventions represent elements of *health care hygienic practice*. Although these elements have traditionally been discussed independently, their effectiveness in clinical settings is substantially interrelated, particularly environmental hygiene and hand hygiene, as will subsequently be discussed. The term “environmental hygiene” can be defined as “cleaning activities directed at removing and/or killing potentially harmful pathogens capable of being transmitted directly from surfaces or indirectly to susceptible individuals or other surfaces.”[5] As noted, it consists of both the physical cleaning of surfaces and surface disinfection cleaning. Although liquid chemistries are well established as the most clinically useful approach to surface disinfection, innovative no-touch technologies that have the potential for complementing traditional liquid chemistry have been developed over the past several years. Each of these components of environmental hygiene will be discussed in detail in later sections, whereas the other components of health care hygienic practice noted in **Fig. 1** will be addressed in other reviews in this issue.

DISINFECTION CLEANING OF ENVIRONMENTAL SURFACES

Chemical Disinfectants: The use of Environmental Protection Association-registered hospital-grade disinfectants to clean and disinfect patient-zone surfaces has been

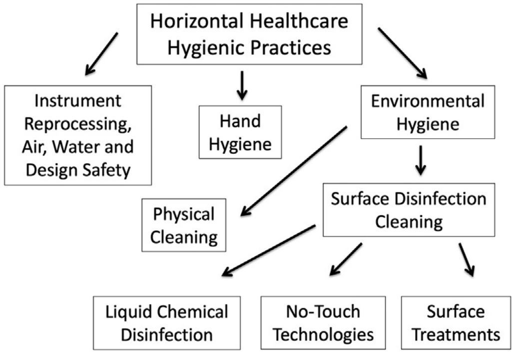

Fig. 1. The elements of horizontal health care hygienic practice.

considered the cornerstone of health care environmental cleaning for many years.[6] As recommended by the Centers for Disease Control and Prevention (CDC), disinfectants are used on all such surfaces in US hospitals.[7] Given the recent detailed review of disinfectant choice and use,[6] the following discussion will focus only on some important generalizations.

Over the past several years, the traditional use of disinfectants on noncritical patient-zone surfaces has been profoundly impacted by the development of broad-spectrum chemistries that are at least as effective as bleach, are not associated with significant damage to surfaces, and are not associated with potentially toxic residuals during either their use or disposal.[8] These chemistries are rapidly sporicidal and effective against *Candida auris* and all viral pathogens, including coronaviruses. Although studies to further quantify the relative clinical value of both hydrogen peroxide/peroxyacetic acid formulations and chlorinated hydrogen peroxide are warranted, these new chemistries have the potential for substantially improving the effectiveness and scope of use of patient-zone surface disinfection cleaning. In clinical studies a hydrogen peroxide/peroxyacetic acid formulation was found to be approximately twice as effective as a quaternary ammonium compound in surface bioburden reduction and as effective as bleach in clinical use.[4,9,10] Given the numerous traditional hospital-grade disinfectants currently marketed and the ongoing development of new chemistries it is critically important that all chemical disinfectants undergo rigorously designed comparative studies in actual clinical settings to quantify their clinical efficacy, similarities, differences, and potential limitations.[6,11,12]

Although premoistened disposable wipes are widely used to clean surfaces in health care settings, their clinical effectiveness has yet to be evaluated in comparative studies. The lack of such studies is particularly notable, given the evidence of the spread of health care-associated pathogens (HAPs) from contaminated to noncontaminated surfaces by wipes.[13–15] Given this important limitation, all premoistened disposable wipes should be tested to ensure that they do not transfer organisms between surfaces. The validity of this approach was confirmed by the recently approved American Society for Testing and Materials standard E2967-15 test. All the 5 wipes tested by the 3 independent testing sites confirmed a greater than 4 $\log_{10}$ reduction in *S aureus* and *Acinetobacter baumannii* on seeded surfaces, but only a wipe using 0.5% accelerated H_2O_2 prevented transfer of the test bacteria to another surface.[15]

Surface Disinfection Technologies

As previously noted, the past decade has seen the development of technological interventions designed to augment physical cleaning of patient-zone surfaces. These innovative technologies using hydrogen peroxide vapor or ultraviolet light systems have been advocated to augment traditional chemical-based disinfection cleaning at the time of discharge or patient transfer. Although these no-touch technologies have shown microbicidal efficacy in laboratory studies, clinical assessment of their effectiveness and potential for augmenting physical disinfection cleaning has been challenging. Ultimately, well-designed, independent, controlled, comparative studies are needed to objectively quantify the cost and potential added value of such technologies when routine cleaning and disinfection has been sustainably optimized.[16]

