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Improving daily patient room cleaning: an observational study using a human factors and systems engineering approach

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Abstract

Background: While playing a critical role in preventing healthcare-associated infections, patient room cleaning is often unsatisfactorily performed. To improve patient room cleaning, a human factors and systems engineering (HFSE) approach is needed to understand the complex cleaning process and associated work system factors.

Purpose: We conducted an observational study to assess the performance of environmental care (EVC) associates during daily patient room cleaning and identify work system factors influencing their performance.

Methods: This study was conducted in eight adult medicine inpatient units at a large urban academic medical center. An HFSE researcher shadowed 10 day-shift EVC associates performing

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daily patient room cleanings and used a semi-structured observation form to collect quantitative data (e.g., duration of room cleaning, orders for surface cleaning) and qualitative data (e.g., challenges to patient room cleaning). Descriptive statistics (e.g., median, interquartile range) were reported for cleaning performance, and bivariate and regression analyses were conducted to identify factors influencing cleaning performance. We also performed link analyses of the workflow of EVC associates and qualitative analyses of observer notes to identify challenges to daily patient room cleaning.

Results: We observed 89 patient room cleanings. Median duration of cleaning a room was 14 minutes, and median percentage of surfaces cleaned in a room was 63%. High-touch surfaces that were frequently missed during daily cleaning included the bedrails, telephone, patient and visitor chairs, and cabinet. Work system factors that could influence cleaning performance included the type of unit, the presence of the patient and family members in the room, cleaning patterns and orders of EVC associates, and interruptions EVC associates encountered while cleaning.

Conclusions: Daily patient room cleaning was influenced by a number of work system factors. To improve daily patient room cleaning, multifaceted interventions are needed to address these system-level factors.

Keywords

Infection control; healthcare environmental hygiene; daily patient room cleaning; human factors engineering; systems approach; observations

INTRODUCTION

The critical role of effective patient room cleaning in preventing healthcare-acquired pathogens has been increasingly recognized (Carling, 2016). Patients admitted to a room where the previous occupant was colonized or infected with a multidrug-resistant organism had been shown to have a higher risk of acquiring the same multidrug-resistant organism (Drees et al., 2008). To reduce the risk of pathogen transmission, environmental surfaces in patient rooms, especially surfaces with frequent hand-contact (high-touch surfaces), are required to be routinely cleaned on a daily basis (daily cleaning) and promptly cleaned upon patient discharge (discharge cleaning). In practice, however, high-touch surfaces are not consistently cleaned during daily cleaning (Boyce et al., 2009) or discharge cleaning (Carling, Briggs, Hylander, & Perkins, 2006; Jefferson, Whelan, Dick, & Carling, 2011). The suboptimal cleaning of high-touch surfaces is commonly attributed to the environmental care (EVC) associate's insufficient knowledge or skills, or inappropriate attitude. Therefore, efforts to improve patient room cleaning have focused on monitoring the performance of EVC associates and providing them feedback and training (Mitchell, Wilson, Dancer, & McGregor, 2013; Weiss et al., 2015). While these efforts helped (Carling, Parry, Bruno-Murtha, & Dick, 2010; Munoz-Price et al., 2011), researchers have highlighted the complex process of cleaning the patient room and appreciated that effective and sustainable interventions to improve patient room cleaning should take into account the broader work system in which EVC associates must perform their work and involve different stakeholders in work system and process redesign (Lindberg & Schneider, 2013; Rock et al., 2016).

Human factors and systems engineering (HFSE), which emphasizes the use of a systems approach to guide healthcare system redesign to improve both system performance and human well-being, has been effectively used to improve the quality and safety of care (Xie & Carayon, 2015). Rock et al. (2016) proposed the use of a HFSE approach to improve patient room cleaning. A cornerstone of this approach is to understand complex processes, in this case the room cleaning process, and associated work system factors, including people involved in or affected by the cleaning (e.g., EVC associates, patients and families, healthcare providers), tools and technologies used (e.g., cleaning tools and supplies, documentation system), tasks performed (e.g., preparing carts, cleaning high-touch surfaces), and physical (e.g., size and layout of the patient room, design of the patient bed and other environmental surfaces) and organizational (e.g., unit culture, work schedule, incentive structure) environments in which EVC associates work (Holden et al., 2013). However, little empirical research has systematically examined the process and work system of patient room cleaning. Boyce, Havill, Lipka, Havill, and Rizvani (2010) observed EVC associates performing daily patient room cleaning and identified substantial variations in practices (e.g., time spent on each surface, use of wipes) among EVC associates. However, they did not investigate the underlying factors resulting in those variations, but rather, suggested continuing education and feedback to EVC associates to standardize cleaning practices.

As part of a large multifaceted project, we convened a transdisciplinary team (including human factors engineers, environmental care associates, hospital facilities management, hospital epidemiologists and physicians, and infection preventionists) to improve patient room cleaning (Xie et al., 2017). We applied an HFSE approach and conducted an observational study to understand the room cleaning process and associated work system. Specifically, we observed EVC associates during daily patient room cleanings and identified work system factors that may influence their performance. This paper presents the findings of the observational study and discusses the implications for system improvement.

METHODS

Setting and Participants

This study was conducted at a 1,059-bed tertiary care medical center in Baltimore, Maryland. Eight adult medicine inpatient units (6 general medicine/infectious diseases units, 1 physical medicine and rehabilitation unit, 1 colorectal specialty unit) participated in this study. Units had between 15 and 24 single-occupancy patient rooms, all with a similar physical layout. Typical room setup included (but was not limited to): a patient bed, over-bed table, side table, family and visitor chairs, bathroom, and in-room sink.

Daily patient room cleaning was primarily performed during the day shift (7:00 AM to 3:00 PM). We recruited a convenience sample of 10 day-shift EVC associates by attending their morning huddles and using posters and handouts. Table 1 shows the demographic characteristics of the associates. The Johns Hopkins Medicine Institutional Review Board approved this study.

