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Cleaning Hospital Room Surfaces to Prevent Health Care–Associated Infections

Dr. Jennifer H. Han, MD, MSCE[*],
Division of Infectious Diseases, Department of Medicine, Hospital of the University of Pennsylvania, 811 Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104

Ms. Nancy Sullivan, BA[*],
ECRI Institute Evidence-based Practice Center and Health Technology Assessment Group, ECRI Institute Headquarters, 5200 Butler Pike, Plymouth Meeting, PA 19462-1298

Mr. Brian F. Leas, MS, MA[*],
Center for Evidence-based Practice, University of Pennsylvania Health System, 3535 Market Street, Suite 50, Philadelphia, PA 19104

Dr. David A. Pegues, MD,
Department of Healthcare Epidemiology, Infection Prevention, and Control, Hospital of the University of Pennsylvania, 3400 Spruce Street, Ground Founders, Philadelphia, PA 19104

Ms. Janice L. Kaczmarek, MS, and
ECRI Institute Evidence-based Practice Center and Health Technology Assessment Group, ECRI Institute Headquarters, 5200 Butler Pike, Plymouth Meeting, PA 19462-1298

Dr. Craig A. Umscheid, MD, MSCE
Center for Evidence-based Practice, University of Pennsylvania Health System, 3535 Market Street, Suite 50, Philadelphia, PA 19104

Requests for Single Reprints: Jennifer Han, MD, MSCE, Division of Infectious Diseases, Department of Medicine, Hospital of the University of Pennsylvania, 811 Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104; jennifer.han@uphs.upenn.edu..

[*]Dr. Han, Ms. Sullivan, and Mr. Leas contributed equally to this work.

From Perelman School of Medicine, University of Pennsylvania, and Center for Evidence-based Practice, University of Pennsylvania Health System, Philadelphia, and ECRI Institute–Penn Medicine Evidence-based Practice Center, Plymouth Meeting, Pennsylvania.

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Analysis and interpretation of the data: J.H. Han, N. Sullivan, B.F. Leas, D.A. Pegues, C.A. Umscheid.
Drafting of the article: J.H. Han, N. Sullivan, D.A. Pegues.
Critical revision of the article for important intellectual content: J.H. Han, B.F. Leas, D.A. Pegues, C.A. Umscheid.
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Administrative, technical, or logistic support: N. Sullivan, B.F. Leas, J.L. Kaczmarek, C.A. Umscheid.
Collection and assembly of data: J.H. Han, N. Sullivan, B.F. Leas, D.A. Pegues.

Abstract

The cleaning of hard surfaces in hospital rooms is critical for reducing health care–associated infections. This review describes the evidence examining current methods of cleaning, disinfecting, and monitoring cleanliness of patient rooms, as well as contextual factors that may affect implementation and effectiveness. Key informants were interviewed, and a systematic search for publications since 1990 was done with the use of several bibliographic and gray literature resources. Studies examining surface contamination, colonization, or infection with *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus*, or vancomycinresistant enterococci were included.

Eighty studies were identified—76 primary studies and 4 systematic reviews. Forty-nine studies examined cleaning methods, 14 evaluated monitoring strategies, and 17 addressed challenges or facilitators to implementation. Only 5 studies were randomized, controlled trials, and surface contamination was the most commonly assessed outcome. Comparative effectiveness studies of disinfecting methods and monitoring strategies were uncommon. Future research should evaluate and compare newly emerging strategies, such as self-disinfecting coatings for disinfecting and adenosine triphosphate and ultraviolet/fluorescent surface markers for monitoring. Studies should also assess patient-centered outcomes, such as infection, when possible. Other challenges include identifying high-touch surfaces that confer the greatest risk for pathogen transmission; developing standard thresholds for defining cleanliness; and using methods to adjust for confounders, such as hand hygiene, when examining the effect of disinfecting methods.

Health care–associated infections (HAIs) are a leading cause of illness and death in the United States and worldwide. In 2011, an estimated 721 800 HAIs occurred in the United States, leading to 75 000 deaths (1). A multifaceted approach to preventing infection is critical to reducing the risk for HAIs, including hand hygiene practices, antimicrobial stewardship, and environmental cleaning and disinfecting.

