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Major Article

Reduced health care-associated infections in an acute care community hospital using a combination of self-disinfecting copper-impregnated composite hard surfaces and linens

Costi D. Sifri MD [a,b,*], Gene H. Burke MD [c], Kyle B. Enfield MD, MS [b,d]

[a] Division of Infectious Diseases & International Health, Department of Medicine, University of Virginia Health System, Charlottesville, VA
[b] Office of Hospital Epidemiology/Infection Prevention & Control, University of Virginia Health System, Charlottesville, VA
[c] Sentara Healthcare, Norfolk, VA
[d] Division of Pulmonary & Critical Care Medicine, Department of Medicine, University of Virginia Health System, Charlottesville, VA

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Antimicrobial surfaces
Antimicrobial textiles
Clostridium difficile

Background: The purpose of this study was to determine the effectiveness of copper-impregnated composite hard surfaces and linens in an acute care hospital to reduce health care-associated infections (HAIs).
Methods: We performed a quasiexperimental study with a control group, assessing development of HAIs due to multidrug resistant organisms (MDROs) and *Clostridium difficile* in the acute care units of a community hospital following the replacement of a 1970s-era clinical wing with a new wing outfitted with copper-impregnated composite hard surfaces and linens.
Results: The study was conducted over a 25.5-month time period that included a 3.5-month washout period. HAI rates obtained from the copper-containing new hospital wing (14,479 patient-days; 72 beds) and the unmodified hospital wing (19,177 patient-days) were compared with those from the baseline period (46,391 patient-days). The new wing had 78% ($P = .023$) fewer HAIs due to MDROs or *C difficile*, 83% ($P = .048$) fewer cases of *C difficile* infection, and 68% ($P = .252$) fewer infections due to MDROs relative to the baseline period. No changes in rates of HAI were observed in the unmodified hospital wing.
Conclusions: Copper-impregnated composite hard surfaces and linens may be useful technologies to prevent HAIs in acute care hospital settings. Additional studies are needed to determine whether reduced HAIs can be attributed to the use of copper-containing antimicrobial hard and soft surfaces.

Important progress has been made to reduce health care-associated infections (HAIs) in the United States during the past decade. However, despite important reductions in certain HAIs, the nation has not yet reached the goals for HAI reduction set by the Department of Health & Human Service's 2009 *National Action Plan to Prevent Health Care-Associated Infections: Road Map to Elimination.*[1] Continued improvement in HAI rates will require sustained promotion and use of proven infection prevention strategies; however, there is a need for new and innovative methods to prevent HAIs.

Development of HAIs are complex processes, involving both host factors and exposure to health care-associated pathogens. Hospital environments play a crucial role in the transmission of health care-associated pathogens. The ability of health care-associated pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), extended-spectrum β-lactamase producing Enterobacteriaceae (ESBL), multidrug-resistant *Acinetobacter* spp, and carbapenem-resistant Enterobacteriaceae (CRE), to remain viable on inanimate surfaces for extended periods of time facilitate their trafficking between patients and health care providers in complex health care environments.[2,3] The spore-forming bacterium *Clostridium difficile* is able to survive for months in a clinical environment.[3] Environmental contamination may serve as a reservoir for nosocomial pathogens, which may then be transmitted to patients through the hands of health care workers, patient care equipment, or direct contact with a contaminated environment.[3-5] Supporting this hypothesis, efforts to reduce environmental bioburden have been shown to reduce transmission of microbial pathogens and development of HAIs in hospitalized patients.[6,7] However, studies suggest

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[*] Address correspondence to Costi D. Sifri, MD, Office of Hospital Epidemiology/Infection Prevention & Control, Division of Infectious Diseases & International Health, Department of Medicine, University of Virginia Health System, PO Box 800473, Charlottesville, VA 22908-0473.
E-mail address: csifri@virginia.edu (C.D. Sifri).