Procedures

Observations were conducted between April and December 2016. To avoid observer fatigue, we kept each observation period under four hours. A researcher with HFSE expertise scheduled two days of observations with each EVC associate who agreed to participate. On the first day, the researcher met the EVC associate before his/her shift, explained the study, obtained written informed consent, and collected demographic information (e.g., gender, age, years of experience as an EVC associate). The researcher then shadowed the EVC associate for the first half of their shift (until lunch break), and returned on a subsequent day to shadow the same EVC associate during the second half of their shift (after lunch). During shadowing, the researcher followed the EVC associate into each patient room (daily or discharge cleaning) and observed their activities without interrupting the natural movement and workflow. When an appropriate opportunity arose, such as finishing a room and moving to the next room, the researcher asked the EVC associate questions for clarification, or to elucidate any specific challenges encountered during the room cleaning process. When family members were present or the patient was awake and alert during an observation, the EVC associate was asked to give them a brief explanation of the study. If the patient or family did not feel comfortable with the proposed process, the researcher would not observe. Observations were done on different days of the week to ensure capturing of any variation in room cleaning process by week day.

Data Collection

The unit of observation was the process of cleaning a single patient room and was defined as the time from when the EVC associate first entered the room to clean to when they had finished cleaning and exited the room. To facilitate data collection, we developed and pilot tested a semi-structured observation form, which integrated surfaces to be cleaned in a patient room with the physical layout of the room (supplementary Appendix A, available online). The bedrail was divided into five surfaces to account for two separate rails on each side of the bed and one at the foot. We followed the guidelines provided by the hospital's Department of Hospital Epidemiology and Infection Control and defined 28 high-touch surfaces (20 in the main room that included the 5 bedrail surfaces, 8 in the bathroom) and 34 non-high-touch surfaces (17 in the main room, 17 in the bathroom) (Table 2).

For each cleaning process, the researcher used the observation form to collect quantitative (structured) data on (1) observation date and unit type (general medicine and infectious diseases, physical medicine and rehabilitation, colorectal specialty), (2) sequence number of the room cleaned by the EVC associate for that day, (3) isolation status of the room, (4) presence of the patient and family members, (5) start and end time of room cleaning (duration reported in minutes), and (6) order of cleaning each surface. A surface was considered cleaned if the EVC associate purposively wiped it using a cleaning tool (e.g., disinfectant wipes, microfiber cloths). Through observations or queries to EVC associates, the researcher also collected qualitative (non-structured) data on the challenges of patient room cleaning in general (e.g., interruptions) and of cleaning certain surfaces (e.g., surfaces used by patients and families, surfaces in contact with medical devices).

Data Analysis

Data analysis only included observation data on daily patient room cleaning. Rooms might vary in number of surfaces. Therefore, a measure of cleaning performance was the percentage of surfaces cleaned in a room (number of surfaces cleaned / total number of surfaces). We respectively assessed the percentage of surfaces cleaned in the entire room, in the main room, and in the bathroom and stratified cleaned surfaces by high-touch and non-high-touch. We also examined the duration of room cleaning, which was not shown to be associated with the thoroughness of cleaning (Rupp et al., 2013). Medians and interquartile ranges were reported to describe these performance measures. In addition, we examined the cleaning of each high-touch surface and calculated the percentage of the rooms where each high-touch surface was cleaned.

Potential work system factors influencing cleaning performance included unit on which the observation was conducted, isolation status of the room, presence of the patient and family members, tools used to clean the room, time period of the shift, main room cleaning patterns, bathroom cleaning orders, and interruptions encountered during cleaning. We reported frequencies and percentages to describe these factors. To identify main room cleaning pattern and order of bathroom cleaning, we conducted link analyses of the cleaning workflow (Stanton, Young, & Harvey, 2014). The analyses involved three researchers who independently examined the movements of the EVC associate in each observation based on the recorded order of surface cleaning, coded the workflow pattern for each observation, and then convened to discuss and reach consensus. Qualitative data were coded to identify interruptions and other challenges encountered by EVC associates during room cleaning.

To identify work system factors that were associated with cleaning performance, we first conducted bivariate analyses using Wilcoxon rank sum tests and Kruskal–Wallis one-way analysis of variance. We then constructed generalized linear models (GLM) with a logit link and the binomial family to assess independent associations while holding other covariates constant. We also used robust standard errors clustered by EVC associate to account for correlation of the error terms across observations with the same EVC associate. Statistical significance had an alpha level of 0.05.

RESULTS

Characteristics of Observations

Table 3 shows the descriptive characteristics of the observations. The 89 observations were conducted on 3 types of units: 71 (80%) on the general medicine/infectious diseases units, 10 (11%) on the physical medicine and rehabilitation unit, and 8 (9%) on the colorectal specialty unit. Of the 89 rooms, 35 (39%) were under isolation precautions and 67 (75%) were cleaned with the presence of patients and/or family members. During the study period, a new cleaning tool (i.e., microfiber cloths) was implemented in the participating units to replace disinfectant wipes. While 69 rooms (78%) were cleaned using disinfectant wipes, 20 (22%) were cleaned using microfiber cloths. EVC associates were observed using disinfectant wipes and microfiber cloths in different ways. When disinfectant wipes were used, some EVC associates returned to the cart every time they needed a new disinfectant

wipe, while others kept a few wipes in hand and used one at a time. There were also EVC associates who brought the wipe container into the room to avoid returning to the cart for new wipes. When microfiber cloths were used, some EVC associates folded the microfiber cloths to increase the number of sides for use and reduce the number of times they returned to the cart to recharge the microfiber cloths, while others simply used the microfiber cloths without folding.

On average, EVC associates cleaned 7 rooms (range=[5, 9]) during the first half of the shift and 4 rooms (range=[1, 7]) during the second half of the shift. They followed four major patterns when cleaning the main room: (1) clockwise or counter-clockwise, (2) horizontal or vertical, (3) random, and (4) local (Table 4). Of the 89 rooms, 28 (31%) were cleaned with a clockwise or counter-clockwise pattern, 37 (42%) with a horizontal or vertical pattern, 15 (17%) with a random pattern, and 9 (10%) with a local pattern. Of the 89 rooms, 86 (97%) bathrooms were cleaned; of the 86 bathrooms, 12 (14%) were cleaned first, 10 (11%) in the middle, and 64 (72%) last in the cleaning order.