Several studies demonstrate that health care–associated pathogens frequently contaminate the patient environment, including both porous surfaces (such as curtains) and hard, nonporous surfaces (such as bed rails and medical equipment) (2–4). Contaminated surfaces are a reservoir for transmission of pathogens directly through patient contact with the environment or indirectly through contamination of health care workers' hands and gloves.

Environmental cleaning is important for reducing microbial contamination of surfaces and subsequent risk for HAIs. Environmental cleaning is a complex, multifaceted process and involves the physical action of cleaning surfaces to remove organic and inorganic material, followed by application of a disinfectant, as well as monitoring strategies to ensure the appropriateness of these practices. In addition, contextual factors, such as management tools and organizational structure, and culture can affect the implementation and effectiveness of cleaning, disinfecting, and monitoring strategies. The goal of this review is to provide a systematic overview on environmental cleaning of hospital room surfaces to prevent HAIs. We focus on environmental cleaning of the hard surfaces most frequently touched by patients and health care workers, which are often called high-touch surfaces or objects. We also discuss key health care–associated pathogens for which there is the most evidence for

environmental transmission, specifically methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and *Clostridium difficile* (5–8). Finally, we enumerate the evidence gaps in the literature and propose future research directions.

METHODS

This review is based on a protocol and technical brief produced by the ECRI Institute–Penn Medicine Evidence-based Practice Center for the Agency for Healthcare Research and Quality (AHRQ) (9). The protocol and final report are available at www.effectivehealthcare.ahrq.gov. Twelve key informants with expertise in infectious diseases, infection control, environmental disinfection, hospital epidemiology, microbiology, and management of environmental services staff in health care settings contributed to the protocol and report, including helping to refine the literature search, review limitations in the current evidence, and discuss potential directions for future research.

Data Sources and Search Strategy

We searched several databases and gray literature sources from 1 January 1990 through 4 February 2015. The complete set of databases searched and the search strategy is available in **Appendix Tables 1** and **2** (available at www.annals.org).

Study Selection

Titles, abstracts, and full-text articles were screened in duplicate using the database Distiller SR (Evidence Partners). We included studies of any design that addressed our clinical questions; examined any inpatient wards (such as medicine, surgery, and critical care); addressed high-touch surfaces; evaluated environmental contamination, colonization, or infection with *C. difficile*, MRSA, or VRE or included several unspecified pathogens that were likely to include those infections; and were published in English. Studies were excluded if they took place exclusively in pediatric, ambulatory, operating room, or long-term care settings; addressed only soft, porous surfaces (such as linens or curtains) or transmission routes not inherent to the environmental reservoir (such as caregiver hands, stethoscopes, or invasive medical devices); examined products or processes not available in the United States or not currently being investigated; or were in vitro studies that did not collect samples from actual patient rooms.

Data Extraction and Synthesis

A standardized data extraction form was used by 1 reviewer to collect information on patient populations; pathogens; high-touch surfaces; type of cleaning, disinfecting, monitoring, and implementation strategy; study design; and study outcomes. A random sample of 25% of abstracted data was verified by another reviewer. Descriptions of cleaning/disinfecting and monitoring methods currently used in hospital settings are shown in **Appendix Tables 3** and **4** (available at www.annals.org), respectively. We developed an evidence map to synthesize information on the type and depth of research available on cleaning, disinfecting, and monitoring processes. We also highlighted important knowledge gaps in the evidence base.

Role of the Funding Source

This project was funded by AHRQ. A representative from AHRQ served as a contracting officer's technical representative and provided technical assistance and feedback during the conduct of the evidence report. AHRQ did not directly participate in the literature search; determination of study eligibility criteria; data analysis or interpretation; or preparation, review, or approval of the manuscript for publication. This work was also supported in part by the National Institutes of Health, which had no role in the design and conduct of the study; collection, management, analysis, or interpretation of the data; or preparation, review, or approval of the manuscript.

RESULTS

The literature searches yielded 80 clinical studies for inclusion in the review, 76 of which were primary studies and 4 of which were systematic reviews. The **Appendix Figure** (available at www.annals.org) shows the study selection process.

