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Major Article

Evaluation of daily environmental cleaning and disinfection practices in veterans affairs acute and long-term care facilities: A mixed methods study

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Objectives: To describe daily environmental cleaning and disinfection practices and their associations with cleaning rates while exploring contextual factors experienced by healthcare workers involved in the cleaning process.
Methods: A convergent mixed methods approach using quantitative observations (ie, direct observation of environmental service staff performing environmental cleaning using a standardized observation form) and qualitative interviews (ie, semistructured interviews of key healthcare workers) across 3 Veterans Affairs acute and long-term care facilities.
Results: Between December 2018 and May 2019 a total of sixty-two room observations (N = 3602 surfaces) were conducted. The average observed surface cleaning rate during daily cleaning in patient rooms was 33.6% for all environmental surfaces and 60.0% for high-touch surfaces (HTS). Higher cleaning rates were observed with bathroom surfaces (Odds Ratio OR = 3.23), HTSs (OR = 1.57), and reusable medical equipment (RME) (OR = 1.40). Lower cleaning rates were observed when cleaning semiprivate rooms (OR = 0.71) and rooms in AC (OR = 0.56). In analysis stratified by patient presence (ie, present, or absent) in the room during cleaning, patient absence was associated with higher cleaning rates for HTSs (OR = 1.71). In addition, the odds that bathroom surfaces being cleaned more frequently than bedroom surfaces decreased (OR = 1.97) as well as the odds that private rooms being cleaned more frequently than semi-private rooms also decreased (OR = 0.26; 0.07-0.93). Between January and June 2019 eighteen qualitative interviews were conducted and found key themes (ie, patient presence and semiprivate rooms) as potential barriers to cleaning; this supports findings from the quantitative analysis.
Conclusion: Overall observed rates of daily cleaning of environmental surfaces in both acute and long-term care was low. Standardized environmental cleaning practices to address known barriers, specifically cleaning practices when patients are present in rooms and semi-private rooms are needed to achieve improvements in cleaning rates.

Abbreviation: Environmental Cleaning, VA; CleanR, Study

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Healthcare associated infections (HAIs) are a common complication of healthcare.[1] Contaminated environmental surfaces can serve as a reservoir of pathogens associated with HAIs[2-6] and MDRO biofilms on hospital surfaces has been found globally.[7] Pathogen acquisition is two times higher for patients admitted to rooms whose prior occupants were infected or colonized.[8] It has been shown that environmental cleaning programs that incorporate both physical cleaning and chemical disinfection can be successful in interrupting transmission and subsequent infection,[9,10] however variations in cleaning practices occur[11] thus measuring impact of cleaning practicing on HAI outcomes is difficult. Although the level of cleanliness required to prevent pathogen colonization from the environment is unknown,[12] cleaning practices applied frequently[7] and consistently can reduce the environmental bioburden,[13] disrupting transmission of these pathogens, and preventing HAIs.

Studies have found that HAIs are preventable when evidence-based practices are effectively implemented.[14] National[15] and International[16] guidelines recommend environmental cleaning for *c. difficile* prevention. Veterans Affairs (VA) has incorporated environmental cleaning practices into their national HAI prevention initiatives,[17-20] and while national VA sanitation guidelines exist that outline which surfaces to clean and the appropriate cleaning and disinfection agents,[21] the guidance lacks details on specific contextual cleaning practices such as cleaning when patient is present in the room or cleaning in semiprivate rooms. Vaughn and colleagues surveyed VA medical facilities (59%-80% response rate between 2005 and 2013) and found 80% of VA facilities self-report daily cleaning of HTSs in patient rooms with *C. difficile.*[22] The authors of this study conducted VA-wide survey (100% response rate) in 2017 to evaluate infection prevention practices identifying significant variation in environmental cleaning, including differences in who was responsible for disinfecting certain surfaces in patient rooms—environmental services or nursing staff—and variation in monitoring practices of the cleaning process.[23] In addition, focus groups with environmental management services (EMS) staff at one VA facility identified lack of standardization regarding which types of surfaces are important to clean regularly in rooms as a key barrier to cleaning.[24]

Efforts to standardize environmental cleaning practices, including the Centers for Disease Control and Prevention (CDC) toolkit,[25] have focused on targeted cleaning of high-touch surfaces (HTSs; ie, surfaces that are frequently touched by healthcare workers and patients such as bedrails, overbed table, IV pole, door knobs, etc.)[26] and monitoring (ie, audit and feedback) of environmental cleaning processes (ie, direct observation of cleaning, microbiological or organic surface sampling or marking surfaces with fluorescent gels) as a means to improve cleaning efficacy and compliance.[27] Like many healthcare organizations, the VA adopted and implemented these CDC tools. Despite wide spread use of these tools, cleaning rates are still low[28] with reports ranging from 35% to 81%.[29] Understanding context of practice variation[30]may help address practice standardization.

The overall goal of this study was to gather information on cleaning practices to inform revisions of standard practice guidelines for environmental cleaning of patient rooms in healthcare settings to improve cleaning rates and patient outcomes (eg, HAIs) in the VA. The aim of this study was to describe daily environmental cleaning and disinfection practices and their associated cleaning rates while exploring healthcare workers experience of the cleaning process within the context of the work system, in VA acute-care (AC) and long-term care (LTC) settings.

METHODS

A convergent mixed methods design[31] was used to compare daily environmental cleaning practices in 3 VA facilities across AC and LTC settings from December 2018 to June 2019. The quantitative phase of the study was comprised of direct observations of daily environmental cleaning of patient rooms. The qualitative phase of the study was comprised of semistructured interviews to better understand contextual factors occurring during the cleaning process healthcare workers' knowledge and experience of environmental cleaning practices. Data analysis for each data set occurred separately.