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only 25%-50% of all hospital surfaces are routinely cleaned, and enhanced surface cleaning practices in health care settings are difficult to sustain.[8-10] New, "no-touch" automated decontamination technologies, such as ultraviolet light and hydrogen peroxide, have been introduced to supplement surface disinfection in healthcare environments.[11] However, these technologies have several limitations, including the need for integration into standard housekeeping practices, use that is restricted to unoccupied rooms during terminal cleaning, need for supervised use to avoid accidental worker or patient exposures, and significant capital expenditures.

Recently, self-disinfecting surfaces have been proposed as a means to reduce new acquisition of nosocomial pathogens and reduce the incidence of HAIs. Copper has potent biocidal activity and is receiving increasing attention for potential applications in health care settings.[12,13] Copper oxide-impregnated composites have been developed that can be incorporated into hard surface countertops and molded hard surfaces and woven into textiles.[13-15] In this study, we investigated the real-world application of this technology following the replacement of a 1970s-era hospital wing with a 124-bed tower outfitted with copper-containing composite hard surfaces and linens.

METHODS

Study setting

The study was conducted at Sentara Leigh Hospital, a community hospital in Norfolk, VA, that averages more than 14,000 admissions per year and has specialty services in orthopedic, gynecologic, urologic, and comprehensive breast care. The study was conducted during the replacement of a 1970s-era clinical wing with a new hospital wing in November 2013. All rooms in both the existing hospital and the new wing were single-occupancy beds. The room size was 118 sq ft in the existing hospital and 250 sq ft in the new wing. Room amenities in the existing hospital included a bathroom with a sink and toilet; rooms in the new wing had bathrooms that included a shower in addition to a sink and toilet. The new wing included 3 24-bed general acute care units as well as a single 20-bed intensive care unit (ICU) and single 24-bed intermediate medical care unit (IMCU). Because no comparable ICU or IMCU level beds remained in the old hospital wing, patients admitted to the ICU and IMCU within the defined period of evaluation were excluded from the analysis. Obstetric, neonatal, and newborn nursery patients were also excluded from the analysis. For the final analysis, the study compared 204 acute care hospital beds of the original hospital from November 15, 2012-November 16, 2013 (baseline period), and 72 and 84 acute care hospital beds in the new wing and the old wing, respectively, from March 1-December 31, 2014 (assessment period). During a 3.5-month washout period between November 17, 2013, and February 28, 2014, the new hospital wing was opened and the study linens were deployed in its units.

Patient rooms and select patient care clinical areas of the new wing were outfitted with 16% copper oxide (weight/weight) impregnated composite countertops and molded surfaces (Cupron Enhanced EOS Solid Surfaces; Cupron Inc, Richmond, VA, and EOS Surfaces LLC, Norfolk, VA), targeting high-touch surfaces. Countertops included sinks, vanities, patient room desks, computer stations, soiled utility rooms, and nurse workstations (Fig 1). Form-fitting copper-impregnated composite molded surfaces included over-the-bed tray tables and bed rails (Fig 1). Between December 1, 2013, and February 14, 2014, copper-impregnated woven linens (Cupron Medical Textiles; Cupron Inc) were sequentially deployed in units of the new wing (1 new unit every few weeks) but not in the old wing. The linens included patient gowns, pillowcases, fitted and flat sheets, washcloths, bath towels, bath blankets, and thermal blankets (Fig 1). Health care workers did not wear copper-impregnated clothing.

The copper-impregnated linens were beige in color, whereas standard linens were white. Additionally, the copper-composite hard surfaces of the new wing had a characteristic beige color. Educational materials about the products were provided to the patients, explaining the reason for their distinctive colors. Consequently, staff and most patients and visitors were aware of assertions for the antimicrobial activity of the copper-composite hard surfaces and linens. Patients were assigned to room based on bed availability and in some cases, clinical specialty of the unit. Nursing personnel, physicians, therapy staff, and support staff were shared across units; in general, nurses tended to remain unit-based, whereas physicians and other staff tended to move between units. Environmental services personnel coordinated deployment of copper-impregnated linens to the new wing alone, and audits by management staff of the units and infection preventionists (IPs) ensured their correct placement. Laundering protocols were the same for both sets of linens and were in accordance with established protocols. Patients were prospectively assessed for the development of potential allergic reactions to copper. Patients who developed possible skin hypersensitivity reactions due to the products were referred to dermatology for dermatologic evaluation.