Of the 80 clinical studies, 49 (61%) (2 systematic reviews) focused on cleaning or disinfecting, 14 (18%) (2 systematic reviews) focused on monitoring, and 17 (21%) focused on implementation of cleaning or monitoring strategies. No conference abstracts presented within the past 2 years were identified for inclusion. **Appendix Tables 5** and **6** (available at www.annals.org) describe identified clinical practice guidelines and clinical trials (ClinicalTrials.gov), respectively.

The primary setting for most studies was the intensive care unit. The most commonly examined hightouch objects included bed rails, call buttons, light switches, side or tray tables, and toilets, but the selection of high-touch objects across studies varied substantially.

Outcomes reported in the 76 primary studies were broadly categorized as surface contamination (such as bacterial burden, number of surfaces cleaned, and positive microbiological cultures), patient colonization (such as new VRE colonization), or infection rate (such as incidence rate expressed per 1000 patient days). Among the primary studies reporting pathogens of interest, the most commonly reported pathogen was *C. difficile* (n = 40), followed by MRSA (n = 30) and VRE (n = 30). Some studies evaluated several pathogens.

Evidence Map

Figure 1 shows the number and research designs of published studies that address major categories of cleaning or disinfection strategies and monitoring methods, respectively. **Figure 2** depicts evidence gaps that suggest high-impact areas for future research, as recommended by our key informants or indicated by our analysis of the current evidence base. The interventions are organized in a framework adapted from McDonald and Arduino's recently proposed “evidence hierarchy” for environmental infection control (10). This framework represents the progression of evidence for the effectiveness of environmental interventions, from laboratory studies that measure surface contamination; to clinical studies that assess contamination in realworld settings; to studies that address patient-centered outcomes, such as pathogen colonization and infection.

Strategies for Environmental Cleaning

Forty-seven primary studies (11–57) and 2 systematic reviews (58, 59) focusing on cleaning and disinfecting were identified. Of the 47 primary studies, 27 (57%) were done in the United States and the remaining 19 were done in the United Kingdom, Australia, Sweden, Canada, Norway, and Italy. Studies were published between 1998 and September 2014; 28 (60%) were published since 2012, reflecting recently intensified interest in this topic.

Only 5 primary studies (11%) were randomized, controlled trials, and 1 (2%) was a randomized crossover study. Study durations ranged from 4 weeks to 43 months. Most studies (n = 31 [66%]) used a primary outcome of surface contamination. Only 16 studies (34%) reported pathogen colonization or infection rate as a primary outcome, and *C. difficile* was mostly commonly assessed.

Cleaning and disinfecting methods were generally categorized as surface cleaning or disinfecting, automated processes, or effectiveness of enhanced coatings or surfaces for disinfecting. Studies examining chemical disinfectants reported mixed findings, including reductions in VRE (51) and *C. difficile* rates (16, 20, 21, 54) with the use of bleach-based disinfectants; decreased *C. difficile* spore levels with the use of accelerated hydrogen peroxide (48); and ineffectiveness of a chlorine-based product in reducing *C. difficile* contamination and infection rates (14). Six studies integrating various wipes (such as hydrogen peroxide) into preventive strategies (15, 17, 25–28) reported positive outcomes, including sustained reductions in *C. difficile* infection rates (15, 27). Seventeen studies implementing no-touch methods (such as ultraviolet [UV] light and hydrogen peroxide vapor) reported positive findings (11, 13, 19, 29 –31, 39, 40, 42, 44 –46, 50, 52, 53, 56), and 3 of these studies specifically found reduced infection rates (29 –31). Seven of 8 studies (88%) evaluating enhanced coatings, such as copper-coated surfaces, reported positive findings (12, 32–37). **Appendix Tables 7** and **8** (available at www.annals.org) describe the characteristics of cleaning and disinfecting studies.

Strategies for Monitoring Cleanliness

Two systematic reviews (60, 61) and 12 primary studies (62–73) evaluated strategies for monitoring environmental cleaning and disinfecting. The locations for 11 of the 12 primary studies were reported and included the United States (n = 7 [64%]), United Kingdom (n = 3 [27%]), and Canada (n = 1 [9%]). Studies were published from 2003 to 2013; 3 (25%) were published since 2012.