Quantitative

Research assistants (RAs) at each site collected standardized observation data. Prior to conducting observations, RAs received approximately two hours of didactic observer training on the data collection process provided by subject matter experts from the research team. Training covered the specific environmental cleaning processes they would observe and how to correctly fill out the observation form to accurately reflect the EMS staff practices. Complementary to the training, each RA was given a comprehensive data collection protocol and training manual (see Appendix). The observation form was adapted by the research team from the CDC environmental checklist for monitoring cleaning[32] and included the following variables: cleaning duration, location of room (eg, facility and patient setting), type of surface (eg, HTS, RME, bedroom, or bathroom area), room characteristics (eg, number of beds, number of people in room, use of isolation precautions, presence of clutter), product characteristics (eg, type of disinfectant, use of microfiber) and practice characteristics (eg, cleaning path, surface friction – number of swipes, surface area – degree of surface area disinfectant applied, surface wetness – degree of disinfectant saturation, number of wipes used, number of staff interruptions, and EMS staff use of hand hygiene and personal protective equipment) (see observation form in supplemental material).

Observations were limited to disinfection and cleaning practices using chemical disinfection and manual cleaning; we did not ask observers to assess practice accuracy (or performed to a certain standard). Convenience sampling was used for selecting observations; the RAs shadowed EMS staff during day shift with each site expected to collect 4 observations per week over 8 weeks for minimum of 24 observations per site. Observation forms were scanned using OpenText TeleForm (OpenText, Waterloo, ON) software.

Descriptive statistics summarize the environmental cleaning practice variables using data from the room observations. Multiple logistic regression analysis was done to evaluate the relationship between specific cleaning variables and cleaning rates using data from the total number of surface observations; cleaning rates were defined by the percentage of surfaces cleaned in a room (number of surfaces cleaned/total number of surfaces). Data were analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

To explore the optimal number of environmental surface observations needed for an effective monitoring program we developed an estimate using a sampling with replacement (ie, bootstrap) method. We examined 6 different sampling strategies: observing 20, 25, 30, 35, 40, and 45 rooms. The observer was assumed to be present in the room for the duration of the cleaning (maximum time of 30 minutes). We calculated each room's cleaning rate by dividing the number of surfaces cleaned (wiped with disinfectant) by total number of surfaces present in a room; total number of surfaces in each room were calculated from the observation form since this differed from room-to-room. We generated 1,000 bootstrap samples for each sampling

strategy. We calculated sampling error, defined as the distance between each sample cleaning rate and the actual cleaning rate, and percent of samples with sampling error of ≤5% and ≤10%, reported for each strategy. The optimal sampling strategy was defined as the minimal number of surfaces needed to reach a tolerable frequency of sampling error (≤10%) for all samples, representing the "tipping point" where additional surfaces would be unlikely to increase accuracy. We stratified the rooms by greater than mean (All Surfaces: <33.7% and HTS: <60.2%) cleaning rate to explore how the prediction might vary.

Qualitative

Prior to conducting interviews, RAs received approximately 8 hours of didactic training on conducting qualitative interviews (eg, the interview process, the notetaking process, time management, etc.) led by our team of qualitative experts. Semistructured in person interviews[33,34] were conducted with key stakeholders (ie, EMS managers and staff, nursing managers and staff, and infection preventionist [IP]) at all 3 sites. Semistructured interview guides were developed by the research team and questions focused on facility environmental cleaning practices (see interview guide in appendix). All interviews were audio-recorded using encrypted recorders and transcribed verbatim. One interview was not recorded due to participant refusal, therefore detailed notes were used in analysis. Electronic transcripts were managed and analyzed using MAXQDA (VERBI Software, Berlin, Germany) software.

Our interdisciplinary team, including trained social scientists with backgrounds in anthropology, public health, nursing, and infection control, conducted a thematic content analysis.[35,36] Through an iterative process of discussing and refining codes and their definitions during group meetings, a comprehensive codebook was developed. The process involved individuals reading transcripts independently and noting potential codes with final codes assigned based on consensus during the group meetings.[37] Half (56%) of the transcripts were coded via this process. Afterwards, the remaining transcripts (44%) were coded by pairs; following a method of initial independent coding followed by paired consensus[37] where discrepancies between the pairs continued to be discussed within the larger group to reach consensus amongst the full group.

Results of both data sets (quantitative and qualitative) were integrated using a convergent design[38] to explain and interpret findings and facilitate understanding of environmental cleaning practices, cleaning rates, and contextual factors.

Human subjects

Human subject review and approvals were obtained from the VA Central Institutional Review Board (CIRB 18-10) and local site Research and Development Committees. We received a waiver of documentation of informed consent for both observations and semi-structured interviews.

RESULTS

Quantitative

From December 2018 to May 2019 trained RAs at each site conducted direct observations by shadowing EMS staff performing daily environmental cleaning of patient rooms. Quantitative results are grouped by unit of analysis, either by the number of room observations (N = 62) or by the number of environmental surface observations (N = 3602).

Room observation (N = 62)

A total of 62 rooms (AC, N = 35 and LTC, N = 27) were observed during daily cleaning; the unit of analysis in this section is the total number of rooms observed. Descriptive statistics of the observations are presented in Table 1**.** EMS staff spent, on average, 4 more minutes performing daily cleaning activities in LTC compared to the AC setting. There were more observations of daily cleaning of isolation rooms in the LTC setting (19% vs 6% in AC) which require EMS staff to wear personal protective equipment (PPE) such as gowns and/or gloves upon room entry and requires specialized cleaning procedures. Of note, less than half of the observations reported EMS staff performing hand hygiene upon room entry.

Surface observation (N = 3602)

During daily cleaning, EMS staff were observed cleaning a total of 3,602 surfaces (AC, = 2,013 and LTC, =1,589); the unit of analysis in this section is the total number of surfaces observed. Cleaning rates across settings (ie, AC and LTC) and surface type (ie, bathroom, bedroom, HTS, and RME) are described in Table 2. The overall cleaning rates for 'all room surfaces' during daily cleaning was low in both settings, rates were higher in LTC compared to AC. Cleaning rates for HTSs was higher in both settings compared to 'all surfaces'.

Multiple logistic regression analysis (Table 3) was used to measure the relationship between (Odds Ratio; OR) the observed variables and cleaning rates of all environmental surfaces. The surfaces associated with higher cleaning rates were bathroom surfaces, HTSs, and RME. Factors associated with lower cleaning rates were cleaning of semiprivate patient rooms and rooms in AC. When analysis was stratified by whether the patient was in the room, cleaning rates increased for HTSs when the patient was absent from the room. The differences between cleaning rates of bathroom surfaces and RME, compared to bedroom surfaces, became less significant when the patient was absent from the room during the daily cleaning process. Of note, in AC nearly all (94%) of the cleaning observations occurred while the patient occupied the room while approximately half (48%) of the cleaning observations in LTC were done with patients present.