OPTIMIZING PATIENT-ZONE SURFACE SAFETY

Evaluating disinfection cleaning: The importance of physically removing visible dirt and soil from surfaces in hospitals has been recognized for more than 150 years.[17] Consequently, acute care hospitals have developed policies and procedures to define the role of environmental services (EVS) personnel for cleaning surfaces in all patient care areas. EVS managers and infection preventionists had implemented joint visual inspection of surfaces in patient care areas well before the CDC recommended that hospitals clean and disinfect “high-touch surfaces” in 2003.[7] EVS managers further recommended that hospitals “monitor, (i.e., supervise and inspect cleaning performance) to insure consistent cleaning and disinfection of surfaces in close proximity to the patient and likely to be touched by the patient and healthcare professionals” in 2006.[18] Such monitoring, referred to as “environmental rounds” in the United States and “visual audits” in Great Britain, is used primarily to identify cleaning deficiencies.[19] Unfortunately, the intrinsically subjective nature of such monitoring along with its episodic and deficiency-oriented features limit its ability to accurately assess the thoroughness of day-to-day cleaning activity. Preliminary studies documenting patient-zone surface contamination with HAPs raised concerns that cleaning practice should be improved.[20] It was not until actual cleaning practice was objectively monitored, initially using a covert visual monitoring program[21] and later with covertly applied fluorescent markers, that actual cleaning practice was objectively evaluated.[22,23] The identification of opportunities to improve the thoroughness of patient-zone surface cleaning as part of discharge cleaning in acute care hospitals spurred an evaluation of cleaning practice in other important venues within hospitals, including the operating rooms (both between-case and terminal cleaning), emergency departments, outpatient clinics, and chemotherapy administration suites.[24] Similar studies have been extended to long-term care facilities and dialysis units as well as dental clinics and EMS vehicles.[24] The evaluations were done in a standardized manner with a metered fluorescent marking system (DAZO, Ecolab Inc, St Paul, MN, USA). The outcome measured was the actual thoroughness of cleaning expressed as the “thoroughness of disinfection cleaning” or “TDC.” The TDC score is an expression of the proportion of actual cleaning documented in comparison with the cleaning expected to be done according to the relevant cleaning policy.[25] As noted in **Fig. 2**, these studies consistently identified substantial opportunities for improving practice in all settings.[24] Visual monitoring as part of environmental rounds remains important for evaluating individual cleaning technique, whereas there are many advantages to the objective monitoring of disinfection cleaning practice.[26,27] Published reports have now confirmed the effectiveness of such programs in more than 120 hospitals in the United States, Canada,

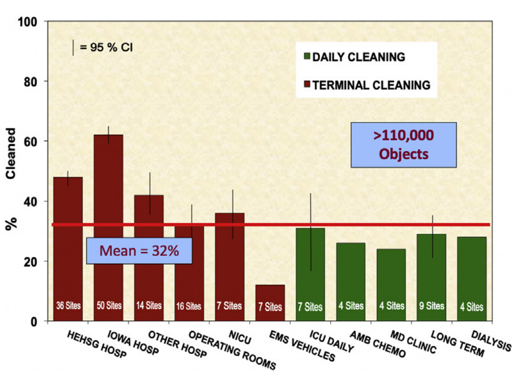

Fig. 2. Thoroughness of environmental cleaning in multiple health care settings. AMB, ambulatory; EMS, emergency medical services; HEHSG, Healthcare Environmental Hygiene Study Group; HOSP, hospitals.

and Australia.[24,28–31] In these hospitals, not only has the thoroughness of cleaning improved from TDC scores in the range of 40% to 60% to 80% to 90% or higher as a result of similar programmatic interventions but also the results have been sustained over at least 3 years where ongoing programs have been evaluated.[32] It has now been shown that improved environmental cleaning decreases HAP contamination of surfaces. In 4 comparable clinical studies objectively evaluating thoroughness of environmental cleaning over many months, contamination of patient-zone surfaces decreased an average of 64% as a result of an average 80% improvement in thoroughness of environmental disinfection cleaning with nonsporicidal disinfectants.[5] Environmental cleaning is not important unless it positively impacts patient outcomes. The complexity and cost of studies to evaluate the clinical impact of decreased patient-zone HAP contamination on patient acquisition has limited research in this area. Two landmark studies found similar statistically significant results. The 2006 study by Hayden confirmed a 66% ($P < .001$) reduction in vancomycin resistant enterococci (VRE) acquisition as a result of a 75% improvement in TDC.[21] A more recent study by Datta and colleagues[33] found a 50% ($P < .001$) reduction in MRSA acquisition and a 28% ($P < .001$) reduction in VRE acquisition as a result of an 80% improvement in environmental cleaning. This study also confirmed significantly decreased prior room occupant transmission for both pathogens during the intervention period. These studies clearly show that direct patient safety benefits can be realized by improving the thoroughness of patient-zone surface cleaning.

Evaluating environmental cleaning—the 2010 CDC *guidance:* As a result of published evidence supporting objective monitoring to evaluate surface cleaning processes and the subsequent improved patient outcomes, the CDC developed the guidance "Options for Evaluating Environmental Cleaning" in 2010.[25] This guidance recommends that all hospitals implement methods to objectively monitor environmental cleaning (**Box 1**). As noted in the guidance, 2 different testing systems can be used to evaluate the TDC, metered fluorescent markers and the adenosine triphosphate technology (ATP), as discussed later.