Differences in patterns of main room cleaning and order of bathroom cleaning were observed both within and across EVC associates (Table 5). One EVC associate used one pattern (horizontal or vertical) to clean all his/her main rooms, while 8 EVC associates used at least three patterns. The clockwise or counter-clockwise pattern and the horizontal or vertical pattern were respectively used by 2 and 3 EVC associates as their primary pattern for main room cleaning (used to cleaned more than 60% of the rooms). There were also 5 EVC associates who did not have a primary pattern for main room cleaning. Similar results were observed for order of cleaning the bathroom. Four EVC associates cleaned all their rooms with the bathroom cleaned last. Five EVC associates cleaned the bathroom following two orders (first and last or middle and last). These 9 EVC associates had their primary order for bathroom cleaning (used to cleaned more than 60% of the rooms). There was one EVC associate who cleaned the bathroom following all three orders and did not have a primary order for bathroom cleaning.

EVC associates were observed encountering at least one interruption in 56% (50/89) of the room cleanings (Table 3). These interruptions were categorized into 5 groups: (1) interruptions by patients and family members (12/89), (2) interruptions by EVC supervisors or other EVC associates (13/89), (3) interruptions by other healthcare workers (e.g., nurses) (34/89), (4) interruptions due to lack of cleaning tools and supplies (9/89), and (5) interruptions due to other environmental situations (e.g., pager, noise) (9/89).

Cleaning Performance

Table 6 summarizes the data on cleaning performance. EVC associates spent a median of 14 minutes (interquartile range (IQR)=[12, 19]) cleaning a room. A median 63% (IQR=[54%, 72%]) of total surfaces were cleaned in a room, 59% (IQR=[50%, 73%]) in the main room, and 65% (IQR=[52%, 78%]) in the bathroom. The median percentages of high-touch surfaces cleaned in the main room and the bathroom were 68% (IQR=[50%, 82%]) and 75% (IQR=[63%, 88%]), respectively. Figure 1 illustrates the patient room layout and the percentage of observed rooms where each high-touch surface was cleaned. While 8 high-touch surfaces (6 in the main room, 2 in the bathroom) were cleaned more than 80% of the

time, 9 high-touch surfaces (all in the main room) were cleaned less than 60% of the time. Bedrails, particularly bedrails 2 and 4, were the most frequently missed surfaces. Please see supplemental Appendix B (available online) for the bivariate analyses between characteristics of room cleaning and cleaning performance.

Work System Factors Influencing Cleaning Performance

Table 7 shows the results of regression analyses.

Units.—Compared to the general medicine and infectious diseases units, the physical medicine and rehabilitation unit had significantly higher percentages of all surfaces cleaned (OR=1.43; p=0.012) and of surfaces cleaned in the main room (total surfaces: OR=2.00, p<0.001; high-touch surfaces: OR=2.22, p<0.001; non-high-touch surfaces: OR=1.92, p<0.001); the colorectal specialty unit had significantly lower percentages of all surfaces cleaned (OR=0.52, p=0.005), of surfaces cleaned in the main room (total surfaces: OR=0.46, p<0.013; non-high-touch surfaces: OR=0.23, p=0.004), and of surfaces cleaned in the bathroom (total surfaces: OR=0.65, p=0.036; non-high-touch surfaces: OR=0.42, p<0.001). Unit type did not impact the duration of room cleaning.

Presence of patient and family members.—The odds of all surfaces being cleaned when patients and family members were in the room was significantly lower compared to when they were not in the room (OR = 0.62; 95% CI, 0.49–0.79; p<0.001). Moreover, the odds of surface cleaning remained significantly lower when compared by room areas (main room and bathroom) and by high touch and non-high touch surfaces. Consistently, Figure 1 shows that high-touch surfaces in the upper part of the room (where the patient and family members usually stay) were more likely to be missed as compared to high-touch surfaces in the lower part of the room (close to the door). A frequently observed challenge to cleaning those surfaces was that they were used by the patient and family members (e.g., patient in the bed) or occupied by patient belongings (e.g., food on over-bed table). The presence of patient and family members in the room did not impact the duration of room cleaning.

Main room cleaning patterns.—The local room cleaning pattern was associated with fewer surfaces cleaned (all surfaces: OR=0.64; p=0.024; total surfaces in main room: OR=0.50; p=0.008; high-touch surfaces in main room: OR=0.43; p=0.008). Differences in performance from other patterns (i.e., clockwise or counter-clockwise, horizontal or vertical, random) were not observed.

Bathroom cleaning orders.—When the bathroom was cleaned first, the percentages of surfaces cleaned in the main room (total surfaces: OR=1.85, p=0.015; high-touch surfaces: OR=1.66, p=0.043) were significantly higher compared to when the bathroom was cleaned last. In addition, not cleaning the bathroom was associated with no surfaces cleaned in the bathroom, lower percentage of all surfaces cleaned (OR=0.37, p<0.001), and shortened duration of room cleaning (coef.=−4.87, p=0.003).

Interruptions.—Overall, interruptions during room cleaning significantly prolonged the duration of cleaning (coef.=3.25, p=0.032). By type of interruption, lack of cleaning tools

and supplies (coef.=4.36, p=0.012) and interruptions by EVC supervisors or other EVC associates (coef.=6.70, p=0.004) were associated with prolonged duration of room cleaning. In addition, interruptions by EVC supervisors or other EVC associates also significantly increased percentage of all surfaces cleaned (OR=1.52, p=0.015) and percentages of surfaces cleaned in the bathroom (total surfaces: OR=2.47, p<0.001; high-touch surfaces: OR=2.17, p=0.027; non-high-touch surfaces: OR=2.82, p=0.003).

DISCUSSION

In this study, we applied a HFSE approach and conducted observations of EVC associates performing daily patient room cleaning. Consistent with previous studies documenting suboptimal cleaning of high-touch surfaces during both daily cleaning (Boyce et al., 2009) and discharge cleaning (Carling et al., 2006; Carling, Von Beheren, Kim, Woods, & Healthcare Environmental Hygiene Study, 2008), our results showed that bedrails, the telephone, and patient and family chairs, all high-touch surfaces, were frequently missed during daily room cleaning. Moreover, this poorer performance by EVC associates could have been influenced by a number of work system factors, including the type of unit, the presence of the patient and family members in the room, cleaning patterns and orders of EVC associates, and interruptions EVC associates encountered while cleaning. Findings of this study will inform future efforts to redesign the cleaning process and associated work system and, therefore, optimize both the performance and well-being of EVC associates. Table 8 summarizes the main findings of this study and implications for system improvement.