Table 4 shows the summary strategies of actual observed surface disinfection cleaning rates with various sampling strategies and frequency of sampling errors (≤10% and 5%) to estimate the number of rooms needed to be observed to meet or exceed the mean compliance threshold.

Qualitative

From January to June 2019, eighteen[33,34] (EMS staff, N = 11; Nursing, N = 4; IP, N = 3) semistructured in-person interviews were conducted with key stakeholders at all 3. Several themes emerged during the analysis which served to clarify our cleaning observations. A joint display[39] of quantitative and qualitative results is provided in Table 5, specifically focusing on themes associated with higher and lower cleaning rates.

HTS, RME and especially bathrooms are targeted and prioritized during daily cleaning

Targeting HTSs emerged as a theme during our qualitative analysis, as one Nurse Manager stated, "*The areas that are frequently handled, (. . .) so the handrails, things to that effect, are often frequently touched and they need to have a super amount of attention*" (Facility A). Bathrooms were especially prioritized during daily cleaning as an EMS staff noted, "*Well, daily clean is I go through (. . .). I mean I don't get to wipe down everything in there. But I make sure that the bathroom is taken care of (. . .)*" (Facility C).

Table 1
Descriptive characteristics of environmental cleaning observations by room observation (N = 62)

	ACN = 35 (%)	LTCN = 27 (%)	TotalN = 62 (%)* *missing data not reported
Facility			
• A	5 (14%)	13 (48%)	18 (29%)
• B	6 (17%)	14 (52%)	20 (32%)
• C	24 (69%)		24 (39%)
Isolation precaution			
• Yes	2 (6%)	5 (19%)	7 (11%)
Type of room			
• Single bed (private room)	28 (80%)	19 (70%)	47 (76%)
• Multibed (semiprivate room)	7 (20%)	8 (30%)	15 (24%)
Surface area			
• 1 ≥ 75%	23 (66%)	0 (0%)	23 (37%)
• 2 = 25%-75%	10 (29%)	25 (93%)	35 (56%)
• 3 ≤ 25%	0 (0%)	1 (4%)	1 (2%)
Surface friction**			
• 1 ≥ 3 wipes	0 (0%)	6 (22%)	6 (10%)
• 2 = 2-3 wipes	33 (94%)	20 (74%)	53 (85%)
• 3 ≤ 2 wipes	0 (0%)	0 (0%)	0 (0%)
**Note: friction refers to 'back and forth' motion			
Surface wetness			
• 1 = saturated	1 (3%)	0 (0%)	1 (2%)
• 2 = wet/damp	34 (97%)	27 (100%)	61 (98%)
• 3 = dry	0 (0%)	0 (0%)	0 (0%)
Patient in room			
• Yes	33 (94%)	13 (48%)	46 (74%)
• No	2 (6%)	12 (48%)	14 (23%)
Healthcare worker in room			
• Yes	14 (40%)	5 (18%)	19 (31%)
• No	20 (59%)	19 (79%)	39 (67%)
Visitor in room			
• Yes	5 (14%)	2 (8%)	7 (11%)
• No	28 (80%)	22 (81%)	50 (81%)
Interruptions (while cleaning)			
• Yes	7 (20%)	4 (15%)	11 (18%)
• No	26 (74%)	23 (85%)	49 (79%)
Surface clutter removed			
• Yes	2 (3%)	12 (44%)	14 (25%)
• No	26 (93%)	15 (56%)	41 (75%)
Disinfectant application method			
• Spray bottle	4 (11%)	8 (30%)	12 (19%)
• Wet cloth	29 (83%)	18 (67%)	47 (76%)
Number of cleaning wipes used			
• >3	5 (14%)	5 (19%)	10 (16%)
• 2-3	18 (51%)	7 (26%)	25 (40%)
• 0-1	10 (29%)	14 (52%)	24 (39%)
Mop method			
• Dry	1 (3%)	2 (7%)	3 (5%)
• Wet	30 (86%)	24 (89%)	54 (87%)
Mop material			
• Reusable cotton	23 (66%)	0 (0%)	23 (37%)
• Microfiber	10 (29%)	27 (100%)	37 (60%)
• Disposable synthetic	0 (0%)	0 (0%)	0 (0%)
Cleaning wipe material			
• Reusable cotton	0 (0%)	0 (0%)	0 (0%)
• Microfiber	10 (29%)	27 (100%)	37 (60%)
• Disposable synthetic	0 (0%)	0 (0%)	0 (0%)
Bedroom disinfectant			
• Quaternary ammonium	33 (94%)	27 (100%)	60 (97%)
• Sodium hypochlorite	0 (0%)	0 (0%)	0 (0%)
Bathroom disinfectant			
• Quaternary ammonium	29 (83%)	21 (78%)	50 (81%)
• Sodium hypochlorite	1 (3%)	0 (0%)	1 (2%)
• Quaternary plus Bleach	3 (9%)	6 (22%)	9 (15%)
Hand Hygiene upon room entry			
• Yes	14 (20%)	12 (44%)	26 (42%)
• No	21 (80%)	15 (56%)	36 (58%)
PPE (glove and/or gown)			
• Yes	10 (29%)	27 (100%)	37 (60%)
• No	25 (71%)	0 (0%)	25 (40%)
	AC Mean (SD)	LTC Mean (SD)	Total Mean (SD)
Cleaning duration (minutes)	9.63 (3.40)	13.63 (3.40)	11.37 (3.90)

Daily cleaning is easier when the patient is absent from the room

An emergent theme was that the room was easier to clean when the patient was not present during daily cleaning. One EMS staff stated: "The Community Living Center (CLC), that's who I do most of my dealing[s] with. (…) For patients that have been there for a while, I'll ask 'em [CNA] if I can um just freshen the bed or something before, they remake it, because they clean, or they change their beds daily. (…) the CNAs will typically allow me to have, you know, those few minutes, 'cause they usually do it when the patient's not in their room (…) I can do that kind of thing up in the CLC. Give the patient a little bit of freshness on their actual bed" (Facility B).