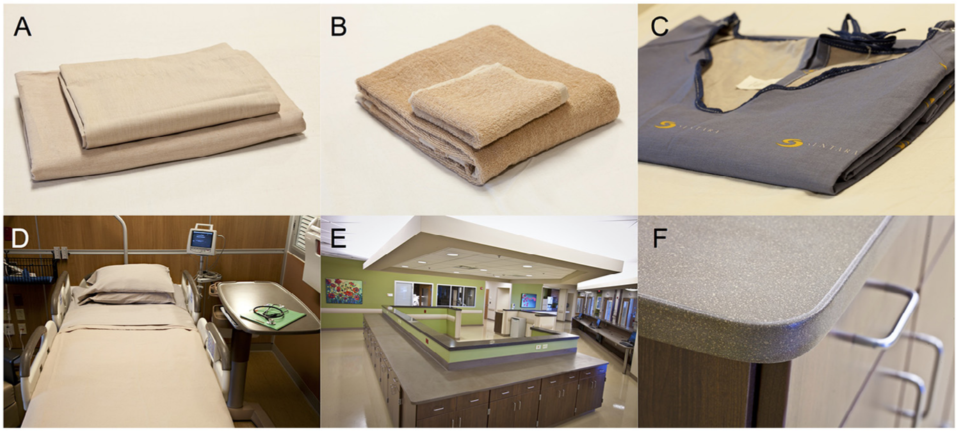

Fig 1. Photographs of representative copper-impregnated composite hard surface and linen products used during the study. (A) Copper-impregnated sheets. (B) Copper-impregnated washcloths and bath towel. (C) Copper-impregnated patient gowns. (D) Molded copper-composite over-the-bed tray table and bed rails and bed with copper-impregnated sheets and blankets. (E) Nurse station with copper-composite hard surfaces. (F) Close-up view of copper-composite hard surface.

Demographic and clinical data were extracted from electronic medical records; these data included the age, gender, and race/ethnicity of the patients, history of *C difficile* infection and/or multidrug-resistant organism (MDRO) colonization or infection at any Sentara Healthsystem Hospital during the prior 6 months, history of hospitalization at any Sentara Healthsystem Hospital during the prior 180 days, total length of stay, need for ICU care, and in-hospital mortality. Classification of hospitalization type was based on the specialty of the primary provider (medicine or surgery/surgical subspecialty) at the time of admission.

Infection prevention and control program

Except where noted below, HAI prevention measures and practice improvement were implemented consistently throughout the entire hospital between the baseline period and the assessment period. Additionally, all HAI prevention measures were implemented equally in both the old and new wings during the assessment period. Hospital room cleaning and disinfection was performed by an environmental services program, which used education, cleaning checklists, and monitoring of cleaning thoroughness using Dazo fluorescent marking gel (Ecolab, St Paul, MN) in a quality assessment program. Routine daily and terminal cleaning used quaternary ammonium disinfectants, except for patients with *C difficile* infection, when a hypochlorite product was used. Isolation precautions practices were in accordance with professional guidelines.[16] Surveillance cultures for MRSA, VRE, or other MDRO colonization were not routinely performed. Neither ultraviolet light nor hydrogen peroxide was used for environmental decontamination. Routine chlorhexidine gluconate bathing was performed only for preoperative orthopedic surgery patients throughout the study, and those patients were usually admitted to the new wing during the assessment period. Unit-level hand hygiene compliance rates were assessed through an ongoing, anonymous auditing program by IPs and unit-based staff; no major changes in the hand hygiene program occurred during the study period.