The most common study design was nonrandomized using concurrent control groups (n = 5 [42%]). Study durations ranged from 4 weeks to 8 months; 4 studies did not report duration. Eight studies (67%) assessed percentage of targets cleaned (62, 65–67) or cleaning rate (63, 64, 68, 69) as the primary outcome. Less commonly reported outcomes included microbial burden counts (71, 73), sensitivity to detect pathogens (70), and number of positive cultures (72). Four studies focused on a single pathogen (63, 66, 68, 72).

Fluorescent/UV surface markers and adenosine triphosphate bioluminescence were the most commonly evaluated monitoring methods. Six of the 8 studies (75%) mainly focusing on fluorescent/UV surface markers (64–69) concluded that these monitoring methods were

useful and highly objective and helped achieve substantial improvements in cleaning and disinfecting practices. Visual observation was found to be inferior to various other monitoring methods in 4 of 5 primary studies (80%) (62, 63, 70 –73) and 1 review (100%) (61). **Appendix Tables 7** and **9** (available at www.annals.org) describe the characteristics of monitoring studies.

Implementing Cleaning and Monitoring Strategies

Implementation Strategies—Seventeen primary studies focused specifically on implementing infection control interventions and contextual factors (74 –90). These studies were published between 2006 and September 2014; 9 (53%) were published since 2012. Most studies (*n* = 14 [82%]) were done in the United States, with remaining studies done in Australia and Canada.

Thirteen studies (76%) used historical controls, including before-and-after study designs (*n* = 9), and interrupted time series (*n* = 4). Three studies (18%) were nonrandomized using concurrent control groups, and 1 (6%) was an uncontrolled, descriptive study. Study length ranged from 8 weeks to 4 years. Most studies reported a primary outcome of surface contamination. Only 2 studies (12%) reported pathogen acquisition as a primary outcome (83, 90). Clinical infection was reported as a primary and secondary outcome in 3 (80, 83, 90) and 2 (75, 76) studies, respectively. With regard to pathogen type, *C. difficile* and VRE were the primary focus of 3 (75, 80, 81) and 2 (85, 90) studies, respectively. The remaining studies focused on at least 2 pathogens of interest.

Three studies (18%) (75, 76, 80) used multicomponent strategies to prevent *C. difficile* infections and reported positive findings. Five studies (64, 76, 81, 84, 87) reporting on sustainability of preventive strategies described ongoing education, direct feedback, and commitment and flexibility of administrative leaders as key components to successful implementation.

Appendix Table 10 (available at www.annals.org) describes the characteristics of the implementation studies.

Contextual Factors—Contextual factors for implementation strategies examined in the 76 primary studies and identified by key informants included structural organizational characteristics, such as outsourcing of environmental services (80, 91) and organization of environmental services within the administrative hierarchy of a hospital. External factors that affect environmental cleaning efforts included adherence to “evidence-based policies and procedures” from various organizations (such as the Centers for Medicare & Medicaid Services and The Joint Commission). A positive patient safety culture that fosters collaboration and respect among clinical and support services staff, as well as between supervisors and front-line personnel, were examined in 5 studies (77, 80, 84, 87, 92). Implementation and management tools were identified as key contextual factors and include staff education and training, dedicated training time, use of internal audit and feedback, and presence of internal or external persons responsible for implementation. Of the 24 studies (32%) that integrated implementation tools, education was reported as a key component in most (*n* = 23 [96%]); 5 studies (21%) specifically reported on training staff (13–15, 77, 84)

and 5 additional studies (21%), all published since 2012, described use of audits (14, 17, 81, 82, 84).

DISCUSSION

Contamination of high-touch environmental surfaces plays an important role in transmission of pathogens in the acute care hospital setting. Increasing attention has been directed toward the importance of environmental cleaning and disinfecting in the prevention of HAIs. We reviewed 4 systematic reviews and 76 primary studies of environmental cleaning. We found considerable diversity with regard to both study design and cleaning/disinfecting and monitoring methods examined across studies, as well as many limitations in the evidence base. There was a lack of direct, rigorous comparative studies of various methods, with only 5 studies designed as randomized, controlled trials. Our review of the literature also highlighted a limited focus on patient-centered outcomes, such as patient colonization or infection. Instead, surface contamination was the most commonly reported outcome.