Daily cleaning is harder when the patient is present in the room

Likewise, an equally important theme arose indicating having the patient in the room during daily cleaning was harder for staff. One EMS manager noted, "*If the patient's in the bed, we kinda have to skip the entire bed (…) the bathroom will still get a thorough cleaning*" (Facility B). EMS staff may also perceive cleaning of these bedroom surfaces as being disruptive to patients supported by following staff quote, "*Now the daily [cleaning], sometimes you can do that and sometimes you can't because some patients don't want you in there [their room]*" (EMS staff, Facility C).

Daily cleaning is harder (more challenging) in semiprivate rooms

Interviews revealed a theme that staff found semi-private rooms harder to clean as an EMS manager stated: "(…) *I mean, you get two patient beds in there and then you get the big chairs for visitors in there, and then trying to get in there and work around everything, it's challenging sometimes* (…)" (Facility C). Healthcare workers also noted the challenges of semi-private rooms as one Nurse Manager described the perceived infection risks for these types of rooms: "*Double rooms, obviously, is a huge challenge. It's a huge infection control challenge (…) we don't have enough staff EMS-wise [EMS staff] to clean the bathrooms after each person uses 'em*" (Facility B).

Various methods used to monitor the environmental cleaning process

Healthcare workers also described variation in how environmental cleaning was monitored across the three facilities. Use of fluorescence gel marking (FGM) for monitoring the cleaning process was referenced frequently as one Nurse Manager describes: "*…I know that housekeeping will come through and swab and light and do some checks and things like that. I've never seen them do that down here [CLC]. I've only heard of them doing it on the [AC] floor, or at their infection control meetings.*" (Facility A) and an EMS manager said: "*So we do observations. We do fluorescent marking.*" (Facility B). Participants also referenced various other methods for monitoring room cleaning, including: 1. Rounding: "*I do environment of care rounds to see if things are, you know, to see if there's issues (…) if things are dirty or not being cleaned…*" (Nurse Manager, Facility B); 2. Direct Observation: "*The trainer will come up and watch you once in a while.*" (EMS staff, Facility B); 3. Checklists: "*Well, they come by and they have a checklist, and they always find something.*" (EMS staff, Facility C); or 4. Informal: "(…) *they [EMS staff] know that if I'm unhappy with something, I'm going to call [EMS department]. (…) So, it's like, 'You don't have to worry about that area, because if she [Nurse Manager] doesn't like something, she's going to let you know'*" (Nurse Manager, Facility A). Some respondents also noted their uncertainty regarding whether cleaning

Table 2
Frequency of observed environmental surface cleaning rates by surface observation (N = 3602)

	ACMean (SD)	LTCMean (SD)	TotalMean (SD)
Cleaning rates – all surfaces	0.27 (0.09)	0.42 (0.11)	33.69 (1.26)
Cleaning rates – HTSs	0.69 (0.12)	0.49 (0.14)	60.17 (1.63)
Surface	AC N = 1571 (%)	LTC N = 1212 (%)	Total N = 2783 (%)
Bedroom			
Bed controls	-	0.15	0.06
Bed frame	-	-	-
Head/foot boards	-	0.19	0.08
Bed rails	-	0.07	0.03
Bedside table	0.09	0.19	0.13
Built-in cabinets	0.29	0.67	0.45
Call button	-	0.04	0.02
Chair	-	0.48	0.21
Privacy curtain	-	-	-
Doorknob	0.34	0.96	0.61
Dresser	-	0.36	0.16
Light fixture	0.11	0.04	0.08
Floor	0.89	0.93	0.90
Light switch	0.09	0.48	0.26
Mattress	-	-	-
Medical gas	-	-	-
Pillow	-	-	-
Remote control	-	0.15	0.06
Sharps container	0.66	0.89	0.76
Sink & fixtures	0.85	0.89	0.87
Soap dispenser	0.23	0.89	0.52
Telephone	-	0.19	0.08
Television & housing	-	0.31	0.13
Tray table	0.20	0.52	0.34
Vents	-	0.41	0.18
Waste basket	0.03	0.37	0.18
Other	0.70	1.00	0.79
Bathroom			
Doorknob	0.46	0.93	0.66
Emergency pull cord	0.03	0.38	0.19
Floor	0.83	0.78	0.81
Handrails by toilet	0.89	0.81	0.85
Light switch	0.18	0.37	0.26
Mirrors	0.36	0.35	0.35
Shelves/ledges	0.30	0.44	0.37
Sink & fixtures	0.81	0.78	0.79
Shower floor	0.59	0.42	0.51
Shower curtain	-	-	-
Shower stall & fixtures	0.48	0.63	0.55
Shower walls	0.04	-	0.02
Soap dispensers	0.39	0.59	0.49
Toilet bedpan cleaner	0.83	-	0.76
Toilet flush handle	0.97	0.74	0.87
Toilet seat	0.94	0.85	0.90
Waste basket	0.03	0.33	0.17
Reusable Medical Equipment			
Bedpan, urinal	-	-	-
Commode	0.50	0.75	0.65
IV pole	0.07	0.55	0.20
Lift	-	-	-
Shower chair	0.46	0.53	0.49
Transfer belt	-	-	-
Walker	-	-	-
Wheelchair	-	-	-
Other	0.86	0.60	0.79

performance was routinely monitored, "*I guess [we monitor] by each other. We don't have one particular person that monitors*." (nurse, Facility A). And others questioned the consistency of monitoring methods: "*If you're asking, are they [EMS staff] monitored by the supervisory staff – not consistently*…" (Nurse Manager, Facility A) and an EMS manager stated: "*So, it's [FGM] at the employee-level, so it's used as a training method*" (Facility B).

DISCUSSION

Higher cleaning rates for HTS, RME, and bathroom surfaces

This study found lower levels of cleaning when counting observations for 'all environmental surfaces,' however cleaning of surfaces classified as 'high-touch' were significantly higher. This is similar to other published reports.[29,40] Environmental cleaning recommendations, including the CDC toolkit for evaluating environmental cleaning, emphasize cleaning and disinfecting environmental surfaces in healthcare settings that have frequent hand contact – HTS.[4,26,41,42] This attention on HTSs has likely influenced policies, trainings and monitoring that focus on HTSs, which could explain the higher cleaning rates of HTSs observed in this study.