Infection control practices implemented during the study period were as follows: In February 2013, a nurse-driven protocol to remove indwelling bladder catheters was introduced. In March 2013, use of isopropyl alcohol disinfection caps (Curos Disinfecting Port Protectors; Ivera Medical Corporation, San Diego, CA) on all unused central venous catheter (CVC) ports started throughout the hospital. Efforts to improve CVC dressing maintenance and reduced CVC use occurred continuously throughout the hospital during the study. Finally, during October 2014, Det Norske Veritas/Germanischer Lloyd designated Sentara Leigh Hospital as a Managing Infection Risk Center for Excellence, based on the efforts of hospital staff and leadership to reduce HAI disease risk and facilitate collaborative practice improvement.

HAI surveillance and definitions

HAI surveillance was performed retrospectively through the existing infection prevention and control (IPC) program of the hospital and was not blinded from the locations of the events. The primary end point was the incident rate (IR) of hospital-onset (HO) infections, using National Healthcare Safety Network (NHSN) definitions, due to an MDRO or *C difficile* for patients admitted to acute care unit rooms during the study period. MDROs included MRSA, VRE, extended-spectrum β-lactamase, multidrug-resistant *Acinetobacter* spp, and CRE. HO was defined as events that occurred on or after the third day of admission to the hospital. The location of attribution was assigned to the inpatient location where the HO infection occurred, following (when applicable) the NHSN transfer rule for events that occurred the day of or after a patient transfer or discharge.

Secondary end points of the study included IRs of HO MDRO infections, HO *C difficile* infection (CDI), HO central line-associated bloodstream infection (CLABSI), and HO catheter-associated urinary tract infection (CAUTI). IRs of HO infections due to MDROs and/or *C difficile* were calculated based on the total number of patient-days of acute care unit occupancy. CLABSI IRs were calculated based on the number of catheter-day exposures to ≥ 1 intravascular catheter that terminated in a great vessel; CAUTI IRs were calculated based on the number of catheter-day exposures to an indwelling bladder catheter. The study was terminated on December 31, 2014, due to a substantial revision of NHSN definitions for several end points in the study. This study was a pragmatic investigation that assessed summary data without individual identifiers; it was reviewed and approved by the Institutional Review Board of Sentara Healthcare Corporation.

Statistical analysis

For the primary outcome, we used a quasiexperimental design to compare all-cause HO infections due to an MDRO or *C difficile* per 10,000 patient-days (pooled MDRO and CDI divided by total patient-days ×10,000) for the study periods. We also compared HO pooled MDRO infections (pooled MDRO divided by total patient-days ×10,000), HO CDI IRs per 10,000 patient-days (CDI divided by total patient-days ×10,000), HO CLABSI IRs per 10,000 catheter-days (CLABSIs divided by total catheter-days ×10,000), and HO CAUTI IRs per 10,000 catheter-days (CAUTI episodes divided by total catheter-days ×10,000) for the study periods.

Incident rate ratios were calculated, comparing IRs between the new wing or old wing during the assessment period and the hospital during the baseline period. Device use rates were calculated by dividing the total number of central venous or indwelling bladder catheter-days by the total number of patient-days, respectively. Comparison of categorical variables was performed using the Pearson χ^2 test. *P* values < .05 were considered statistically significant. All analyses were performed using SPSS, version 21.0 (IBM-SPSS Inc, Armonk, NY).

