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Original Article

Educational interventions to improve compliance with disinfection practices of noncritical portable medical equipment: A systematic review

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Abstract

Objective: To describe educational interventions that have been implemented in healthcare settings to increase the compliance of healthcare personnel (HCP) with cleaning and disinfection of noncritical portable medical equipment (PME) requiring low-level disinfection (LLD).

Design: Systematic review.

Methods: Studies evaluating interventions for improving LLD practices in settings with HCP, including healthcare students and trainees, were eligible for inclusion.

Results: In total, 1,493 abstracts were identified and 1,416 were excluded, resulting in 77 studies that underwent full text review. Among these, 68 were further excluded due to study design, setting, or intervention. Finally, 9 full-text studies were extracted; 1 study was excluded during the critical appraisal process, leaving 8 studies. Various forms of interventions were implemented in the studies, including luminescence, surveillance of contamination with feedback, visual signage, enhanced training, and improved accessibility of LLD supplies. Of the 8 included studies, 4 studies reported successes in improving LLD practices among HCP.

Conclusions: The available literature was limited, indicating the need for additional research on pedagogical methods to improve LLD practices. Use of visual indicators of contamination and multifaceted interventions improved LLD practice by HCP.

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Healthcare-associated infections (HAIs) have a significant impact on patients and health systems.[1,2] Critical to the prevention of HAIs is maintaining a clean and disinfected environment of care. In addition to environmental surfaces within the healthcare environment, noncritical portable medical equipment (PME), such as vitals machines, ultrasound machines, and stethoscopes, present an opportunity for fomite transmission of pathogens.[3,4] PME frequently comes in contact with patients,[5] but it is inconsistently cleaned and disinfected,[6,7] and it serves as a potential reservoir and opportunity for onward transmission of pathogens.[3] In 2008, the Centers for Disease Control and Prevention (CDC) published recommendations for the cleaning and disinfection of PME.[8] Despite these recommendations, numerous studies have documented failures in cleaning and disinfection of noncritical PME that require low-level disinfection (LLD). These failures have been noted through both observed and self-reported healthcare personnel (HCP) behavior, as well as inferred by studies demonstrating contamination rates of PME between 25% and 100%,[9] including with clinically important pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and resistant gram-negative organisms.[10]

PME is increasing in volume and variety across many healthcare environments, resulting in an increase in opportunities for failures in cleaning and disinfection and the risk of transmission. A recent study in Veterans' Affairs medical centers showed an increase in the proportion of point-of-care ultrasound (POCUS) machine availability from 29% to 71% between 2015 and 2020.[11] This growth also occurred in emergency departments across the United States,[12] where workflow challenges, such as high patient volume, crowding, and frequent interruptions, present barriers to routine IPC practices.[13]

The reasons for failures in LLD of noncritical PME vary. HCP report perceived barriers to LLD that include a lack of understanding of who is responsible for LLD of PME, a lack of training for or understanding of the required LLD procedures, especially when protocols vary between equipment, as well as a lack of time and materials.[14] In this review, we examined published literature to identify educational and administrative interventions aimed at

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improving HCP performance of LLD of noncritical PME. Systematic reviews have been conducted regarding educational strategies for improving infection prevention broadly.[15] Reviews have been also conducted regarding interventions aimed at improving hand hygiene behavior[16] and environmental cleaning and disinfection are limited.[17,18] To our knowledge, no systematic review has been published specifically targeting interventions to improve LLD of noncritical PME in the United States.

Methods

This study has been reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting standards.[19]

Search strategy

In January 2023, searches were developed by a medical librarian (L.L.P.) and were executed in the Ovid Medline, Cochrane CENTRAL Registry via Ovid, Embase, CINAHL, and Web of Science Core Collection databases. The search combined keywords and database-specific subject headings for 3 concepts: disinfection, portable medical equipment, and intervention studies. A publication date range of January 1, 2006 through January 23, 2023, was applied. Literature focused on populations outside the United States were excluded. The full search strategies are included (Supplement 1 online).