Fluorescent markers: As discussed earlier, studies in the United States and abroad during the past 10 years have used a specially developed fluorescent gel or "test soil" to covertly evaluate environmental cleaning in a wide range of health care settings.[22,28–31,34] These studies have used a standardized metered transparent gel specifically formulated for the covert evaluation of health care surface cleaning. While nonstandardized fluorescent powders and lotions have been used in a noncovert

Box 1
CDC environmental hygiene guidance recommendations 2010

Hospitals should implement programs to improve current environmental hygiene practice by adopting a 2-phase stepwise programmatic approach:

Level I program:
Basic interventions to optimize disinfection cleaning policies, procedures, and ES staff education and practice. When completed move to Level II program.

Level II program:
All elements of Level 1 program + objective monitoring

Data from Guh A, Carling P, and the environmental cleaning work group. Options for monitoring environmental cleaning. December 2010. Available at: http://www.cdc.gov/HAI/toolkits/Evaluating-Environmental-Cleaning.html. Accessed January 10, 2021.

manner for education,[35] studies by Munoz-Price[36,37] demonstrated that the visibility of these substances in ambient light limits their effective use in programs to objectively monitor cleaning practice as a result of their ability to induce a Hawthorne effect. In 2019 a study from Johns Hopkins compared the clinical use of the metered applicator to a cotton swab applicator of a nonstandardized fluorescent gel and found the metered applicator to provide a more accurate assessment of cleaning practice. The investigators concluded that, “Infection control programs implementing Evaluation of Environmental Cleaning programs should carefully consider the type and method of applying fluorescent gel marks to standardize and optimize the measurement of fluorescent gel removal.”[38] As noted in an Agency for Healthcare Research and Quality[11(p14)] technical brief, “Metered fluorescent gel is the most commonly used formulation because it dries to a transparent finish on surfaces, it is abrasion-resistant, and unlike powder, is not easily disturbed. For these reasons, the fluorescent gel formulation has been the most well-studied method to assess surface disinfection and to quantify the impact of educational interventions.” The report also notes that additional advantages of the made-for-purpose fluorescent surface markers include their “relatively low cost, ease of implementation and their use for direct feedback to the EVS staff.”[11(p14)]

Adenosine triphosphate assays: ATP bioluminescence technology detects the presence of organic material, including viable and nonviable bioburden, on surfaces. Although ATP systems are easy to use, attempts to quantify health care surface bioburden have been challenging because of the presence of nonviable organic material and the systems’ relative insensitivity to some HAPs.[39–41] As noted by Mulvey and colleagues[42(p29)] in a detailed evaluation of the ATP technology, “Sensitivity and specificity of 57% (with the ATP tool) means that the margin for error is too high to justify stringent monitoring of the hospital environment (with ATP technology) at present.” Furthermore, significant intrinsic limitations of the technology that would impact its use in objectively monitoring cleaning practice have been recently identified by Whitley and colleagues[40,43] who noted both the poor sensitivity in measuring viable surface bioburden and the absence of standardization between luminometers by different manufacturers. Additional challenges to using an ATP tool to assess hospital cleaning were noted in a review by Nante and colleagues[44] in 2017, which pointed out the variation in sensitivity between systems made by different manufacturers as well as their lack of standardization. Although not yet investigated, it is plausible that the ATP assay could be used for prospective monitoring of cleaning practice over time if the type of prepost cleaning target evaluation system recommended in the 2010 guidance is followed.

Benefits and Challenges of Environmental Cleaning Monitoring

Although disinfection cleaning process improvement programs developed in accordance with the CDC 2010 guidance have been successful in improving patient zone cleaning as well as decreasing HAP surface contamination and transmission as discussed earlier, recent studies have begun to identify both the collateral benefits and the challenges of these programs.

As part of an HAI prevention initiative in Iowa, a diverse group of 56 hospitals implemented objective monitoring and standardized process improvement activities for discharge cleaning practice using the fluorescent marking system and programmatic interventions modeled after previously published reports.[28,32] Preintervention cleaning thoroughness averaged 60% and was similar in most hospitals (95% confidence interval [CI], 56.7–64.4). As noted in **Fig. 3**, following education and ongoing feedback of performance to the EVS staff, cleaning ultimately improved to 89% for the group (*P*

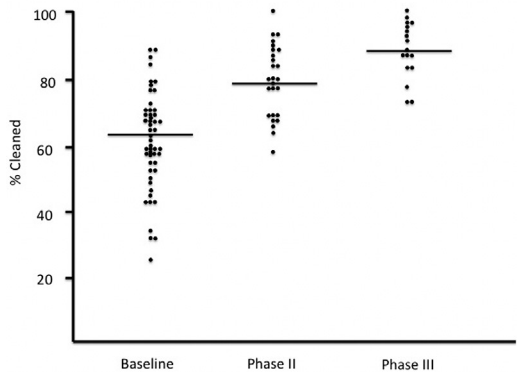

Fig. 3. Thoroughness of discharge cleaning (TDC) during the three phases of the Iowa disinfection cleaning project. Phase I is TDC after a single standardized educational intervention and Phase II is following 2 to 3 cycles of monitoring and feedback. (*Adapted from* Carling PC, Herwaldt LA, VonBeheren S. The Iowa Disinfection Cleaning Project: Opportunities, Successes and Challenges of a Structured Intervention Project in 56 Hospitals. *Infect Control Hosp Epidemiol*. 2017 Aug;38(8):960965; with permission.)