The results of these studies, as well as synthesis of key informant input, suggest that evaluating the clinical effectiveness of cleaning and disinfecting methods is challenging. A major limitation is the gap between optimized use of surface cleaning or disinfecting agents in studies and practical implementation in real-world settings (such as appropriate dwell time and type of surface targeted). Manufacturers provide recommendations for proper use of their products, but most studies do not report thoroughness of cleaning or adherence to disinfectant dwell time; this information also remains largely unknown in daily practice. An important related concern is uncertainty by end users about the applicability of some manufacturer recommendations. Guidance that accompanies products may be based on laboratory testing under ideal conditions rather than clinical settings. Recommendations may also be developed based on certain types of pathogens, but users may choose to implement a product or technology for broader effects. Few studies directly compared the effectiveness of different methods; instead, many used before-and-after study designs to assess the effect of a single disinfecting method.

Another challenge to interpreting the results of the current evidence base is determining the specific effect of environmental cleaning and disinfecting interventions in the context of multicomponent infection prevention strategies (93). Infection prevention comprises many critical components in addition to hard surface cleaning, including sterilization of instruments, implementation of appropriate isolation precautions, and proper hand hygiene. These and other elements may sometimes be included as interventions within a larger infection prevention strategy, limiting the ability to discern the specific effect of any single approach. These factors also have the potential to modify the effectiveness of environmental cleaning interventions. Considerable uncertainty also remains about which surfaces, including high-touch objects, should be targeted for cleaning and disinfecting.

Limitations in the evidence base for monitoring methods were also identified, including the lack of direct, rigorous comparative studies of various technologies. Key informants noted that hospitals may be reluctant to adopt such methods as adenosine triphosphate and UV/fluorescent surface markers given the relative absence of data. Another important limitation

in the literature is the lack of consensus for thresholds of cleanliness. Specifically, although various cleanliness thresholds with the use of adenosine triphosphate and certain microbiological methods were described across studies, there is no established benchmark for defining a surface as "clean." The real-world goal of environmental cleaning and disinfecting should be to reduce risk for pathogen transmission rather than establishing a continuously sterile surface. Benchmarks for surface cleanliness that correlate with decreases in pathogen acquisition should therefore be determined. As with studies evaluating cleaning and disinfecting methods, studies on monitoring methods demonstrated considerable variation in high-touch objects selected for evaluation, making it challenging to determine which surfaces are at greatest risk for microbial contamination and pathogen transmission.

Our review has important limitations. First, it provides only an inventory of available evidence and does not appraise the risk of bias of individual studies or provide overall ratings of the strength of evidence for each intervention and outcome examined. Second, the review was restricted to studies of *C. difficile*, MRSA, and VRE; thus, our findings may not be fully generalizable to interventions aimed at reducing infections due to other organisms (such as gram-negative pathogens). Future research should seek to review the evidence base for other pathogens. Further, many of the studies included in this review were undertaken during outbreaks and may not be representative of the effect of cleaning/disinfecting and monitoring in nonoutbreak settings.

Future research on environmental cleaning and disinfecting to reduce HAIs should address the following key questions: What surfaces, including high-touch objects, should be cleaned and disinfected? How should surfaces be cleaned and disinfected, and what is the comparative effectiveness of different methods? How should cleaning and disinfecting be monitored and measured, and what would be appropriate benchmarks for cleanliness and reduced risk for pathogen transmission? How should interventions be implemented, including in-depth study of facilitators and barriers to real-world implementation?

In summary, our review of the literature indicates an increased interest in environmental cleaning and disinfecting for the prevention of HAIs. However, there are many limitations in the current evidence base. Future research on environmental cleaning that addresses these limitations and evidence gaps will be critical for informing real-world interventions for reducing the risk for HAIs in the hospital setting.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Summary Points