Eligibility criteria

The review was limited to studies in the United States published during or after 2006, due to the release of updated CDC guidance on managing multidrug-resistant organisms in healthcare settings in that year.[20] Studies were included if educational or administrative interventions aimed at behavior change were carried out in acute or ambulatory care settings and involved LLD of PME, also described as "mobile patient equipment" or "noncritical" medical devices (NCMDs), as described in the Spaulding Classification System and the CDC Rational Approach to Disinfection and Sterilization.[21,22] Studies were excluded if they took place in settings such as home healthcare or nursing homes, if they involved only semicritical or critical equipment, or if they focused on the utilization and evaluation of specific cleaning products or methods, such as UV disinfection, without inclusion of educational or administrative interventions.

Screening

The systematic review screening software Covidence (Veritas Health Innovation, Melbourne, Australia) was used for both the title and abstract screening by 3 authors (A.B., C.V.G., and M.D.) and full-text review stages (A.B. and C.V.G.). Conflicts were resolved through consensus with arbitration when needed by the senior author (E.S.S.).

Data extraction and critical appraisal

Data extraction and quality assessment were completed by 2 reviewers (A.B. and C.V.G.). Articles were dually, independently screened, and conflicts were resolved through consensus. Population, setting, year, intervention protocol, type of PME, number of participants and/or observations, and results of the intervention were extracted from eligible publications.

Quality assessment was conducted using the Johanna Briggs Institute (JBI) 9-question critical appraisal tool for quasi-experimental studies.[23] These assessments were conducted independently by each reviewer and then resolved through consensus (Supplement 2 online).

Results

The database searches retrieved 2,198 citations (Fig. 1). Duplicate citations were removed using Endnote reference software, resulting in 1,493 citations for title and abstract screening. Of these, 1,416 studies were subsequently excluded during title and abstract screening. Of 77 publications that were assessed for eligibility in a full-text review, 68 were excluded, resulting in 9 studies that were further evaluated.[24–32] From these, 1 study was later excluded after data extraction and critical appraisal as it did not meet the quality assessment inclusion criteria (Supplement 2 online).[32]

Each of the 8 included studies described an educational intervention to improve disinfection practices of noncritical PME. Studies included a variety of PME: 3 included stethoscopes[24–26]; 2 included POCUS machines[27,28]; 1 included ultrasound equipment[29]; 1 included vitals machines, ultrasound machines, and bladder scanners[30]; and 1 included vitals machines (VMs) and workstations on wheels (WOWs).[31] Seven studies were conducted in hospital settings,[24–28,30,31] and 1 study was conducted in a student sonography laboratory.[29] Four studies described the use of a combined, multimodal intervention,[25,26,28,30] and 4 studies described a single intervention strategy.[24,27,29,31] Details of the interventions and reported outcomes are provided in Table 1.

Interventions

Intervention strategies included luminescence or other visual indicators of contamination, surveillance and feedback, visual reminders in the environment of care, the strategic placement of materials needed for LLD, or educational modules [eg, a short PowerPoint (PPT) presentation or an educational website].

Overall, 3 studies used luminescence tools, including Glo Germ Powder (Glo Germ Company, Moab, UT) and ATP bioluminescence, to visually demonstrate or simulate contamination of PME to HCP as part of a single educational intervention and/or ongoing education, surveillance, and feedback.[24,29,30] Of these 3 studies, 1 study also used culturing to visually demonstrate contamination of PME to participants. In 1 study, a disinfection tracking system (DTS) was used as a visual intervention. The DTS was a small device attached to the PME that monitored disinfection and indicated on a screen when the last disinfection event on the PME had occurred.[31]

Three studies strategically placed LLD supplies and visual LLD reminders near where LLD should take place.[25,26,28] Of these, 2 studies introduced baskets of alcohol wipes outside patient rooms accompanied by visual reminders for stethoscope LLD.[25,26] One of these studies coupled this intervention with an educational presentation on stethoscope hygiene.[26] In another study, a website was created to provide educational materials, supplemented with an informational placard and the provision of appropriate disinfectant wipe canisters affixed to the PME.[28]