< .001).[32] A structured questionnaire by the hospitals completing the project found that the EVS staff at all hospitals appreciated and were enthusiastic about being evaluated, particularly because the program provided them with a new and unique opportunity to show other health care workers how well they were performing disinfection cleaning activities. Approximately half of the sites noted that the program led to new senior management recognition of the value of the patient safety-oriented work performed by EVS personnel, that the program redefined EVS' role in patient safety, and that the targeting system was valuable for one-on-one training. Twenty percent of the hospitals noted that the study led to identification of opportunities for improving EVS program issues related to manpower resources and communication. A similar number of sites commented on the favorable response the program received from the Board of Trustees. Three of 20 sites (15%) noted that the program initially met resistance from EVS management. Three other sites noted that the program resulted in some transient anxiety among the EVS personnel, which resolved once the value of the program and its nonpunitive orientation was understood. Although the study confirmed the value of an objective structured programmatic process to broadly improve cleaning practice, it also documented the challenges of implementing such activities. Owing primarily to resource limitations (infection preventionists' time constraints) and personnel turnover, more than one-third (23 of 56, 41%) of the sites that likely could have benefitted significantly from the program withdrew from the study before achieving cleaning scores of greater than 80% (see Fig. 3). In contrast, it is notable that 71% of the sites in which the initial assessment disclosed opportunities to improve disinfection cleaning were motivated enough to pursue the study and ultimately achieve cleaning scores of greater than 80%. Furthermore, 27% of the hospitals completing the study independently maintained cleaning thoroughness at greater than 90% for more than 3 years.[32] Similar sustainability of cleaning thoroughness (92%) was also found in a group of 14 hospitals in California using the same program for more than a year.[45]

An important component of these monitoring and process improvement programs relates to the importance of their having a validation component. As noted in the 2010

CDC guidance, “It is important that the monitoring be performed by hospital epidemiologists, infection preventionists or their designees who are not part of the actual EVS cleaning program. Such an approach assures the validity of the information collected”.[25 Appendix B, (p1)] The importance of this issue was confirmed in a study that found that when EVS managers monitored the discharge room cleaning, they documented an average TDC score of 82.5%, whereas a research team covertly evaluating the same 2 hospitals documented an average score of 52.4%.[46] Given that neither the Joint Commission nor the World Health Organization considers self-monitoring of hand hygiene practice to be acceptable, it seems reasonable that a similar expectation should be applied to monitoring disinfection cleaning activities.

Mitigating Clostridiodes difficile Spore Transfer from Environmental Surfaces

For more than 50 years, disinfection cleaning in hospitals has primarily used chemical disinfectants based on quaternary ammonium compounds because of their ease of use and good vegetative bacterial killing. Unfortunately, the evolution of *Clostridiodes difficile* (CD) as a major pathogen contaminating the environment in hospitals led to the recognition that these ammonium-based compounds were ineffective in killing CD spores. Research on this issue led to studies using chlorine-based disinfectants, particularly diluted commercial-grade bleach, confirming the clinical effectiveness of bleach-based disinfecting in reducing environmental contamination with CD spores[47] and reducing transmission of CD from surfaces to patients in several studies.[48,49] Unfortunately, the impact of bleach on patient-zone surfaces and the resulting physical damage to both hard and soft materials has precluded it from being widely used as a general disinfectant for daily patient-zone cleaning. Although many hospitals use bleach-based disinfectants for terminal cleaning of rooms vacated by patients with confirmed CD infection, its general use in discharge cleaning is currently recommended by the CDC only for outbreak settings.[50] In the context of these issues, the development of the previously sporicidal disinfectant chemistries raises the possibility that there may be clinical benefit of substituting these newer chemistries for quaternary ammonium disinfectants for daily cleaning of all patient-zone surfaces.

Evolving insights into environmental C difficile epidemiology: While it has long been recognized that spore-contaminated environments have a role in CD transmission, recent studies have clarified and quantified many aspects of the environmental epidemiology of CD in hospitals as outlined in **Table 1**. Several of these elements are of particular note. As noted in Elements 1 and 2, recent studies have shown that asymptomatic patients are CD colonized at the time of admission (average incidence density 10.6%, range 2.8%–21%)[48–60] or during their hospitalization (average prevalence density 12.5%, range 2.9%–21%).[48,61–66] As a result, approximately 11% of acute care hospitalized patients represent an ongoing risk of CD transmission to the environment and susceptible patients. Genomic epidemiology has now confirmed the environmental transmission of spores from these patients to other patients.[62,63,67–69] As noted in Element 3, patients recovering from acute CD infection are associated with significant transmission of spores to their environment.[70–72] This issue was carefully analyzed in a multisite study by Davies and colleagues[73] in 2020 that evaluated the impact of treatment of CD infection on patient-zone environmental contamination. Treatment of CD infection with metronidazole, vancomycin, or fidaxomicin similarly decreased a proportion of patients with positive stool cultures from 100% to 35% immediately after treatment. After treatment the rate rebounded to 80% to 90% by 2 to 4 weeks later. Although there was some decrease in the proportion of environmental sites contaminated with CD spores from 36% before treatment to 20% immediately following treatment, environmental contamination by these patients was still at