Like HTSs, higher cleaning rates were also observed for bathroom surfaces and RME when compared to surfaces found in the bedroom. Our qualitative analysis provided insight supporting these findings. One possible explanation is that these surfaces are often considered high touch surfaces (HTS) and therefore more likely to be focused on when cleaning. However, when we stratified the data by presence of patient in the bedroom, that difference decreased when the patient was not in the room suggesting that bedroom surfaces may be easier to access for cleaning when the patient is not present.

Higher cleaning rates, when patient absent during cleaning

We found higher cleaning rates when the patient was not present in the room for daily cleaning. Since patients were present during cleaning in most AC observations (94%), we focus primarily on the LTC setting to examine cleaning practices when the patient is absent from the room. In more than half (52%) of the LTC observations, the patients were not present during cleaning, which likely allowed for easier access to cleaning of environmental surfaces. Since LTC residents are often not bed-bound, and LTC facilities offer a variety of community activities providing opportunities to leave their room.

We also observed longer cleaning times in the LTC setting which could explain higher cleaning rates. Longer cleaning times may also be due to the higher number of isolation room observed in the LTC setting; isolation room cleaning typically have additional cleaning requirements[43] that may have led to higher cleaning rates.

Others have found clutter to be a barrier to cleaning,[44] especially in LTC[45,46] so our observations attempted to quantify whether clutter was removed prior to cleaning. Although our study did not find removal of clutter as an independent predictor for cleaning rates, removal of clutter was reportedly higher in LTC (31%) than AC (25%) albeit lack of removing clutter prior to cleaning was high in both settings; LTC (N = 69%) and AC (N = 50%) and clutter was reportedly higher in LTC (64%) than AC (36%). Staff interviews did note the longer the patient was hospitalized the longer it took to clean their room, as one EMS staff stated, "*Yeah, if you put on the CLC, I mean, those guys have been there for months, some of 'em years and those take a LONG time to clean*" (Facility C). The extra time it took to clean the room may be due to having time to accumulate personal belongings (ie, clutter) in this setting.

Lower cleaning rates when patient present during cleaning

Initial analysis found observed cleaning rates significantly lower in AC compared to LTC. Based on the emergence of the themes derived from interviews (ie, rooms with patient presence are harder to clean and rooms without patient presence are easier to clean), data stratification by patient presence was added to the analysis. Using a mixed method approach led to a significant study finding, the presence of the patient impacted cleaning rates.

Table 3
Regression analysis: effects of cleaning practices on cleaning rates using surface observations (N = 3602)

	Surfaces in ACN = 1571OR (95% CI)	Surfaces in LTCN = 1212OR (95% CI)	All SurfacesN = 2783 OR (95% CI)	All SurfacesStratified by patient in roomOR (95% CI)	
				Yes (N = 2066)	No (N = 717)
HTS (Y/N)	1.37 (1.07, 1.75)	1.78 (1.39, 2.28)	1.57 (1.32, 1.86)	1.51 (1.23, 1.86)	1.71 (1.24, 2.36)
Bathroom vs bedroom surface	5.17 (4.01, 6.67)	2.03 (1.58, 2.60)	3.23 (2.70, 3.85)	3.96 (3.20, 4.89)	1.97 (1.42, 2.74)
RME vs bedroom surface	1.99 (1.27, 3.13)	0.99 (0.60, 1.63)	1.40 (2.70, 3.85)	1.59 (1.07, 2.35)	1.063 (0.56, 2.01)
Multi-bed (semi-private) vs single-bed room (private)	2.57 (1.02, 6.49)	0.68 (0.43, 1.07)	0.71 (0.53, 0.97)	0.73 (0.49, 1.07)	0.26 (0.07, 0.93)
AC vs LTC	_	_	0.56 (0.42, 0.75)	0.52 (0.35, 0.78)	0.63 (0.30, 1.32)
Cleaning wipe utilization (≥ 2 vs ≤ 1)	2.00 (0.77, 5.16)	0.91 (0.66, 1.24)	0.68 (0.52, 0.88)	0.63 (0.44, 0.92)	0.88 (0.49, 1.57)
Surface wetness (saturated vs wet/damp)	4.71 (1.86, 11.96)	0.77 (0.50, 1.18)	1.07 (0.78, 1.47)	1.07 (0.71, 1.62)	0.95 (0.51, 1.77)
Surface wetness (dry vs wet/damp)	0.51 (0.23, 1.17)	NA	0.91 (0.46, 1.80)	0.91 (0.45, 1.85)	NA

Rooms absent of patients during cleaning were associated with improved environmental cleaning rates. Also, fewer differences were seen between private and semiprivate patient rooms when no patients were present during the cleaning of the room. A recent observational study found HTSs in close proximity to the patient are more likely missed than other environmental surfaces[47] and previous qualitative studies have reported EMS staff may avoid cleaning near patients so as not to disturb them.[48]

Lower cleaning compliance in semiprivate rooms

Our study found cleaning rates were significantly lower in semiprivate patient rooms; semiprivate rooms were observed in both AC and LTC units. A recent meta-analysis found significant benefit of single patient bedrooms for reducing HAIs and colonization.[49] Stiller et al. and others[50] note that single patient rooms are easier to clean after discharge in comparison to larger and more heavily equipped (and occupied) multipatient bedrooms.

Identification of patient presence as a barrier to environmental cleaning adds to our current knowledge of barriers to successful environmental cleaning which may not have been fully characterized previously. Cleaning bundles have been recommended [29,51-53] but do not address specific cleaning practices, especially how to overcome barriers to task completion.