Finally, one study utilized a short PPT presentation aimed at providing education on multiple aspects of PME handling, including LLD.[27]

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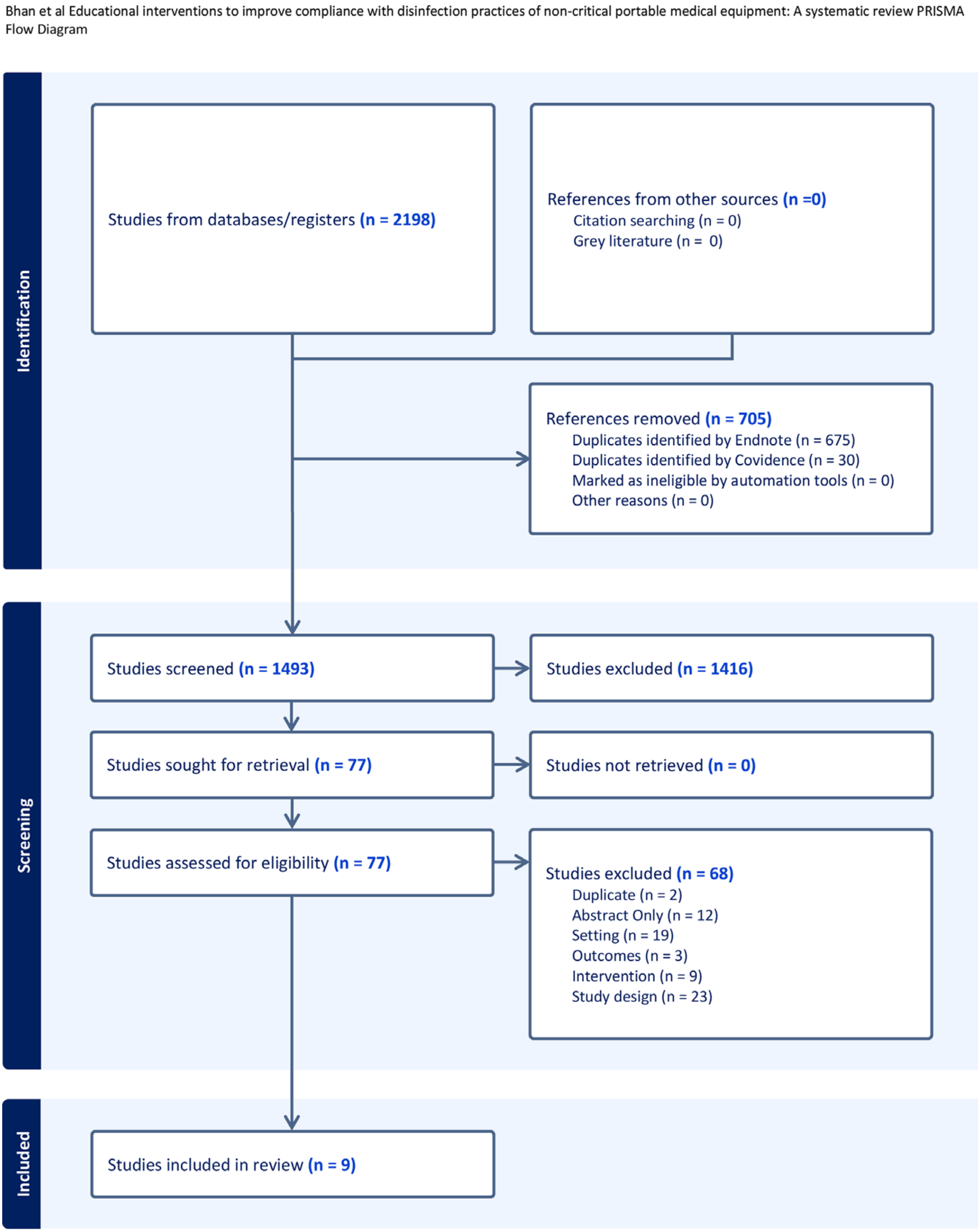

Figure 1. PRISMA flow diagram. Diagram illustrates the selection of studies included in this review.