Table 1
Elements of *Clostrididoides difficile* environmental epidemiology

1. At the time of hospitalization 10.6% of patients (range 2.8%–21%) are CD carriers	48–60
2. During hospitalization 12.5% of patients (range 2.9%–21%) are CD carriers	48,61–66
3. Transmission of CD spores to environmental surfaces is associated with: Patients with acute infection Patients recovering from acute infection Asymptomatic CD-colonized patients	70–72
4. Treatment does not decrease ongoing environmental spore contamination for more than a month	73
5. Widespread surface contamination far from known CD-infected patients	47,60
6. Increased cleaning and disinfection result in: Decreased surface and hand contamination Decreased CD acquisition	47,69,70,75
7. Genomic confirmation of the role of asymptomatic CD carriers in transmission	62,63,67–69
8. Acquisition of CD from a prior room occupant is significantly dependent on the prior room occupant receiving antibiotics	74

27% 4 weeks after completing treatment, confirming the significant ongoing risk of transmission of CD to other patients and health care workers by patients who had completed treatment of CD infection. The most striking new insight into the elemental epidemiology of CD was reported by Freedburg and colleagues[74] in 2016. As noted in **Table 1**, Element 8, a cohort of more than 100,000 patients who sequentially occupied a given hospital bed was evaluated to assess the factors relevant to CD spore transmission. The investigators found that administration of antibiotics to the prior bed occupant was the most significant risk factor associated with an increased risk of the subsequent bed occupant developing CD infection, independent of prior room occupants' CD infection status. This finding can only be explained by recipient acquisition of residual CD spores asymptomatically shed onto patient-zone surfaces by the preceding room occupant.

Assessment of the impact of daily sporicidal disinfection cleaning: Given the understanding that CD spore shedding is ongoing in both symptomatic and asymptomatic patients, the inability to clinically recognize CD-colonized patients, and the now feasible general use of sporicidal disinfectants on patient-zone surfaces, it has recently become feasible to consider the potential clinical value of moving to daily sporicidal disinfection cleaning of all high-touch objects. The feasibility of this structured intervention to objectively monitor and improve the thoroughness of daily sporicidal disinfection cleaning on health care-onset CD infection (HO-CDI) was first evaluated in a single-site quasi-experimental study in 2016.[75] As noted in **Fig. 4**, during the 33-month intervention period, TDC rapidly improved from 81% to 92% and remained greater than 88% during the remainder of the study ($P = .01$). HO-CDI rates decreased significantly during the intervention period from an average of 8.9 to 3.2 per 10,000 patient-days ($P = .0001$, 95% CI 3.48–7.81). The potential value of such daily sporicidal cleaning was also evaluated in 2018 using an agent-based model of CD transmission in a 200-bed hospital, and it was found that daily cleaning with a

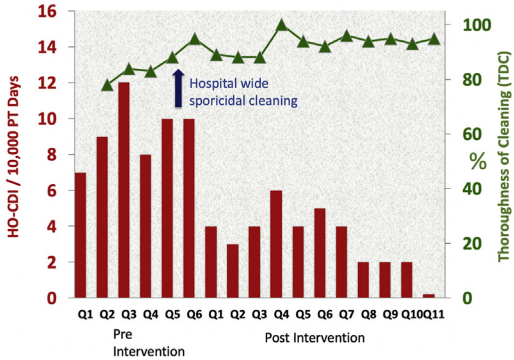

Fig. 4. The impact of optimizing environmental hygiene to decrease *Clostrididoides difficile* transmission (*From* Carling P, Scott M. Optimizing envitonmental hygiene to successfully decrease Clostridiun difficile transmission. *Open Forum Infect Dis*. Volume 4, Issue suppl_1, 1 October 2017, Pages S404–S405, https://doi.org/10.1093/ofid/ofx163.1011 Accessed 10 January 2021; with permission.)

sporicidal disinfectant had the potential for reducing hospital-onset CD infections by 68.9%.[76]