First, we found significant differences in cleaning performance across the different types of units, which could result from various unit-level factors (e.g., acuity of care, safety culture, hierarchical structure, teamwork among healthcare workers). Many of these unit-level factors were difficult to capture by observations. Further research (e.g., in-depth interviews with EVC associates and other stakeholders), therefore, is needed to systematically identify underlying causes of performance differences across units. In addition, a mechanism for cross-unit sharing of experience with room cleaning (e.g., facilitators and barriers to room cleaning, strategies for improving room cleaning) should be developed.

Second, surfaces used by the patient and family members or occupied by patient belongings was a frequently observed challenge to daily cleaning. Lower percentages of surfaces (total, in main room, in bathroom) were cleaned when the patient and family members were in the room. High-touch surfaces close to the patient (e.g., bedrails, telephone), although had a higher risk to be contaminated with bacteria (Dancer, 2008), were more likely to be missed than those further away. To mitigate the impact of patient and family presence, patients and family members should be educated about the importance of EVC work and how they can help facilitate the daily cleaning process. In addition, EVC associates should be trained on how to communicate with patients and family members. EVC associates need to know not only how to greet the patient and family members, but also how to explain EVC work to them, how to ask them for their preference, and how to address their concerns with room cleaning. Finally, other strategies (e.g., starting with rooms without patients and family

members) should be identified and shared among EVC associates to mitigate the influence of patients and family members on daily cleaning.

Third, EVC associates were observed following different patterns cleaning the main room and different orders cleaning the bathroom. Some cleaning patterns/orders (e.g., cleaning main room following a local pattern, not cleaning bathroom) should be clearly avoided. We also observed variations in the selection of main room cleaning patterns and bathroom cleaning orders within and across EVC associates, which suggested that in addition to the characteristics of EVC associates (e.g., habit), the selection of main room cleaning patterns and bathroom cleaning orders might also be influenced by other contextual factors (e.g., patient and family presence, presence of medical devices and equipment, use of cleaning tools and supplies). To improve daily patient room cleaning, further research is needed to understand contextual factors resulting in variations in cleaning patterns/orders and identify both desired and undesired cleaning patterns/orders based on their effectiveness and efficiency, as well as on general infection prevention principles (e.g., cleaning surfaces from clean to dirty). While undesired cleaning patterns/orders should be precluded (standardization of cleaning patterns/orders), EVC associates should be allowed to select desired cleaning patterns/orders according to the context (autonomy of EVC associates). To facilitate the use of desired cleaning patterns/orders and hinder the use of undesired cleaning patterns/orders, innovative tools and technologies may also be developed (e.g., combining the checklist of high-touch surfaces with desired cleaning patterns/orders).

Finally, EVC associates were also observed encountering different types of interruptions that prolonged the duration of room cleaning. When coding interruptions of EVC work, we focused on the interrupters (e.g., patients and family members, EVC supervisors or other EVC associates, other healthcare workers) or the sources of interruptions (e.g., lack of cleaning tools and supplies, other environmental situations). Further research is needed to understand the nature or necessity of these interruptions (Rivera-Rodriguez, 2014). While patients, family members, and other healthcare workers should be educated to avoid unnecessary interruptions of EVC work, strategies for dealing with interruptions (e.g., engaging, multi-tasking, mediating, blocking) should be identified and shared among EVC associates (Colligan & Bass, 2012). In addition, interventions may also be developed to address the impacts of specific types of interruptions (e.g., facilitating teamwork among EVC associates and between EVC associates and supervisors, ensuring the availability of cleaning tools and supplies).

This study has several limitations. First, it was focused only on the cleaning of individual patient rooms. Further studies are needed to examine other EVC tasks (e.g., EVC morning huddle, cart preparation, common area cleaning) that may also influence the daily patient room cleaning process. Second, it relied solely on observation data. We defined clean as observation of a surface being wiped purposefully and did not use a surrogate method (e.g., fluorescent gel removal) to assess the effectiveness of microbial removal. Observations were primarily used for performance monitoring in previous studies on patient room cleaning (Al-Hamad & Maxwell, 2008; Malik, Cooper, & Griffith, 2003; Mulvey et al., 2011; Smith et al., 2013; Snyder et al., 2013). When used as a performance monitoring tool, observations were considered less effective due to its inability to detect microbial contamination, poor

inter-observer reliability, and biases secondary to the Hawthorne effect (Weiss et al., 2015). However, our study showed that detailed ethnographic observations are valuable in developing an in-depth understanding of the patient room cleaning process and identifying opportunities for improvement. Third, it included a convenience sample of EVC associates, which might not represent the EVC population at the participating hospital. However, our sample included EVC associates with different genders, ages, and levels of experience, which allowed us to identify variations in cleaning practices and performance across a variety of EVC associates. Last but not least, it was conducted at one academic hospital. The findings may only be applicable to hospitals of similar type. However, the application of HFSE approaches to patient room cleaning is generalizable. Tools from this study could be adapted for different healthcare settings (e.g. community hospitals, long term acute care hospital), as well as for future quality improvement efforts addressing other healthcare challenges beyond patient room cleaning.

CONCLUSION

EVC associates performing patient room cleaning face multiple challenges. Understanding and improving the cleaning process and the associated work system has been identified by the Centers for Disease Control and Prevention as a key area of interest for further research (Centers for Disease Control and Prevention, 2015). In this study, we observed EVC associates performing daily patient room cleaning and found that cleaning performance could be influenced by the type of unit, the presence of the patient and family members in the room, cleaning patterns and orders of EVC associates, and interruptions EVC associates encountered while cleaning. Effective and sustainable interventions for improving daily patient room cleaning need to address these work system factors and redesign the cleaning process to optimize both the performance and well-being of EVC associates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References:

Al-Hamad A, & Maxwell S (2008). How clean is clean? Proposed methods for hospital cleaning assessment. J Hosp Infect, 70(4), 328–334. [PubMed: 18848370]

Boyce JM, Havill NL, Dumigan DG, Golebiewski M, Balogun O, & Rizvani R (2009). Monitoring the effectiveness of hospital cleaning practices by use of an adenosine triphosphate bioluminescence assay. Infect Control Hosp Epidemiol, 30(7), 678–684. [PubMed: 19489715]

Boyce JM, Havill NL, Lipka A, Havill H, & Rizvani R (2010). Variations in hospital daily cleaning practices. Infect Control Hosp Epidemiol, 31(1), 99–101. [PubMed: 19951203]