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Table 1. Interventions Implemented for Improving Compliance With Cleaning and Disinfecting PME, and Whether These Interventions Were Successful in Effecting Change in Behavior

Population and Setting (Year)	Intervention Description	Type of PME	Total No. of Participants; Total No. of Observations	Success; Results	Reference
Medical students, house staff, and attendings in medical wards in a VA tertiary-care teaching hospital (2020)	Before-and-after study using direct observation of disinfection practices of stethoscopes. The intervention included HCP participating in sampling of their stethoscopes for culture and ATP bioluminescence testing both before and after disinfection. Bioluminescence scores were provided in real time, and HCP were provided with deidentified stethoscope culture results.	Stethoscopes	NR; 590	No; there was no significant change in stethoscope disinfection pre and postintervention, changing from 10% to 5%.	Holleck et al[24]
Physicians and nurses in inpatient units and emergency department of a major pediatric hospital (2013)	Before-and-after study using direct observation of disinfection practices of stethoscopes. The intervention included installation of baskets with alcohol prep pads and stickers reminding about disinfection outside of patient rooms.	Stethoscopes	NR; 487	Yes; stethoscope disinfection increased from 34% to 59% after intervention.	Zaghi et al[25]
Medical students, resident physicians, and attending physicians, nursing staff in a tertiary-care Department of VA teaching hospital (2017)	Before-and-after study using direct observation of disinfection practices of stethoscopes. The intervention included an interactive 11-slide PowerPoint educational presentation on stethoscope cleaning and disinfection, provision of boxes of alcohol swabs and placement of educational flyers in workspaces and at the entrance to each nursing unit.	Stethoscopes	NR; 169	No; stethoscope disinfection never occurred, both before and after intervention.	Holleck et al[26]
All faculty and staff in emergency departments at a quaternary care center and community hospital (2019)	Before-and-after study using direct observation of POCUS machines cleaning and disinfection. The intervention included a 5-minute educational presentation on the CLEAR protocol, which was followed up by a summary e-mail. This protocol included (C)leaning ultrasound machines.	POCUS machines	NR; 76	Not clear; cleaning of point-of-care ultrasound equipment rose from 61% to 66% after the intervention, though statistical significance was not measured.	Prats et al[27]
Physicians (2021)	Before-and-after study using fluorescent marking to monitor contamination of POCUS machines. The intervention included: an informational and instructional website for POCUS cleaning that was distributed via email, the placement of placards containing a summary of cleaning protocol on POCUS machines, and the provision of fully stocked disinfecting wipes on machines.	POCUS machines	NR; 1272	Yes; 44% improvement in thoroughness of cleaning post intervention. Prior to the intervention, there were 12 instances of gross debris reported on PME, and only 1 after the intervention.	Van Kalsbeek et al[28]

(*Continued*)

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Table 1. (*Continued*)

Population and Setting (Year)	Intervention Description	Type of PME	Total No. of Participants; Total No. of Observations	Success; Results	Reference
Sonography students in a student sonography scan laboratory (2019)	Before-and-after study using fluorescent marking to monitor contamination of a laboratory environment, including ultrasound equipment and cardiac transducers. The intervention included: the contamination of lab equipment using Glo Germ powder and a debriefing session on infection control.	Ultrasound equipment, cardiac transducers	23; NR	Yes; students were found to consistently clean a curved 3.5-MHz transducer, and improved their cleaning of cardiac transducers after intervention.	Pessin et al[29]
All staff, including nurses and healthcare technicians in the acute-care floor and emergency department in a public safety net and teaching hospital (2019)	Before-and-after study using ATP bioluminescence assays to monitor contamination of VMs, ultrasound machines, and bladder scanners. The intervention included an ongoing weekly measurement and submission of contamination results to nurse educators and managers, which was then shared with staff on a regular basis over the course of 6 months.	VMs (including blood pressure cuff, pulse oximeter, and thermometer), ultrasound machines, bladder scanners	NR; 859	Yes; median contamination of PME in RLU decreased by 75% during implementation period. Lower contamination was also observed during the maintenance period.	Reese et al[30]
Nursing staff in a single acute care facility mixed medical surgical unit of a Veterans Healthcare System (2022)	Before-and-after study using a DTS placed on WOWs and VMs to monitor the number of disinfection events completed during each period of the study. The intervention included: the DTS that displayed disinfection prompts, stating when the last disinfection event occurred. This involved an initial "screen off" period, when no such prompt was shown, followed by a "screen on" period, during which prompts were shown.	WOWs and VMs	NR; 1190	Not clear; the "screen on" period had 32% more disinfection events than the "screen off" period for WOWs but showed no change for VMs.	Crowley et al[31]