The potential clinical usefulness of daily hospital-wide sporicidal disinfectant (Oxy-Cide, Ecolab Inc) for all patient-zone hygienic cleaning was recently evaluated using a quasi-experimental interrupted time series in a group of 8 acute care hospitals with stable endemic Standardized Infection Ratio (SIR) (mean 1.0 for the group) during an 18-month preintervention period.[77] Thoroughness of cleaning was programmatically monitored in accordance with the 2010 CDC guidance using a standardized metered fluorescent marking system (DAZO). As noted in **Fig. 5**, TDC following educational activities during the 3-month wash-in period improved rapidly from 52% to 88%. Ongoing monitoring and education resulted in a further sustained improvement to greater than 90% for all sites. During the initial quarter following the wash-in the SIRs for all hospitals dropped to 60% for the group, as noted in **Fig. 6**. During the final 9 months of the study the mean SIR for the group had decreased to 0.3, representing a greater than 60% improvement from the 18-month preintervention period ($P = .001$), a result highly consistent with the modeling study noted previously.[76] Seven potentially significant confounders were evaluated preintervention and postintervention and were found not to have had an impact on the results. Although a randomized controlled trial could further clarify and quantify the results of this intervention, such an undertaking would require considerable resources as well as the need for sites to defer implementing potentially effective design elements of the intervention. Given the challenges of a randomized trial, it should be noted that an agent-based modeling study by Barker and colleagues[78] (2020) evaluating the impact of multiple single and bundled interventions on HO-CDI prevention found that the single most clinically effective as well as cost-effective intervention was daily sporicidal cleaning of all patient-zone surfaces. Furthermore, quantitative input analysis of the model found only a limited additional incremental benefit from increasing modeling parameters of thoroughness of cleaning from an “enhanced level” (80% TDC) to an “ideal level” (94% TDC), suggesting that daily patient-zone sporicidal cleaning could have a substantial impact on CD transmission when TDC is lower than those achieved by the intervention group of hospitals discussed earlier.[78]

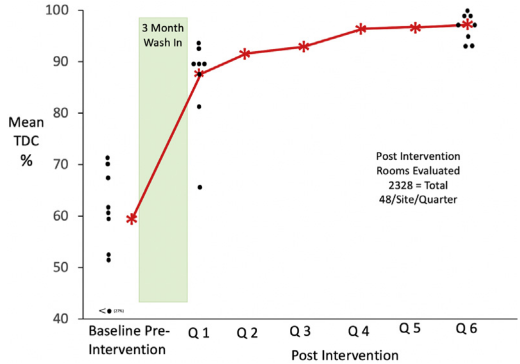

Fig. 5. Thoroughness of daily hospital-wide sporicidal cleaning of patient-zone surfaces. (*From* Carling P, O'Hara L, Harris A, Olmstead R. Mitigating hospital onset *C. difficile*: evaluation of a standardized environmental hygiene program in eight hospitals. The Sixth Decennial International Conference on Healthcare-Associated Infections Abstracts, March 2020. Infect Control Hosp Epidemiol 2020 October;41(S1):s43; with permission.)

ENVIRONMENTAL HYGIENE AND HAND HYGIENE: AN INTEGRATED APPROACH

Over the past several years it has become increasingly evident that infection prevention initiatives focused on optimizing hand hygiene have not realized their hoped-for impact on HAP transmission in well-resourced health care settings.[79–83] Accepting our inability to quantify the absolute risk of pathogen acquisition directly from health care workers' hands, there is good circumstantial evidence that such transmission accounts for a substantial proportion of HAP transmission. Indeed, it has become widely accepted that hand hygiene, as noted by Palamore and Henderson,[84(p8)] is "critically important for the prevention of HAIs". In response many health care organizations have undertaken extensive, resource-intensive efforts to improve hand hygiene compliance.[85] Despite extensive translational research and strong support from accrediting institutions, the enthusiasm for quickly reaping substantial benefits from optimizing hand hygiene practice has been tempered by the realization that

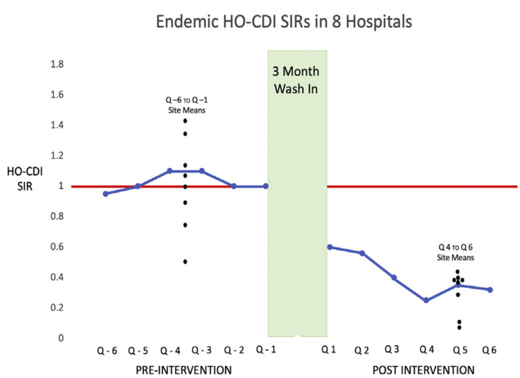

Fig. 6. Endemic HO-CDI SIRs in the study hospitals before and after the study intervention. (*From* Carling P, O'Hara L, Harris A, Olmstead R. Mitigating hospital onset *C. difficile*: evaluation of a standardized environmental hygiene program in eight hospitals. The Sixth Decennial International Conference on Healthcare-Associated Infections Abstracts, March 2020. Infect Control Hosp Epidemiol 2020 October;41(S1):s43; with permission.)

acceptance inertia, psychological barriers, suboptimal application technique, and most particularly, the pressures of providing direct patient care adversely impact the effectiveness of this intervention.[86] These issues along with the challenges of performing hand hygiene as recommended by the World Health Organization Five Moments construct while caring for acutely ill patients and the fact that 10% to 60% of patient-zone surfaces contain HAPs make it likely that pathogen-contaminated environmental surfaces will negate some of the benefits of optimized hand hygiene practice.[87]