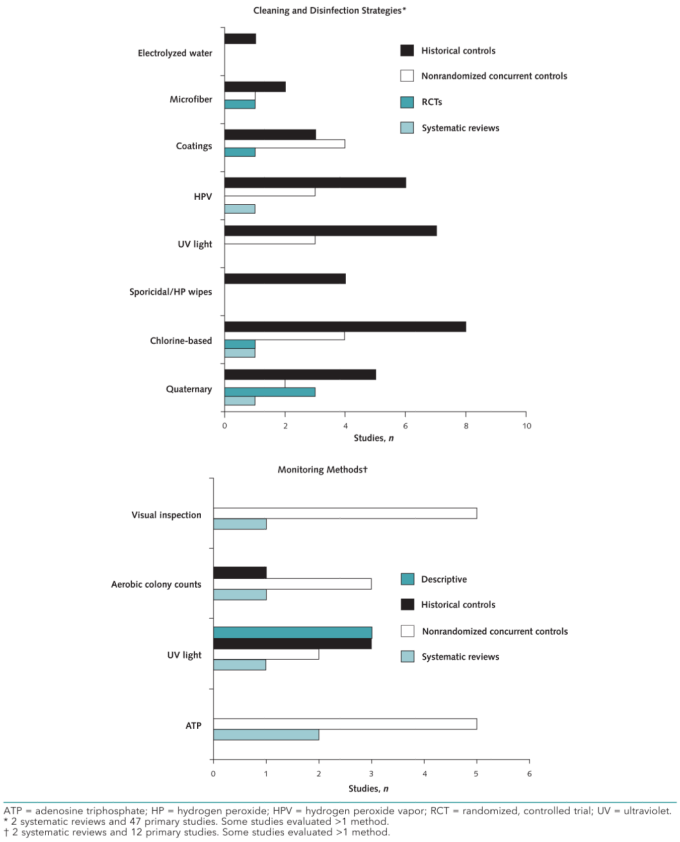
Environmental cleaning is an important component of a multifaceted infection control strategy to prevent health care–associated infections.

Emerging technologies have led to increased interest in evaluating environmental cleaning, disinfecting, and monitoring in the acute care hospital setting.

A major limitation of the evidence base is the lack of comparative studies addressing the relative effectiveness of various cleaning, disinfecting, and monitoring strategies.

Few studies assess clinical, patient-centered outcomes, including patient colonization and health care–associated infection rates.

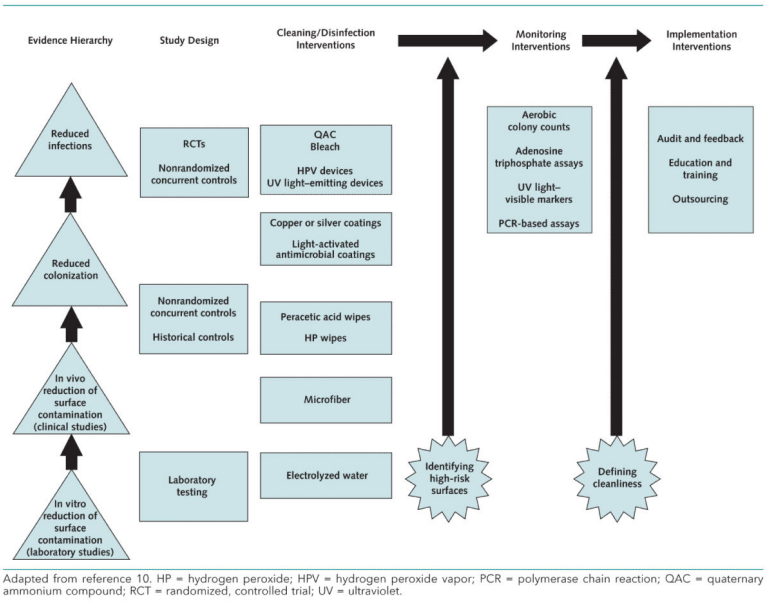
Future studies are needed that directly compare newer disinfecting and monitoring methods, assess the effect of contextual factors on implementation, and evaluate patient-centered outcomes.



ATP = adenosine triphosphate; HP = hydrogen peroxide; HPV = hydrogen peroxide vapor; RCT = randomized, controlled trial; UV = ultraviolet.
* 2 systematic reviews and 47 primary studies. Some studies evaluated >1 method.
† 2 systematic reviews and 12 primary studies. Some studies evaluated >1 method.

Figure 1.

Evidence map showing the number and study designs of published studies that address major categories of cleaning and disinfection strategies and monitoring methods.



Adapted from reference 10. HP = hydrogen peroxide; HPV = hydrogen peroxide vapor; PCR = polymerase chain reaction; QAC = quaternary ammonium compound; RCT = randomized, controlled trial; UV = ultraviolet.

Figure 2.
Evidence needs for future research in environmental cleaning.