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Concise Communication

Enhanced disinfection leads to reduction of microbial contamination and a decrease in patient colonization and infection

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Abstract

In this prospective study, we monitored 4 epidemiologically important pathogens (EIPs): methicillin-resistane *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Clostridium difficile,* and multidrug-resistant (MDR) *Acinetobacter* to assess the effectiveness of 3 enhanced disinfection strategies for terminal room disinfection against standard practice. Our data demonstrated that a decrease in room contamination with EIPs of 94% was associated with a 35% decrease in subsequent patient colonization and/or infection.

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Over the last decade, substantial scientific evidence has accumulated that contamination of environmental surfaces in hospital rooms plays an important role in the transmission of several epidemiologically important pathogens (EIPs); methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Acinetobacter* spp, and *Clostridium difficile*.[1] Noncritical environmental surfaces and medical equipment surfaces are defined as those that contact intact skin. These surfaces may become contaminated with infectious agents and may contribute to cross transmission by acquisition of transient hand carriage by healthcare personnel (HCP) with subsequent transfer to patients. Thus, disinfection of the noncritical environmental surfaces and medical equipment surfaces is an essential component of infection prevention.[2] Disinfection should render surfaces and equipment free of pathogens in sufficient numbers to prevent disease transmission.[3] Because cleaning and disinfecting of environmental room surfaces is often inadequate,[4] the use of no-touch automated methods of disinfection (eg, ultraviolet C [UV-C]) has been studied using primarily before-and-after design studies.[5]

In this study, we analyzed additional microbiological data from the Benefits of Enhanced Terminal Room (BETR) Disinfection Study[6] to assess the effectiveness of 3 enhanced methods of room decontamination (ie, quaternary ammonium manual disinfection [Quat] followed by ultraviolet light [UV], bleach, or bleach plus UV) compared to a standard method (ie, Quat alone) to reduce the level of surface contamination with 4 epidemiologically important pathogens (ie, multidrug-resistant [MDR] *Acinetobacter*, *C. difficile*, MRSA, VRE) if they were present only in patient rooms, only in the bathroom, or in both. These organisms are ideal markers to study bacterial transmission in the hospital setting and were chosen due to their importance as pathogens in healthcare-associated infections (HAIs),[7] and the propensity to contaminate and persist on hospital room surfaces.

Methods

This substudy of the BETR Disinfection Study was a pragmatic, prospective, multicenter, cluster-randomized trial that evaluated 4 different strategies for terminal room disinfection in 9 hospitals from April 2012 through July 2014.[6,8] We performed microbiological analysis of randomly selected "seed" rooms to determine the total and average number of colony-forming units (CFU) of the 4 target organisms that remained in the patient room following terminal room decontamination at 3 study hospitals in central North Carolina: Duke University Hospital, a 921-bed tertiary-care academic medical center; Duke Regional Hospital, a 250-bed community hospital; and Duke Raleigh Hospital, a 148-bed community hospital. A seed room was

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defined as a single-patient room from which a patient on contact precautions was discharged or transferred.

The Duke University Health System Institutional Review Board approved this study, and it was registered on ClinicalTrials.gov as NCT01803100.[6]

Subject enrollment

We prospectively identified subjects with an anticipated hospitalization of >48 hours using the admission/discharge/transfer dataset of the electronic medical record. All patients admitted into newly cleaned and disinfected rooms at participating hospitals were eligible. Informed consent was obtained for study subjects.[6,8]

Specimen collection

The sampling was done as described in the BETR study publication.[6] In brief, at each study visit, microbiological samples were collected from 8 of 10 environmental surfaces in the hospital room of the enrolled subject; these surfaces included the bed rail, over-bed table, supply or medicine cart, chair, sink, toilet seat, shower floor, side counter, linen hamper lid, and bathroom floor.[6,8,9] Each surface area was sampled in a different location using 10 individual replicate organism detection and counting (Rodac) plates (Becton Dickinson, Franklin Lakes, NJ) to enhance microbiological yield and to reduce sampling error: 5 Rodacs for aerobic culture (~125 cm^2) and 5 for anaerobic culture (Anaeropack, Mitsubishi Gas Chemical). Each Rodac plate sampled ~25 cm^2. Microbiological analyses and identification were performed using standard protocols.[6,8] We attempted to sample 25 rooms for each EIP: MRSA, VRE, *Acinetobacter*, and *C. difficile*. No other selection criteria were used. In total, 92 rooms were sampled: Quat disinfection (ie, the standard, 21 rooms), Quat plus UV (28 rooms; Tru-D, Memphis, TN), bleach (23 rooms), and bleach plus UV (20 rooms). The total number of Rodac plates for all 92 rooms was 7,360.