Carling PC (2016). Optimizing health care environmental hygiene. Infect Dis Clin North Am, 30(3), 639–660. [PubMed: 27515141]

Carling PC, Briggs J, Hylander D, & Perkins J (2006). An evaluation of patient area cleaning in 3 hospitals using a novel targeting methodology. Am J Infect Control, 34(8), 513–519. [PubMed: 17015157]

Carling PC, Parry MF, Bruno-Murtha LA, & Dick B (2010). Improving environmental hygiene in 27 intensive care units to decrease multidrug-resistant bacterial transmission. Crit Care Med, 38(4), 1054–1059. [PubMed: 20081531]

Carling PC, Von Beheren S, Kim P, Woods C, & Healthcare Environmental Hygiene Study, G. (2008). Intensive care unit environmental cleaning: an evaluation in sixteen hospitals using a novel assessment tool. J Hosp Infect, 68(1), 39–44. [PubMed: 18069083]

Centers for Disease Control and Prevention. (2015). Environmental Hygiene in Healthcare. Retrieved October 30, 2017 https://www.cdc.gov/hai/research/eic-meeting.html

Colligan L, & Bass EJ (2012). Interruption handling strategies during paediatric medication administration. BMJ Quality & Safety, 21(11), 912–917.

Dancer SJ (2008). Importance of the environment in methicillin-resistant Staphylococcus aureus acquisition: the case for hospital cleaning. The Lancet Infectious Diseases, 8(2), 101–113. [PubMed: 17974481]

Drees M, Snydman D, Schmid C, Barefoot L, Hansjosten K, Vue P, Cronin M, Nasrway S, & Golan Y (2008). Prior environmental contamination increases the risk of acquisition of vancomy in-resistant enterococci. Clinical Infectious Diseases, 46(5), 678–685. [PubMed: 18230044]

Holden RJ, Carayon P, Gurses AP, Hoonakker P, Hundt AS, Ozok AA, & Rivera-Rodriguez AJ (2013). SEIPS 2.0: a human factors framework for studying and improving the work of healthcare professionals and patients. Ergonomics, 56(11), 1669–1686. [PubMed: 24088063]

Jefferson J, Whelan R, Dick B, & Carling P (2011). A novel technique for identifying opportunities to improve environmental hygiene in the operating room. AORN J, 93(3), 358–364. [PubMed: 21353808]

Lindberg C, & Schneider M (2013). Combating infections at Maine medcial center: insights into complexity-informed leadership from positive deviance. Leadership, 9(2), 229–253.

Malik RE, Cooper RA, & Griffith CJ (2003). Use of audit tools to evaluate the efficacy of cleaning systems in hospitals. Am J Infect Control, 31(3), 181–187. [PubMed: 12734526]

Mitchell BG, Wilson F, Dancer SJ, & McGregor A (2013). Methods to evaluate environmental cleanliness in healthcare facilities. Healthcare infection, 18(1), 23–30.

Mulvey D, Redding P, Robertson C, Woodall C, Kingsmore P, Bedwell D, & Dancer SJ (2011). Finding a benchmark for monitoring hospital cleanliness. J Hosp Infect, 77(1), 25–30. [PubMed: 21129820]

Munoz-Price LS, Ariza-Heredia E, Adams S, Olivier M, Francois L, Socarras M, Coro G, Adedokun A, Pappas T, Tamayo M, McDade R, & Dezfulian C (2011). Use of UV powder for surveillance to improve environmental cleaning. Infect Control Hosp Epidemiol, 32(3), 283–285. [PubMed: 21460514]

Rivera-Rodriguez AJ (2014). A socio-technical systems approach to studying interruptions: understanding the interrupter's perspective. Applied Ergonomics, 45(3), 747–756. [PubMed: 24103213]

Rock C, Cosgrove SE, Keller SC, Enos-Graves H, Andonian J, Maragakis LL, Gurses AP, & Xie A (2016). Using a human factors engineering approach to improve patient room cleaning and disinfection. Infect Control Hosp Epidemiol, 37(12), 1502–1506. [PubMed: 27666398]

Rupp ME, Adler A, Schellen M, Cassling K, Fitzgerald T, Sholtz L, Lyden E, & Carling P (2013). The time spent cleaning a hospital room does not correlate with the thoroughness of cleaning. Infect Control Hosp Epidemiol, 34(1), 100–102. [PubMed: 23221202]

Smith PW, Gibbs S, Sayles H, Hewlett A, Rupp ME, & Iwen PC (2013). Observations on hospital room contamination testing. Healthcare infection, 18(1), 10–13.

Snyder GM, Holyoak AD, Leary KE, Sullivan BF, Davis RB, & Wright SB (2013). Effectiveness of visual inspection compared with non-microbiologic methods to determine the thoroughness of post-discharge cleaning. Antimicrob Resist Infect Control, 2(1), 26. [PubMed: 24088298]

Stanton NA, Young M, & Harvey C (2014). Guide to Methodology in Ergonomics: Designing for Human Use (2nd ed.). Boca Raton, FL: Tayler and Francis.

Weiss SL, Fitzgerald JC, Pappachan J, Wheeler D, Jaramillo-Bustamante JC, Salloo A, Singhi SC, Erickson S, Roy JA, Bush JL, Nadkarni VM, & Thomas NJ (2015). Global epidemiology of pediatric severe sepsis: The sepsis prevalence, outcomes, and therapies study. Am J Respir Crit Care Med, 191(10), 1147–1157. [PubMed: 25734408]

Xie A, & Carayon P (2015). A systematic review of human factors and ergonomics (HFE)-based healthcare system redesign for quality of care and patient safety. Ergonomics, 58(1), 33–49. [PubMed: 25323570]

Xie A, Rock C, Osei P, Hsu Y-J, Andonian J, Scheeler V, Keller SC, Cosgrove SE, & Gurses AP (2017). Using a participatory ergonomics approach to improve patient room cleaning and prevent healthcare-associated infections. Paper presented at the The 12th International Symposium on Human Factors in Organizational Design and Management, and 48th Annual Conference of the Association of Canadian Ergonomists, Banff, Canada.