Environmental cleaning monitoring

Our study found that FGM and direct observations were frequently cited as methods of monitoring (ie, audit and feedback) environmental cleaning albeit using various methodologies and consistency. Audit and feedback of healthcare practices is evidence-based and used commonly to improve care[54] and monitoring of environmental cleaning has become a cornerstone of environmental cleaning programs. In addition, environmental cleaning monitoring is recommended in professional[25] and regulatory[55] guidelines. Monitoring of environmental cleaning can be done via microbial, nonmicrobial and visual observation.[25] Direct visual monitoring of cleaning practices can be achieved by assessing the amount of surface soiling that remains after a surface is cleaned or by a standardized evaluation of the cleaning process.[56] The accuracy of direct visual observation has been questioned[28] but most healthcare organizations, both national and international, perform monitoring using direct observation.[56,57] Direct observation provides an opportunity for assessing cleaning process as opposed to being limited to surface 'cleanliness'[58] as well as the cost effectiveness benefits of visual inspection make it a preferred method for many healthcare facilities.[28,59]

Our study provides an estimate for the number of observations, 20 rooms with 10% error, needed for accurately predicting cleaning rates of 60.2% for 'HTS'. Other recommendations have similar estimates; approximately 10-15 rooms with 20% error for

Table 4
Summary statistics of actual observed cleaning rates, sampling error, and percentage of rooms with sampling error ≤10% and 5% using surface observations

	Actual cleaning rates	Sample error		% with sampling error	% with sampling error
	Mean (SD)	Mean	SD	≤10%	≤5%
Number of rooms needed to be observed to meet or exceed the mean cleaning rate threshold					
All Surfaces (N = 2783)					
20 rooms		0.0153	0.0116	92	62.8
25 rooms	0.337	0.0128	0.0096	96.6	71.1
30 rooms	(0.126)	0.0099	0.0078	98.9	82.4
35 rooms		0.0086	0.0066	99.8	88.3
40 rooms		0.0062	0.0047	100	97.3
45 rooms		0.0042	0.0032	100	100
HTS (N = 1029)					
20 rooms		0.0224	0.0175	84.7	54.4
25 rooms	0.602	0.0208	0.0151	88.7	54.8
30 rooms	(0.163)	0.0162	0.012	95.1	67.6
35 rooms		0.0147	0.0104	97.9	71.1
40 rooms		0.0123	0.0088	99.8	79.6
45 rooms		0.0104	0.0064	100	91.8

All Surfaces and High-touch Surfaces (HTS).

Table 5
Data integration visual joint display – cleaning observations (N=62) and healthcare worker interviews (N = 18)

Observation variable (Quantitative)	Findings	Interview themes (Qualitative)	Quotes
- HTS - Bathroom Surfaces - RME Surfaces	Higher Cleaning Rates	HTS, RME and especially bathrooms are targeted and prioritized during daily cleaning.	"The patients are always very glad to see me mopping the floors on a regular basis, cleaning the sinks, cleaning the high-touch areas (. . .)" EMS staff, Facility A "We strictly do the low level, which would be the blood pressure cuff, beds, anything that would need to be touched (. . .)" Nurse Manager, Facility A "But day shift, their primary task is doing their daily cleanings. And they go through, they're supposed to hit the bathroom, high-touch areas." EMS staff, Facility A "But all your high-touch is, you know, like your bathrooms, you know, sinks, knobs, toilet, flush handle, stuff, the handrails that's in the bathrooms (. . .) it's all that different stuff is considered a high-touch where the patients are constantly touching 'em." EMS manager, Facility C
- Patient not in room	Higher Cleaning Rates	Daily cleaning is easier when the patient is absent from the room.	"If he's [patient] sitting in the chair next to the bed, it gives us [EMS staff] an opportunity to do handrails and stuff like that." EMS manager, Facility B "If they [patient] got the blankets all hanging down, you really can't pull their blankets up and get to the side rails. You know, the beds are REALLY gone through as when the patient's gone." EMS manager, Facility C
- Patient in room	Lower Cleaning Rates	Daily cleaning is harder when the patient is present in the room.	". . .that's [an] example [HTS], remote controls, although we don't really take that out of the patient's hand to clean that." EMS staff, Facility B "The over-the-bed table, that normally doesn't get done 'cause it's piled high with patient belongings (. . .)" EMS manager, Facility B "But, as far as the patient bed, you know, it's, while they're in it, it's kinda hard. You know?" EMS manager, Facility C
- Semi-private patient rooms	Lower Cleaning Rates	Daily cleaning is harder in semi-private rooms.	"Shared bathrooms are just, I mean, I think that can be very problematic, even cleaning when. . . it's a two-person room. Trying to get in there and (. . .) there's a person in the bed and there might be a curtain, trying to take care of that and take care of the bathroom while there's still a patient (. . .)" EMS staff, Facility A

less than 80% cleaning rate.[25,56] Estimates using sampling error have been suggested for optimal environmental cleaning monitoring via FGM systems.[60,61]

Standardized guidance needs to be developed and evaluated for environmental cleaning of patient rooms in several different contexts (eg, AC or LTC, patient presence or absence, and private or semiprivate rooms) to improve environmental cleaning practices and patient outcomes. Our qualitative findings uncovered contextual barriers to cleaning patient rooms that needs to be evaluated as a potential entry point for intervention to improve cleaning practices.

STUDY STRENGTHS/LIMITATIONS

A convergent mixed method design allowed us to analyze qualitative and quantitative data separately; thus, providing a deeper understanding of the individual data sets prior to consolidating the data. The analysis was based on VA data and may not be generalizable to other populations, however the methods are reproducible and can be evaluated in non-VA settings. The study design was focused on cleaning rates via direct observation, and therefore we did not assess other outcomes such as actual surface contamination or HAI outcomes. We also note the number of room cleaning observations was low, but the numbers of surfaces observed allowed us to generate additional analysis. Some of the information from observations are not reported due to missing data though these account for a low proportion of the data collected; all but one of the variables (ie, cloth material) were collected at a rate greater than 80%.

CONCLUSION/FUTURE RESEARCH

Overall, observed daily cleaning rates of environmental surfaces in both AC and LTC settings within the VA was low. Analysis identified semiprivate patient rooms and surfaces (ie, HTS, RME) within the patient room (ie, proximity to patient or patient bed) as barriers to cleaning. Cleaning rates improved when the patient was not present during cleaning of the room. Future research should evaluate interventions that standardized cleaning procedures by setting (AC, LTC), room type (private, semiprivate), and/or presence or absence of patient. Additional research is needed to evaluate whether estimates for direct observation audit frequency (number of rooms observed) presented here are feasible and can optimize monitoring of cleaning processes. Development of standardized contextual environmental cleaning practices and cleaning monitoring can help to improve cleaning compliance and thus reduce the transmission of HAIs.