Microbiological methods

Dey/Engley (D/E) Neutralizing Agar (Becton Dickinson) or *C. difficile* selective agar was used on the Rodac plates. The D/E plates were incubated at 37°C for 48 hours; *C. difficile* plates were incubated anaerobically. Two quantitative microbiologic outcomes were determined: CFUs on each plate for each of the EIPs studied and the total CFUs of all EIPs studied. For *C. difficile*, only the total number of CFUs of *C. difficile* present on each plate was determined. In either scenario, the number of targeted pathogens was quantified by first identifying morphologies suggestive of the target organisms. These colonies were then subcultured and identified using standard microbiological methods.[6] Statistical significance was determined by the Wilcoxon test, and $P \leq .05$ was considered significant.

Results

The mean CFUs for each EIP studied and the total of all EIPs for each of the 4 room decontamination methods are displayed in Table 1.

Quat plus UV (an enhanced disinfection intervention) was significantly superior to Quat alone (standard method) in reducing EIPs in the patient room, bathroom, and patient room plus bathroom. In addition, Quat plus UV significantly reduced MRSA, VRE, and MDR *Acinetobacter* in the patient room plus bathroom, and it reduced MDR *Acinetobacter* and MRSA in the bathroom alone (Table 1). The other 2 enhanced methods (ie, bleach and bleach plus UV) led to a decrease in EIPs, but these reductions did not reach statistical significance compared to Quat alone. We detected no statistical difference between bleach and bleach plus UV in reducing *C. difficile* for any surfaces (ie, patient room only, bathroom only, or patient room plus bathroom).

As reported in the BETR study, comparing the best strategy with the worst strategy for reducing EIPs in a patient room plus bathroom, revealed that a reduction of 94% in EIPs (Quat, 60.8 CFU per room vs Quat plus UV, 3.36 CFU per room) led to a 35% decrease in colonization and/or infection (Quat, 2.3% vs Quat plus UV, 1.5%) (Table 2).

Discussion

The contaminated surface environment in patient rooms has been demonstrated to be a risk factor for the development of HAIs.[1,3,4] Multiple studies have demonstrated that improved room cleaning and disinfection reduces HAIs.[2] Finally, more than a dozen intervention trials have now demonstrated that the use of a "no-touch" technology (eg, UV or vaporized hydrogen peroxide) for terminal room decontamination reduces HAIs.[5] However, most published studies for terminal room decontamination and HAI reduction used a before-and-after design and often failed to assess potential confounders such as hand hygiene compliance and cleaning effectiveness.[5] Further, all of these studies compared only 2 room decontamination methods.[5] The BETR Disinfection Study was a cluster-randomized prospective trial designed to assess 3 different enhanced methods of room decontamination to a standard method, as well as to monitor potential confounders such as hand hygiene compliance and room cleaning.[6]

This study demonstrated that an enhanced method of room decontamination (ie, Quat plus UV) was superior in reducing room surface contamination with EIPs compared to a standard method (ie, Quat alone). The BETR Disinfection Study demonstrated that the rate of colonization and/or infection in a patient subsequently admitted to a room of a patient colonized and/or infected with an EIP was related to the decontamination method used: Quat, 2.3%; Quat plus UV, 1.5%; bleach, 1.9%; and bleach plus UV, 2.2%.[6] Our finding that Quat with UV was superior to chlorine or chlorine with UV has been previously discussed and may be related to improved cleaning compliance and study power.[6]