Note. DTS, disinfection tracking system; PME, portable medical equipment; POCUS, point-of-care ultrasound; RLU, relative light unit; VM, vitals machine; WOW, workstation on wheels.

Reported outcomes

Of the 8 studies included in the review, 4 studies were successful in improving LLD practices, with their respective interventions involving luminescence, workflow changes, and educational sessions.[25,28–30] Also, 2 studies were unclear about the success of the intervention; 1 study involved the DTS; and the other involved an educational PPT.[27,31] In the DTS study, only the DTSs on the WOWs documented more cleaning events, but the DTSs on VMs did not.[31] In the study with an educational PPT, disinfection improved from 61% before the intervention to 66% after the intervention, but the statistical significance of this change was not calculated.[27] The 2 studies focused on cleaning and disinfection of stethoscopes that failed to demonstrate improvement were conducted by the same research team. These researchers used a workflow improvement and educational session in one study and cultures or bioluminescence before and after LLD to demonstrate contamination in the other.[24,26]

Study duration and sustainability

Of the 8 included studies, 4 were between 4 and 14 weeks in duration[25–27,31]; 2 studies did not specify their duration[24,29] and 2 studies were conducted over longer periods (1 year, 30 months).[28,30] In only 1 study was follow-up data collected during a maintenance period. This study demonstrated the sustainability of the effects of their intervention; maintenance data were collected for 6 months after a 6-month implementation period.[30] In the other 7 studies, before-and-after data were collected without an assessment of long-term sustained improvement.[24–29,31]

Luminescence and visual indicators

Of the 4 studies involving visual indicators of contamination, 2 reported successful interventions,[29,30] the DTS study showed mixed success,[31] and 1 study was entirely unsuccessful in causing a change in behavior in HCP.[24]

Combined, multifaceted interventions

Of the 8 studies, 4 included a combination of 1 or more of the interventional strategies described above.[25,26,28,30] One of these studies combined ongoing education with ongoing ATP bioluminescence feedback on performance.[30] In another study, in addition to their targeted educational campaign, access to cleaning products was increased by ensuring that appropriate wipes were stocked directly on the POCUS units themselves.[28] In a third study, access to stethoscope cleaning supplies was improved and visual reminders regarding stethoscope hygiene were introduced.[25] In a fourth study, reminder signage was installed and boxes of alcohol wipes were made available at the entrances to patient rooms in addition to an educational intervention.[26] Of these combined intervention studies, 3 showed improvement in either observed LLD of PME or the objective measurements of cleanliness of PME.[25,28,30] In the fourth study, no change in stethoscope hygiene was achieved, and the intervention was discontinued after 1 month.[26]

Four studies described a single intervention type.[24,27,29,31] Of these 4 studies, 3 showed some improvement in observed LLD of PME, objectively measured cleanliness of PME, or in the case of the DTS, objective measurement of cleaning events.[27,29,31] Notably, in 1 study, the effect of a Glow Powder exercise on LLD techniques by sonography students was investigated, but these students were also receiving infection prevention and control (IPC) education as part of their sonography training during the study, which may have affected the findings.[29]