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SUPPLEMENTARY MATERIALS

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References

1. Klevens RM, Edwards JR, Richards Jr. CL, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. *Public Health Rep*. 2007;122:160–166.
2. Hota B. Contamination, disinfection, and cross-colonization: are hospital surfaces reservoirs for nosocomial infection? *Clin Infect Dis*. 2004;39:1182–1189.
3. Boyce JM. Environmental contamination makes an important contribution to hospital infection. *J Hosp Infect*. 2007;65(suppl 2):50–54.
4. Dancer SJ. Importance of the environment in meticillin-resistant Staphylococcus aureus acquisition: the case for hospital cleaning. *Lancet Infect Dis*. 2008;8:101–113.
5. Otter JA, Yezli S, French GL. The role played by contaminated surfaces in the transmission of nosocomial pathogens. *Infect Control Hosp Epidemiol*. 2011;32:687–699.
6. Weber DJ, Anderson DJ, Sexton DJ, Rutala WA. Role of the environment in the transmission of Clostridium difficile in health care facilities. *Am J Infect Control*. 2013;41(suppl 5):S105–S110.
7. Anwar S. *Multi-Drug Resistant Organisms within Biofilms on Dry Hospital Surfaces: Is this Worldwide?* San Diego, CA: presented at: The Society for Healthcare Epidemiology of America; 2017.
8. Mitchell BG, Dancer SJ, Anderson M, Dehn E. Risk of organism acquisition from prior room occupants: a systematic review and meta-analysis. *J Hosp Infect*. 2015;91:211–217.
9. Donskey CJ. Does improving surface cleaning and disinfection reduce health care-associated infections? *Am J Infect Control*. 2013;41(suppl 5):S12–S19.
10. Leas BF, Sullivan N, Han JH, Pegues DA, Kaczmarek JL, Umscheid CA. AHRQ comparative effectiveness technical briefs. *Environmental Cleaning for the Prevention of Healthcare-Associated Infections*. Agency for Healthcare Research and Quality (US); 2015.
11. Mitchell BG, Farrington A, Allen M, et al. Variation in hospital cleaning practice and process in Australian hospitals: a structured mapping exercise. *Infect Dis Health*. 2017;22:195–202. 2017/12/01/.
12. Dancer SJ. Controlling hospital-acquired infection: focus on the role of the environment and new technologies for decontamination. *Clin Microbiol Rev*. 2014;27:665–690.
13. Sitzlar B, Deshpande A, Fertelli D, Kundrapu S, Sethi AK, Donskey CJ. An environmental disinfection odyssey: evaluation of sequential interventions to improve disinfection of Clostridium difficile isolation rooms. *Infect Control Hosp Epidemiol*. 2013;34:459–465.
14. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med*. 2006;355:2725–2732.
15. Dubberke ER, Carling P, Carrico R, et al. Strategies to prevent Clostridium difficile infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol*. Sep 2014;35(suppl 2):S48–S65.
16. Doll M, Marra AR, Apisarnthanarak A, Al-Maani AS, Abbas S, Rosenthal VD. Prevention of Clostridioides difficile in hospitals: a position paper of the International Society for Infectious Diseases. *Int J Infect Dis*. 2021;102:188–195.
17. Jain R, Kralovic SM, Evans ME, et al. Veterans Affairs initiative to prevent methicillin-resistant Staphylococcus aureus infections. *N Engl J Med*. 2011;364:1419–1430.
18. Evans ME, Kralovic SM, Simbartl LA, et al. Veterans Affairs methicillin-resistant Staphylococcus aureus prevention initiative associated with a sustained reduction in transmissions and health care-associated infections. *Am J Infect Control*. 2013;41:1093–1095.
19. Evans ME, Simbartl LA, Kralovic SM, Jain R, Roselle GA. Clostridium difficile infections in Veterans Health Administration acute care facilities. *Infect Control Hosp Epidemiol*. 2014;35:1037–1042.
20. Evans ME, Kralovic SM, Simbartl LA, Jain R, Roselle GA. Effect of a Clostridium difficile infection prevention initiative in veterans affairs acute care facilities. *Infect Control Hosp Epidemiol*. 2016;37:720–722.
21. The Environmental Management Services. *Sanitation Procedure Guide*. 2016.
22. Vaughn VM, Saint S, Greene MT, et al. Trends in health care-associated infection prevention practices in us veterans affairs hospitals from 2005 to 2017. *JAMA Netw Open*. 2020;3:e1920464.
23. Keating JA, Obasi C, McKinley L, et al. Building implementation science for veterans affairs healthcare associated infection prevention: VA Healthcare-Associated Infection Prevention Network (VHIN). *Infection Control & Hospital Epidemiology*. 2018;39:1–5.
24. Yanke E, Moriarty H, Carayon P, Safdar N. A qualitative, interprofessional analysis of barriers to and facilitators of implementation of the Department of Veterans Affairs' Clostridium difficile prevention bundle using a human factors engineering approach. *Am J Infect Control*. 2018;46:276–284.
25. Guh A, Carling P. Options for Evaluating Environmental Cleaning. Centers for Disease Control and Prevention. 2010. Accessed June 22, 2022. https://www.cdc.gov/hai/toolkits/evaluating-environmental-cleaning.html.
26. Sehulster L, Chinn RY. Guidelines for environmental infection control in health-care facilities. Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). *MMWR Recomm Rep*. 2003;52(Rr-10):1–42.
27. Siegel JD, Rhinehart E, Jackson M, Chiarello L. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in health care settings. *Am J Infect Control*. 2007;35(10 Suppl 2):S65–164.
28. Doll M, Stevens M, Bearman G. Environmental cleaning and disinfection of patient areas. *Int J Infect Dis*. 2018;67:52–57.
29. Rutala WA, Weber DJ. Best practices for disinfection of noncritical environmental surfaces and equipment in health care facilities: a bundle approach. *Am J Infect Control*. 2019;47s:A96–a105.
30. Atsma F, Elwyn G, Westert G. Understanding unwarranted variation in clinical practice: a focus on network effects, reflective medicine and learning health systems. *Int J Qual Health Care*. 2020;32:271–274.
31. JW C, AC K, VL C, KC S. *Best practices for mixed methods research in health sciences*. Office of Behavioral and Social Sciences: National Institute of Health; 2011.
32. CDC Environmental Checklist for Monitoring Terminal Cleaning. Centers for Disease Control. 2010. Accessed June 22, 2022. https://www.cdc.gov/hai/pdfs/toolkits/environmental-cleaning-checklist-10-6-2010.
33. Marshall B, Cardon P, Poddar A, Fontenot R. Does sample size matter in qualitative research?: A review of qualitative interviews in is research. Article. *J Comput Informat Systems*. 2013;54:11–22.
34. Bengtsson M. How to plan and perform a qualitative study using content analysis. *NursingPlus Open*. 2016;2:8–14. 2016/01/01/.
35. Ryan GW, Bernard HR. Techniques to identify themes. *Field Methods*. 2003;15:85–109. 2003/02/01.
36. Pope C, Ziebland S, Mays N. Qualitative research in health care. Analysing qualitative data. *BMJ*. 2000;320:114–116.
37. Elo S, Kääriäinen M, Kanste O, Pölkki T, Utriainen K, Kyngäs H. Qualitative content analysis: a focus on trustworthiness. *SAGE Open*. 2014;4: 2158244014522633. 2014/01/01.
38. Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs-principles and practices. *Health Serv Res*. 2013;48(6 Pt 2):2134–2156.
39. Guetterman TC, Fetters MD, Creswell JW. Integrating quantitative and qualitative results in health science mixed methods research through joint displays. *Ann Fam Med*. 2015;13:554–561.
40. Carling PC, Bartley JM. Evaluating hygienic cleaning in health care settings: what you do not know can harm your patients. *Am J Infect Control*. 2010;38(5 suppl 1): S41–S50.
41. Huslage K, Rutala WA, Sickbert-Bennett E, Weber DJ. A quantitative approach to defining "high-touch" surfaces in hospitals. *Infect Control Hosp Epidemiol*. 2010;31:850–853.
42. Han JH, Sullivan N, Leas BF, Pegues DA, Kaczmarek JL, Umscheid CA. Cleaning hospital room surfaces to prevent health care-associated infections: a technical brief. *Ann Intern Med*. 2015;163:598–607.
43. Schoyer E, Hall K. Environmental cleaning and decontamination to prevent Clostridioides difficile infection in health care settings: a systematic review. *J Patient safety*. 2020;16(3S suppl 1):S12–S15.
44. Yanke E, Moriarty H, Carayon P, Safdar N. The invisible staff": a qualitative analysis of environmental service workers' perceptions of the VA Clostridium difficile prevention bundle using a human factors engineering approach. *J Patient Saf*. 2021;17:e806–e814.
45. Van Tiem JM, Friberg JE, Cunningham Goedken C, et al. Environmental service workers as potential designers of infection control policy in long-term care settings. *Am J Infect Control*. 2020;48:398–402.
46. Cullen D, Thomas Y. EOC-113 - The Impact of Clutter on Healthcare Acquired Infections in a Long-Term Acute Care Hospital. *Am J Infect Control*. 2018;46(suppl 6): S71.. 2018/06/01/.
47. Xie A, Rock C, Hsu YJ, et al. Improving daily patient room cleaning: an observational study using a human factors and systems engineering approach. *IISE Trans Occup Ergon Hum Factors*. 2018;6:178–191.
48. Bernstein DA, Salsgiver E, Simon MS, et al. Understanding barriers to optimal cleaning and disinfection in hospitals: a knowledge, attitudes, and practices survey of environmental services workers. *Infect Control Hosp Epidemiol*. Dec 2016;37:1492–1495.
49. Stiller A, Salm F, Bischoff P, Gastmeier P. Relationship between hospital ward design and healthcare-associated infection rates: a systematic review and meta-analysis. *Antimicrob Resist Infect Control*. 2016;5:51.
50. CDC A, APIC, ASHE. Using the health care physical environment to prevent and control infection: A Best Practice Guide to Help Healthcare Organizations Create Safe, Healing Environment. 2015.
51. Havill NL. Best practices in disinfection of noncritical surfaces in the health care setting: creating a bundle for success. *Am J Infect Control*. 2013;41(suppl 5):S26–S30.
52. Allen M, Hall L, Halton K, Graves N. Improving hospital environmental hygiene with the use of a targeted multi-modal bundle strategy. *Infection Dis Health*. 2018;23:107–113.