OCCUPATIONAL APPLICATIONS

Environmental care (EVC) associates are often considered solely responsible for suboptimal cleaning of patient rooms. Thus, performance improvement efforts have focused on EVC monitoring and training. Little attention has been paid to the large work system that may impede the performance (e.g., completeness of cleaning, efficiency) and well-being (e.g., job satisfaction, burnout) of EVC associates. Using a human factors and systems engineering approach, we conducted observations of EVC associates performing daily patient room cleaning and identified various work system factors that could influence the quality of daily patient room cleaning (e.g., patient and family presence, cleaning patterns, interruptions). Effective and sustainable interventions for improving daily patient room cleaning need to address these factors by redesigning the work system and the cleaning process.

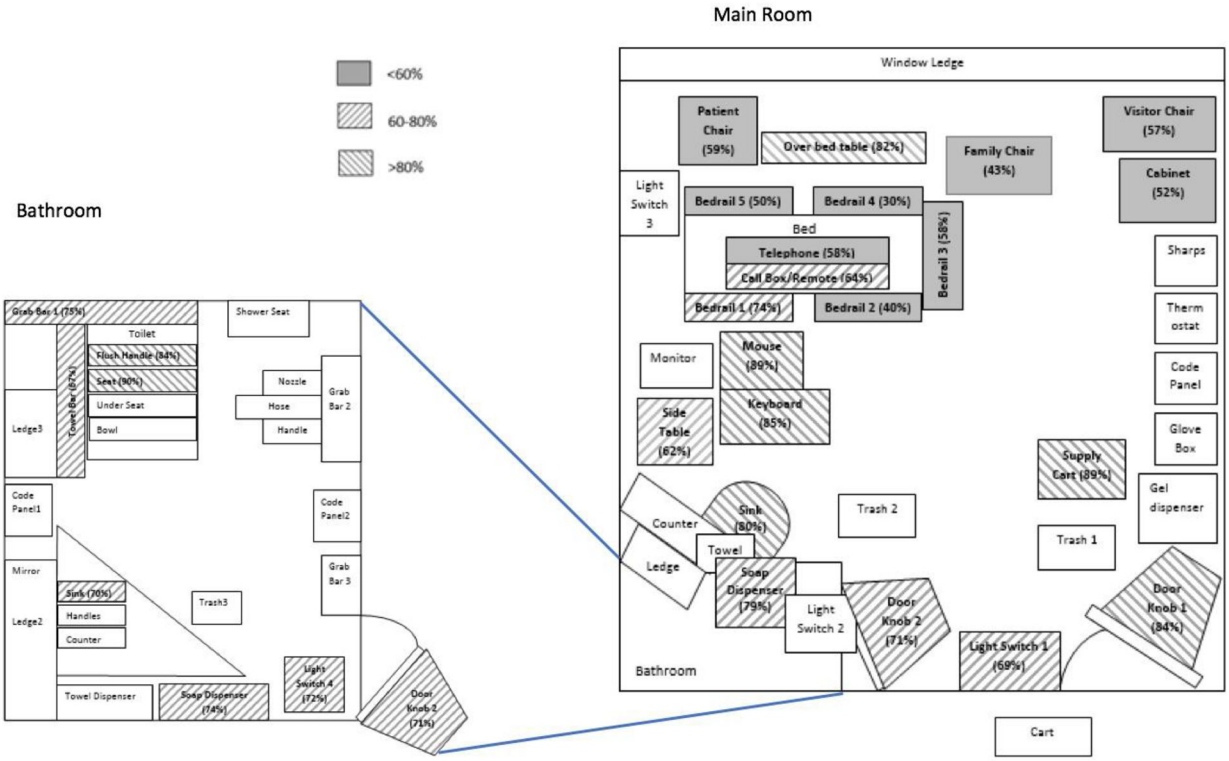


Figure 1.
Cleaning of High-touch Surfaces in Main Room and Bathroom

Table 1.

Demographic Information

Characteristics	n (%)
Gender	
Female	7 (70)
Male	3 (30)
Age	
20–40	2 (20)
40–60	3 (30)
>60	1 (30)
Missing	4 (40)
Years of experience as an EVC associate	
<5	2 (20)
5–10	1 (20)
>10	3 (30)
Missing	4 (40)

Table 2

High-touch and Non-high-touch Surfaces in Patient Rooms

Main room surfaces		Bathroom surfaces	
High-touch	**Non-high-touch**	**High-touch**	**Non-high-touch**
Bed rails 1	Code panel	Bathroom sink	Bathroom code panel 1
Bed rails 2	Gel dispenser	Bathroom soap	Bathroom code panel 2
Bed rails 3	Glove box	dispenser	Bathroom mirror
Bed rails 4	Headboard	Door knob 2	Bathroom sink counter
Bed rails 5	Ledge 1	Flush handle	Bathroom sink handles
Cabinet	Light switch 2	Grab bar 1	Bathroom towel
Call box/remote	Light switch 3	Light switch 4	dispenser
Door knob 1	Main room sink counter	Toilet Seat	Bathroom window ledge
Family Chair	Main room sink handles	Towel bar	Grab bar 2
Keyboard	Main room sink pipes		Grab bar 3
Light switch 1	Main room towel		Ledge 2
Main room sink	dispenser		Ledge 3
Main room soap	Monitor		Shower handle
dispenser Mouse	Sharps		Shower hose
Over-bed table	Thermostat		Shower nozzle
Patient Chair	Window Ledge 1		Shower seat
Side table	Window Ledge 2		Toilet bowl
Supply cart	Window Ledge 3		Underneath seat
Telephone			
Visitor Chair			

Table 3.

Descriptive Characteristics of Observations (N=89)

	n (%)
Type of unit*	
General medicine and infectious diseases units	71 (80)
Physical medicine and rehabilitation unit	10 (11)
Colorectal specialty unit	8 (9)
Under contact precautions	
No	54 (61)
Yes	35 (39)
Presence of patient/family	
Neither	22 (25)
Patient only	54 (61)
Patient & family	13 (14)
Type of wipe used	
Disinfectant wipe	69 (78)
Microfiber cloth	20 (22)
Time period of shift	
First half	67 (75)
Second half	22 (25)
Main room cleaning pattern**	
Clockwise or counter-clockwise	28 (31)
Horizontal or vertical	37 (42)
Random	15 (17)
Local	9 (10)
Bathroom cleaning order	
Last	64 (72)
Middle	10 (11)
First	12 (14)
Not cleaned	3 (3)
Any interruptions during cleaning	
No	39 (44)
Yes	50 (56)

Table 4.