HCP beliefs and reported barriers to LLD of PME

Of the 8 studies included in the review, 3 studies included surveys and/or needs assessments of HCP beliefs regarding the importance of LLD of PME, as well as their perceived barriers to doing so.[24,25,28] Two groups of researchers used survey data or conducted needs assessments to inform targeted interventions.[25,28] Two groups surveyed participants before and after their interventions to demonstrate the influence of their intervention on the knowledge and attitudes of their staff.[24,28] One group of researchers designed their intervention to address 2 important barriers identified in a previous survey they had conducted on stethoscope hygiene at the same institution: lack of access to disinfection supplies and lack of visual reminders to disinfect.[25] Another study created their targeted intervention to change physician POCUS LLD behavior based on the outcomes of a needs assessment conducted with these physicians.[28] A third study's pre- and post-survey results demonstrated an improvement in providers' reported belief in the importance of stethoscope hygiene after their educational intervention, as well as an increase in the self-reported frequency of LLD. However, observed behavior did not improve after the intervention.[24] Using a survey, this study identified that lack of available LLD supplies was among the top 3 barriers to stethoscope hygiene, but this barrier was not addressed in the intervention and it remained among the top 3 barriers in the postintervention survey.[24]

Quality assessment

The results of the critical appraisal are provided in Supplement 2 (online).

Discussion

Although failures in cleaning and disinfection of noncritical PME have been well documented, our review of published literature revealed a paucity of studies assessing the impact of educational and administrative interventions to improve practice. Across the included interventions, however, the features of those that were successful in improving the LLD of PME are notable.

The successes of 2 of the 4 study interventions involving visual indicators of contamination,[29,30] and mixed success of the DTS in one of these studies,[31] suggest that providing HCP visual evidence or simulation of contamination can be an effective method in influencing behavior. In one study that was unsuccessful at changing behavior, the visual indicators did appear to change beliefs in the importance of cleaning and disinfection of PME, and staff responded in a survey that seeing the ATP results from their own PME was more influential in motivating them to clean and disinfect stethoscopes than peer-reviewed literature.[24]

Based on this review, multimodal interventions that include a combination of educational strategies appear to be more effective in improving behavior regarding LLD practices, which is supported by existing approaches. The 2017 World Health Organization "Core Components of Effective Infection Prevention and Control Programs" suggests the value of multimodal programs to improve IPC practice.[33] Multimodal interventions have been successfully employed to address other challenging areas of IPC compliance, such as hand hygiene.[34] Four of the included studies took this approach, whereas 4 studies employed 1 strategy alone. The study that demonstrated the largest impact on LLD included an ongoing, multimodal intervention including weekly ATP bioluminescence surveillance, feedback, and education over a 6-month period involving both managers and staff.[30] This finding is consistent with the findings of a recent review of factors associated with improved environmental cleaning and disinfection practices more broadly. This study described the most successful interventions as those that combined education and training with the provision of feedback, as well as those that utilized continuous education and training.[17]

Interventions that address the needs and perceived barriers HCP face in implementing LLD require further investigation to identify how these may influence compliance with LLD and the sustainability of these improvements.

This analysis had several limitations. A small number of studies ultimately met criteria for inclusion, limiting the ability to draw broader conclusions. This lack of studies demonstrates an important gap in our understanding of effective interventions. Studies conducted outside the United States were also excluded. The frequency and duration of interventions were varied across the included studies, limiting ability to draw any conclusions related to optimal frequency and duration of educational interventions. Lack of long-term follow-up further limited assessment of the impact of interventions over time and the sustainability of any improvements.

In conclusion, as the use of PME in healthcare continues to expand, and care is delivered in ever more complex and diverse environments, the need to understand how to optimize HCP education, training, and competency in LLD has never been greater. Ensuring correct and consistent LLD of PME will be essential to patient safety. This review revealed that studies examining educational interventions to improve LLD of PME are limited; further investigation to demonstrate effective teaching modalities is needed. In particular, randomized control trials of educational and administrative interventions and studies that demonstrate the sustainability of interventions to improve LLD of PME are needed. Studies of interventions to improve environmental cleaning and LLD of equipment should provide data on equipment and environmental surfaces separately to better elucidate the impact of interventions on the practice of LLD across surfaces in the patient environment.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2023.234

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