53. Mitchell BG, Hall L, White N, et al. An environmental cleaning bundle and healthcare-associated infections in hospitals (REACH): a multicentre, randomised trial. *Lancet Infect Dis*. 2019;19:410–418.
54. Ivers N, Jamtvedt G, Flottorp S, et al. Audit and feedback: effects on professional practice and healthcare outcomes. *Cochrane Database Syst Rev*. 2012 CD000259.
55. Centers for Medicare & Medicaid Service. 42 CFR 482.42 Condition of participation: Infection Prevention and Antibiotic Stewardship Programs. 2016.
56. Carling PC, Bartley JM. Evaluating hygienic cleaning in health care settings: what you do not know can harm your patients. *Am J Infect Control*. 2010;38:S41–S50.
57. Kenters N, Gottlieb T, Hopman J, et al. An international survey of cleaning and disinfection practices in the healthcare environment. *J Hosp Infect*. 2018;100:236–241.
58. Carling P. Methods for assessing the adequacy of practice and improving room disinfection. *Am J Infect Control*. 2013;41(suppl 5):S20–S25.
59. Snyder GM, Holyoak AD, Leary KE, Sullivan BF, Davis RB, Wright SB. Effectiveness of visual inspection compared with non-microbiologic methods to determine the thoroughness of post-discharge cleaning. *Antimicrob Resist Infect Control*. 2013;2:26.
60. Rock C, Xie A, Andonian J, et al. Evaluation of environmental cleaning of patient rooms: impact of different fluorescent gel markers. *Infect Control Hosp Epidemiol*. 2019;40:100–102.
61. Rock C, Small BA, Hsu YJ, et al. Evaluating accuracy of sampling strategies for fluorescent gel monitoring of patient room cleaning. *Infect Control Hosp Epidemiol*. 2019;40:794–797.