Main Room Cleaning Patterns

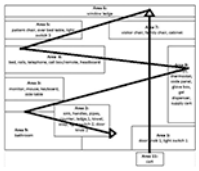
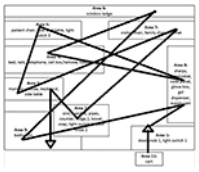
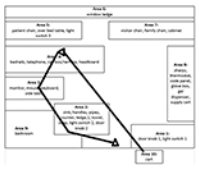
Main room cleaning pattern	Description	Example
Clockwise or counter-clockwise	EVC associates cleaning surfaces around the room and moving between surfaces in the same area or in adjacent areas	
Horizontal or vertical	EVC associates cleaning surfaces on one side of the room (e.g., top/down, left/right) and moving to surfaces on the other side of the room	
Random	EVC associate cleaning a surface and moving to another surface that might not be in the same area or in an adjacent area	
Local	EVC associates only cleaning surfaces in a few areas that covered less than half of the room	

Table 5.

Cleaning Patterns and Orders of EVC Associates (N=89)

EVC associate	Number of rooms cleaned	Main room cleaning patterns*				Bathroom cleaning orders			
		C/CC n (%)	H/V n (%)	Random n (%)	Local n (%)	First n (%)	Middle n (%)	Last n (%)	Not cleaned n (%)
1	9	3 (33)	2 (22)	1 (12)	3 (33)	0 (0)	3 (33)	6 (67)	0 (0)
2	8	7 (88)	0 (0)	0 (0)	1 (12)	0 (0)	0 (0)	8 (100)	0 (0)
3	8	5 (63)	2 (25)	1 (12)	0 (0)	7 (88)	0 (0)	1 (12)	0 (0)
4	10	1 (10)	5 (50)	4 (40)	0 (0)	0 (0)	0 (0)	10 (100)	0 (0)
5	11	1 (9)	8 (73)	2 (18)	0 (0)	0 (0)	0 (0)	9 (82)	2 (18)
6	13	2 (15)	7 (54)	4 (31)	0 (0)	4 (31)	4 (31)	5 (38)	0 (0)
7	10	4 (40)	3 (30)	0 (0)	3 (30)	0 (0)	2 (20)	8 (80)	0 (0)
8	5	0 (0)	5 (100)	0 (0)	0 (0)	0 (0)	0 (0)	5 (100)	0 (0)
9	5	2 (40)	1 (20)	2 (40)	0 (0)	0 (0)	1 (20)	4 (80)	0 (0)
10	10	3 (30)	4 (40)	1 (10)	2 (20)	1 (10)	0 (0)	8 (80)	1 (10)
Total	89	28 (31)	37 (42)	15 (17)	9 (10)	12 (13)	10 (11)	64 (72)	3 (4)

*C/CC: clockwise or counter-clockwise; H/V: horizontal or vertical

Table 6

Cleaning Performance (N=89)

	Median (IQR)
Percentages of all surfaces cleaned, %	63 (54, 72)
Percentages of surfaces cleaned in main room, %	
Total	59 (50, 73)
High-touch surfaces	68 (50, 82)
Non-high-touch surfaces	50 (36, 60)
Percentages of surfaces cleaned in bathroom, %	
Total	65 (52, 78)
High-touch surfaces	75 (63, 88)
Non-high-touch surfaces	56 (40, 73)
Cleaning duration, min	14 (12, 19)

Table 7.

Regression Analysis: Numbers of Surfaces Cleaned and Duration (N = 89)

	Percentages of all surfaces cleaned		Percentages of surfaces cleaned in main room						Percentages of surfaces cleaned in bathroom						Cleaning duration (min)	
			Total		High-touch surfaces		Non-high-touch surfaces		Total		High-touch surfaces		Non-high-touch surfaces			
	OR (95% CI)*	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	Coef. (SE)**	p
Type of unit ***																
G	1.00		1.00		1.00		1.00		1.00		1.00		1.00		Ref	
P	1.43 (1.08, 1.89)	.012	2.00 (1.50, 2.66)	< *.001*	2.22 (1.55, 3.17)	< *.001*	1.92 (1.35, 2.74)	< *.001*	1.02 (0.67, 1.56)	.912	1.13 (0.65, 1.97)	.655	0.99 (0.63, 1.55)	.973	3.25 (1.59)	.071
C	0.52 (0.33, 0.82)	.005	0.46 (0.25, 0.85)	*.013*	0.68 (0.43, 1.09)	.110	0.23 (0.08, 0.63)	*.004*	0.65 (0.43, 0.97)	*.036*	1.93 (1.17, 3.18)	*.010*	0.42 (0.26, 0.68)	< *.001*	−5.48 (2.71)	.074
Presence of patient/family																
Neither	1.00		1.00		1.00		1.00		1.00		1.00		1.00		(ref)	
Patient only	0.85 (0.69, 1.04)	.123	0.87 (0.70, 1.07)	.181	0.80 (0.51, 1.26)	.328	0.93 (0.62, 1.40)	.726	0.81 (0.49, 1.33)	.402	1.12 (0.61, 2.05)	.723	0.70 (0.40, 1.24)	.228	1.00 (1.74)	.581
Patient and family	0.62 (0.49, 0.79)	< *.001*	0.65 (0.47, 0.90)	*.010*	0.64 (0.40, 1.01)	.055	0.65 (0.51, 0.83)	< *.001*	0.58 (0.44, 0.77)	< *.001*	0.61 (0.40, 0.93)	*.021*	0.58 (0.40, 0.84)	*.004*	0.68 (1.81)	.714
Main room cleaning pattern ****																
C/CC	1.00		1.00		1.00		1.00		1.00		1.00		1.00		(ref)	
H/V	1.11 (0.84, 1.47)	.449	1.03 (0.71, 1.50)	.870	1.02 (0.59, 1.77)	.939	1.07 (0.79, 1.45)	.667	1.23 (0.79, 1.91)	.360	1.09 (0.71, 1.67)	.701	1.31 (0.78, 2.19)	.303	−0.55 (1.58)	.738
Random	1.49 (0.84, 2.63)	.170	1.72 (0.93, 3.18)	.085	1.80 (0.71, 4.56)	.213	1.71 (0.90, 3.28)	.103	1.07 (0.52, 2.17)	.859	0.91 (0.45, 1.84)	.790	1.10 (0.46, 2.62)	.828	−1.54 (2.66)	.578
Local	0.64 (0.44, 0.94)	*.024*	0.50 (0.30, 0.83)	*.008*	0.43 (0.23, 0.81)	*.008*	0.61 (0.33, 1.13)	.116	0.92 (0.62, 1.39)	.705	1.46 (0.76, 2.82)	.257	0.75 (0.46, 1.24)	.262	1.19 (2.06)	.578
Bathroom cleaning order																
Last	1.00		1.00		1.00		1.00		1.00		1.00		1.00		(ref)	
Middle	0.92 (0.69, 1.22)	.553	0.99 (0.70, 1.39)	.943	1.13 (0.72, 1.78)	.595	0.85 (0.61, 1.17)	.321	0.83 (0.47, 1.46)	.524	0.85 (0.37, 1.95)	.696	0.91 (0.35, 2.33)	.842	−3.75 (2.96)	.236