Given the fact that patient-zone surfaces not contaminated by HAPs cannot be a source of pathogen transmission even in the absence of hand hygiene, further consideration must be given to viewing both environmental hygiene and hand hygiene as being interdependent interventions. As these 2 interventions are intrinsically relevant, together they represent what can be termed “hygienic practice.” When viewed in this manner, it becomes evident that the mandates and challenges of these 2 interventions represent an inverse continuum as noted in Fig. 7. For example, in the intensive care unit (ICU) setting where hand hygiene often becomes logistically challenging and glove use without hand hygiene is frequent, there would be a particularly strong mandate to optimize hygienic cleaning. In contrast, in ambulatory and nonpatient care settings where there are few intrinsic barriers to hand hygiene, enhanced hygienic cleaning practices would not be as strongly mandated. In this context, the specific elements of hygienic practice can be characterized along a complexity gradient. By relating these constructs to the various settings noted in Fig. 8, interventions can be defined along the continuum outlined to provide a framework for analyzing and prioritizing the relative cost/benefit of different levels of complementary hygienic practices. By characterizing intrinsic patient/personnel risk and setting modifiers, a particular site can be moved up or down diagonally along the range of settings. For example, if an immunologically compromised person was in an ambulatory care setting, it would be reasonable to consider moving to a higher level of hygienic cleaning intervention than would otherwise be warranted. Similarly, if the patient population assisted living arrangements required only minimal assistance, it would be reasonable to move down the intervention continuum toward simpler interventions as noted in Fig. 8. Once the particular features of a setting are defined in this manner, programmatic interventions that maximize the components of health care hygienic practice for the best cost/benefit to improving patient/personnel safety can be identified and optimized.

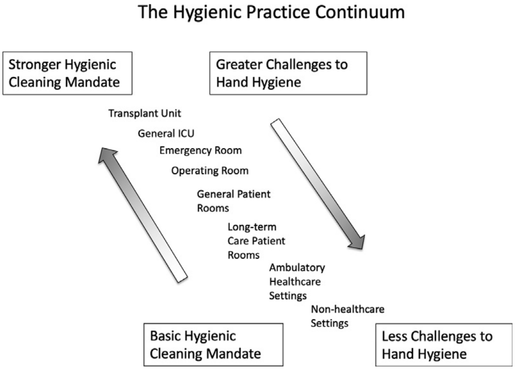

Fig. 7. The Continuum of practices to mitigate pathogen transmission.

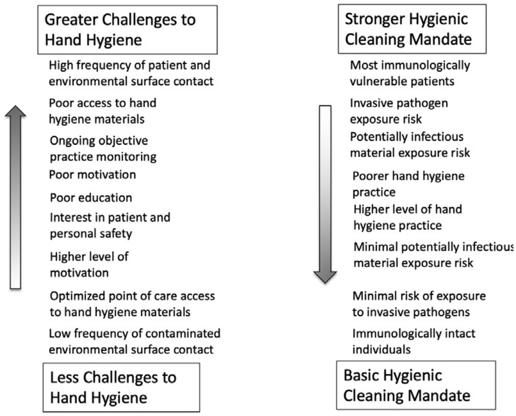

Fig. 8. Elements of hygienic practice.

IMPLEMENTING THE 2020 CDC GUIDANCE: CORE COMPONENTS OF ENVIRONMENTAL CLEANING AND DISINFECTION IN HOSPITALS

In October 2020 the CDC published a guidance document to provide hospitals with a detailed roadmap for the development of programs to optimize all aspects of patient-zone environmental hygiene because “maintaining a clean hospital environment and minimizing the presence of hospital pathogens is critical for keeping patients safe.”[88(pe1)] The 6 individual “core components” (**Box 2**) and the specific recommendations within each of the strategies specify what “every healthcare facility should consider to ensure appropriate environmental cleaning and disinfection.”[89(pe1)] The components described were developed primarily for acute care hospitals, but the document notes that “they can be applied to all healthcare facilities including long-term care facilities and outpatient settings, although special considerations may be needed for these other healthcare settings.” Although not specifically discussed in the document, describing the EVS staff involved in patient-zone cleaning and disinfection as “healthcare personnel” represents a reflection of the relevance these activities have to safe patient care.

Box 2
Core components of environmental cleaning and disinfection in hospitals

1. Integrate environmental services into the hospital’s safety culture
2. Educate and train all healthcare providers responsible for cleaning and disinfecting patient care areas
3. Select appropriate cleaning and disinfection technologies and products
4. Standardize setting-specific cleaning and disinfection protocols
5. Monitor effectiveness and adherence to cleaning and disinfection protocols
6. Provide feedback on adequacy and effectiveness of cleaning and disinfection to all responsible healthcare providers as well as relevant stakeholders (eg, infection control, hospital leadership)

Adapted from Reducing risk from surfaces: core components of environmental cleaning and disinfection in hospitals. Available at: https://www.cdc.gov/hai/prevent/environment/surfaces.html Accessed 10 January 2021.