In summary, this analysis adds further support to the key finding in the BETR disinfection study: enhanced environmental disinfection leads to decreased room contamination, which translates to decreases in subsequent patient colonization and/or infection. Multiple papers have shown that enhanced disinfection leads to a reduction in microbial contamination.[2] Similarly, multiple papers have described enhanced disinfection that resulted in reduction of HAIs.[2,5] However, to our knowledge, the BETR disinfection study[6] and this analysis of the BETR disinfection study data are the first that quantitatively describe the entire pathway whereby enhanced disinfection decreases microbial contamination, which in turn reduces patient colonization and infection. Further, we have shown that several enhanced methods of room decontamination were significantly superior to a standard cleaning method. Therefore, we believe that hospitals

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Table 1. Epidemiologically Important Pathogens (EIPs) by Intervention and Contamination in 92 Patient Rooms During the Benefits of Enhanced Terminal Room Disinfection Study

		Mean CFU per Room by Treatment Type				*P* Value[a]		
Room Type	Pathogen	Quat (N = 21 rooms)	Quat plus UV (N = 28 rooms)	Bleach (N = 23 rooms)	Bleach plus UV (N = 20 rooms)	Quat vs Quat plus UV	Quat vs Bleach	Quat vs Bleach plus UV
Patient room only	MDR *Acinetobacter*	8.76	0.18	0.39	0.25			
	C. difficile	0	0.07	0.04	0			
	MRSA	2.33	0.11	2.13	0.05			
	VRE	8.62	0.07	0.78	0.35			
	EIPs[b]	19.71	0.43	3.35	0.65	.013		
Bathroom only	MDR-*Acinetobacter*	0.19	0	0	0	.018	.032	.045
	C. difficile	3.76	2.79	4.43	3.25			
	MRSA	6.19	0	2.26	0.80	.044		
	VRE	30.95	0.14	1.65	1.55			
	EIPs[b]	41.10	2.93	8.35	5.60	.015		
Patient room or bathroom[c]	MDR *Acinetobacter*	8.95	0.18	0.39	0.25	.017	.035	
	C. difficile	3.76	2.86	4.48	3.25			
	MRSA	8.52	0.11	4.39	0.85	.032		
	VRE	39.57	0.21	2.43	1.90	.034		
	EIPs[a]	60.81	3.36	11.70	6.25	.001		

Note. CFU, colony-forming units; Quat, quaternary ammonium compound; MDR, multidrug resistant; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus*; UV, ultraviolet light.
[a]Statistical significance was determined using the Wilcoxon test for an enhanced group (ie, Quat plus UV, bleach, or bleach plus UV) compared to a standard group Quat. *P* values are shown only when $P < .05$.
[b]EIPs include MDR-*Acinetobacter*, MRSA, VRE, and *C. difficile*. Table displays the CFUs by pathogen and decontamination method for surfaces in the patient room, bathroom, and room plus bathroom.
[c]Data on mean CFU per room in patient room or bathroom were published by coauthors[3] and reanalyzed with additional data (ie, patient only, bedroom only).

Table 2. Relationship Between Microbial Reduction of Epidemiologically Important Pathogens (EIPs) and Colonization and/or Infection in a Patient Subsequently Admitted to a Room of a Patient Colonized and/or Infected with an EIP by Decontamination Method

	Standard Method	Enhanced Method		
Outcome	Quat	Quat plus UV	Bleach	Bleach plus UV
EIPs, mean CFU per room[a]	60.8	3.4	11.7	6.3
Reduction, %		94	81	90
Colonization and/or infection rate, %[a]	2.3	1.5	1.9	2.2
Reduction, %		35	17	4

Note. CFU, colony forming units; Quat, quaternary ammonium compound; UV, ultraviolet light. Reduction in an enhanced method is calculated compared to standard method.
[a]Data on mean CFU per room of EIPs and colonization and/or infection rate were published by coauthors,[3] then a reanalysis was done in which each reduction was calculated and compared in this study.

should use an enhanced terminal disinfection method for contact precaution patient rooms to reduce the risk of HAIs originating in the environment.

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Conflicts of interest. Drs Rutala and Weber are consultants for Professional Disposables International (PDI) in 2017–2018 and were consultants for Clorox in 2012–2016. Dr Weber is a consultant for Germitec.

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