	Percentages of all surfaces cleaned		Percentages of surfaces cleaned in main room						Percentages of surfaces cleaned in bathroom						Cleaning duration (min)	
			Total		High-touch surfaces		Non-high-touch surfaces		Total		High-touch surfaces		Non-high-touch surfaces			
	OR (95% CI)*	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	Coef. (SE)**	p
First	1.44 (0.90, 2.33)	.131	1.85 (1.13, 3.04)	*.015*	1.66 (1.02, 2.73)	*.043*	2.04 (0.78, 5.32)	.146	0.92 (0.47, 1.78)	.798	0.83 (0.45, 1.54)	.556	0.95 (0.40, 2.24)	.904	4.02 (3.32)	.256
Not cleaned	0.37 (0.22, 0.63)	< *.001*	0.78 (0.47, 1.29)	.333	0.78 (0.36, 1.68)	.523	0.80 (0.54, 1.18)	.252	0.00 (0.00, 0.00)	< *.001*	0.00 (0.00, 0.00)	< *.001*	0.00 (0.00, 0.00)	< *.001*	−4.87 (1.21)	*.003*
Any interruptions during cleaning																
No	1.00		1.00		1.00		1.00		1.00		1.00		1.00		(ref)	
Yes	0.95 (0.76, 1.20)	.681	0.95 (0.72, 1.27)	.747	0.94 (0.64, 1.38)	.750	0.97 (0.74, 1.27)	.813	0.99 (0.67, 1.46)	.962	0.99 (0.60, 1.64)	.981	1.06 (0.63, 1.80)	.814	3.25 (1.29)	*.032*

*OR: odds ratio; CI: confidence interval

**Coef.: coefficient; SE: standard error

***G: general medicine and infectious diseases units; P: physical medicine and rehabilitation unit; C: colorectal specialty unit

****C/CC: clockwise or counter-clockwise; H/V: horizontal or vertical

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Table 8.

Implications of study findings

Factors	Main findings	Implications
Unit type	• There were variations in percentages of surfaces cleaned across different types of units.	• To identify unit-level factors (e.g., acuity of care, safety culture, unit hierarchy, teamwork) that may influence cleaning performance and variations across units • To share experience with patient room cleaning (e.g., facilitators and barriers to room cleaning, strategies for improving room cleaning) across units to improve performance of the entire organization
Patient and family presence in room	• Lower percentages of surfaces were cleaned with the presence of the patient and family members in the room. • High-touch surfaces close to the patient and family members were more likely to be missed. • Surfaces used by the patient and family members or occupied by patient belongings is a frequently observed challenge to patient room cleaning.	• To educate patients and family members about the importance of EVC work to care quality and safety and how they can facilitate EVC work (e.g., including education materials in patient and family orientation) • To train and empower EVC associates to communicate with patients and family members (e.g., greeting patients and family members, explaining EVC work to patients and family members, asking patients and family members for their preference) • To identify and share strategies for mitigating the impact of patient and family presence (e.g., cleaning rooms when patient is out for tests and procedures) among EVC associates
Workflow (main room cleaning patterns, bathroom cleaning orders)	• EVC associates followed different main room cleaning patterns and different bathroom cleaning orders. • Fewer surfaces were cleaned when using the local pattern. • Other main room cleaning patterns did not significantly influence the performance of EVC associates. • There were variations in selecting main room cleaning patterns and bathroom cleaning orders within and across EVC associates.	• To understand contextual factors resulting in variations in patterns/orders for daily patient room cleaning • To identify both desired (e.g., clockwise/counter-clockwise) and undesired (e.g., local) patterns/orders for daily patient room cleaning • To balance standardization of cleaning patterns/orders (e.g., precluding undesired cleaning patterns/orders) and autonomy of EVC associates (e.g., allowing EVC associates to select cleaning patterns/orders according to the context) • To develop innovative tools and technologies to facilitate desired cleaning patterns/orders and hinder undesired cleaning patterns/orders (e.g., combining the checklist of high-touch surfaces with desired cleaning patterns/orders)
Interruptions during cleaning	• EVC associates encountered different types of interruptions during daily cleaning (e.g., interruptions by patients and family members, by EVC supervisors or other EVC associates, by other healthcare workers, due to lack of cleaning tools and supplies, and due to other environmental situations). • In general, interruptions encountered by EVC associates did not influence the percentages of surfaces cleaned, but prolonged the duration of room cleaning. • Interruptions by EVC supervisors or other EVC associates were associated with longer duration of room cleaning and higher percentages of surfaces cleaned. • Interruptions due to lack of cleaning tools and supplies were associated with longer duration of room cleaning.	• To understand the nature of interruptions encountered by EVC associates and differentiating avoidable (e.g., interruptions that can be delayed) and unavoidable (e.g., interruptions that are necessary and value-adding to the process) interruptions • To educate patients, family members, and other healthcare workers to avoid unnecessary interruptions of EVC work (e.g., including education materials in patient admission package, discussing in unit/staff meetings) • To identify and share strategies for dealing with interruptions (e.g., engaging, multi-tasking, mediating, blocking) among EVC associates • To facilitate teamwork among EVC associates and between EVC associates and supervisors (e.g., EVC supervisors having daily face-to-face communication with EVC associates)

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Factors	Main findings	Implications
		• To ensure the availability of cleaning tools and supplies (e.g., improving the cart preparation process to help EVC associates allocate sufficient cleaning tools and supplies before shift)