Component 1: Integrate Environmental Services into the Hospital's Safety Culture

This component provides specific recommendations that define institutional responsibilities related to the development and ongoing maintenance of an integrated program to optimize infection prevention activities related to environmental hygiene. Recommendations related to specific pragmatic elements include leadership, multidepartmental involvement, and the need to define programmatic responsibilities including reporting and accountability. Also addressed are the development of both performance evaluation based on objective monitoring procedures (see Component 5) and career advancement opportunities for EVS personnel. .

Component 2: Educate and Train all Health Care Providers Responsible for Cleaning and Disinfecting Patient Care Areas

This component provides a detailed set of recommendations on critical elements of an optimized approach to the education and training of health care professionals involved in environmental hygiene activities along with the components of such training. Additional recommendations include documentation of such training, as well as the need for documentation of corrective actions disclosed as part of ongoing performance monitoring activities (see Component 5). It is also noted that training include information related to facility infection rates and prevention practices.

Component 3: Select Appropriate Cleaning and Disinfection Technologies and Products

This core component emphasizes the importance of validating the clinical and cost benefits of any product or technology being considered; it reflects the recognition that hospitals have adopted technologies and products whose clinical effectiveness and cost benefit value have been incompletely scientifically validated. In response to this issue, it is specifically recommended that hospitals use a prospective "systematic process" to evaluate all such technologies and products, which incorporates analysis by relevant leadership personnel to consider the clinical value, as well as direct and indirect costs, before implementing new programs and technologies.

Component 4: Standardize Setting-Specific Cleaning and Disinfection Protocols

This multifaceted component begins by noting the need for cleaning and disinfection procedures to account for differences in the specialized use of distinct patient care areas (ie, ICU, patient room, emergency department, etc.), taking into account the layout, equipment, and patient exposure with specific protocols in each setting. To ensure optimally effective cleaning disinfection practices, hospitals are also asked to develop specific "minimal cleaning times," which are to be monitored to ensure that they are being appropriately maintained. It is further recommended that the EVS staff be empowered to require adherence to these defined minimal cleaning times.

Component 5: Monitor Effectiveness and Adherence to Cleaning and Disinfection Protocols

This core component defines the need for institutions to develop a patient-zone cleaning disinfection monitoring strategy, as detailed in the 2010 CDC Guidance Options for Monitoring Environmental Cleaning.[25] In addition to implementing a level II program (see **Box 1**), the need to define who should do such monitoring and how data collected will be used is noted. Specific reference to the need for validation of the monitoring program by a person who is not directly responsible for cleaning practice was based on research that confirmed the need for such validation (see previous discussion).

Component 6: Provide Feedback on Adequacy and Effectiveness of Cleaning and Disinfection to all Responsible healthcare providers as well as Relevant Stakeholders (eg, Infection Control, Hospital Leadership)

The final core component addresses the need to have a structured ongoing system for process improvement using the objective monitoring results from the program developed in component 5 and the 2010 CDC guidance referenced earlier. In addition to using such a program for improving patient safety, it is further recommended that the audit data be presented to hospital leadership to "identify active issues and strategies to mitigate opportunities for improvement while validating the effectiveness of the overall cleaning strategy."

Taken together, these core components provide a detailed, clearly structured, and comprehensive template, based on implementation science studies over the past 20 years, to optimize all aspects of environmental hygiene practice for acute care hospitals, which can be adapted to a wide range of patient care settings.

RESEARCH OPPORTUNITIES AND CHALLENGES

Along with an evolving awareness of the need to optimize both the process and structural elements of hygienic cleaning as noted in **Fig. 1**, it has become increasingly evident that there is a need to develop quantifiable evidence to guide best practices.[11,90,91]

During the past 20 years many published reports have described improved outcomes as the result of modifications in basic hygienic cleaning. Unfortunately, causal analysis of almost all of these studies has been greatly hampered by the simultaneous implementation of multiple interventions in addition to "improved cleaning." This issue is particularly well illustrated by the reports of interventions to minimize health care-onset CD infection beginning in the mid-1980s. Although more than 20 quasi-experimental, often outbreak-associated, studies have supported the likely role of improved environmental hygiene on CD transmission, all these studies consist of several interventions implemented simultaneously. Because of confounding variables (some known, some unknown) in each study, it has been impossible to specifically quantify the impact of disinfection cleaning on CD transmission. Even when a single environmental intervention such as cleaning agent change or no-touch technology is being evaluated, published studies have not separated the thoroughness of cleaning from the specific intervention being tested.[92,93]

CLINICS CARE POINTS

- Implementing the CDCs 2020 guidance Core Components of Environmental Cleaning and Disinfection in Hospitals will provide hospitals with a detailed roadmap for the development of programs to optimize all aspects of patient zone environmental hygiene.
- "Hygienic practice" is optimized through coordinated, objectively monitored compliance practice of environmental hygiene and hand hygiene as integrated horizontal infection prevention interventions.

- Objectively validated, daily, hospital-wide patient-zone disinfection cleaning with advanced formula surface disinfectants has the potential for providing optimal mitigation of HAP transmission from environmental surfaces.

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DISCLOSURE

The author reports having served as a consultant to AORN and Ecolab and has licensed patents to Ecolab.

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