RESULTS

A total of 23,889 hospitalized patients were evaluated during the study, of whom 13,928 and 9,961 were hospitalized during the baseline and assessment periods, respectively. During the assessment period, 5,257 patients were hospitalized in the old wing, equipped with standard surfaces and linens, and 4,704 patients were hospitalized in the new wing, outfitted with copper-composite hard surfaces and linens through all beds (Fig 1). Demographic and clinical characteristics are summarized in Table 1. Compared with the baseline period, individuals hospitalized in the old hospital wing during the assessment period were primarily medicine patients, whereas those hospitalized the new wing were more likely to be surgical or surgical subspecialty patients, reflecting the geographic admitting practices of the hospital following the opening to the new wing. Individuals hospitalized in the old wing were more likely to be black, less likely to be white or Asian, and more like to have congestive heart failure, cirrhosis, end-stage renal disease, or HIV or AIDS compared with the baseline period. Individuals admitted to the new hospital wing were more likely to be white, less likely to be black or Asian, and less likely to have congestive heart failure, chronic obstructive pulmonary disease, diabetes mellitus, or end-stage renal disease compared with the baseline period. Individuals admitted to the old wing but not the new wing were more likely

Table 1
Demographic and patient characteristics

Characteristic	Admissions				
	Baseline period (n = 13,928)	New hospital wing (n = 4,704)	*P* value[*]	Old hospital wing (n = 5,257)	*P* value[*]
Age (y)					
Median	59.5	58.5		60.5	
Interquartile rage	37.0-82.0	36.5-80.5		38.5-82.5	
(min, max)	(15, 106)	(15, 113)		(17, 107)	
Gender					
female	8,845 (63.5)	2,806 (59.6)	< .001	2,949 (56.1)	< .001
Race/ethnicity					
White	8182 (58.7)	3059 (65.0)	< .001	2947 (56.1)	< .001
Black	4,199 (30.2)	1,295 (27.5)	.001	2037 (38.8)	< .001
Asian	337 (2.4)	86 (1.8)	.019	94 (1.8)	.009
Hispanic/Latino	230 (1.6)	67 (1.4)	.282	68 (1.3)	.074
Other/unknown	980 (7.0)	197 (4.2)	< .001	111 (2.1)	< .001
Comorbidities					
Congestive heart failure	435 (3.1)	76 (1.6)	.001	420 (8.0)	< .001
Cirrhosis/liver failure	60 (0.4)	12 (0.3)	.093	41 (0.8)	.003
Chronic obstructive pulmonary disease	310 (2.2)	27 (0.6)	< .001	130 (2.5)	.308
Diabetes mellitus	192 (1.4)	42 (0.9)	.010	85 (1.6)	.217
End-stage renal disease	373 (2.7)	59 (1.2)	< .001	264 (5.0)	< .001
HIV/AIDS	19 (0.1)	6 (0.1)	.886	22 (0.4)	< .001
Prior admissions[†]					
Prior 1-30 d	541 (3.9)	187 (4.0)	.781	348 (6.6)	< .001
Prior 31-180 d	1,781 (12.8)	647 (13.8)	.089	1,016 (19.3)	< .001
Prior *Clostridium difficile* infection[†‡]	36 (2.58)	16 (3.40)	.359	29 (5.52)	.002
Prior multidrug-resistant organism colonization/infection[†‡§]					
Methicillin resistant *Staphylococcus aureus*	31 (2.22)	15 (3.19)	.250	19 (3.61)	.093
Vancomycin-resistant *Enterococcus*	5 (0.36)	2 (0.43)	.840	2 (0.38)	.945
Multidrug-resistant *Acinetobacter* spp	4 (0.29)	1 (0.21)	.787	4 (0.76)	.711
Admission service					
Medicine service	6,376 (66.1)	1,722 (37.0)	< .001	5,134 (93.1)	< .001
Surgery/surgical subspecialty service	2,928 (33.9)	2,927 (63.0)	< .001	383 (6.9)	< .001
Admission characteristics					
Mean length of stay	4.49	4.65		4.66	
Need for intensive care unit care	5,209 (37.4)	2,651 (56.4)	< .001	2192 (41.7)	< .001
In-hospital mortality	388 (2.8)	195 (4.1)	< .001	94 (1.8)	< .001

NOTE. Data are presented as n (%) of admissions, unless otherwise indicated.

[*] Compared with baseline period.

[†] Within the past 30 days.

[‡] Number (cases/1,000 admissions).

[§] No patients were identified with prior known carbapenem-resistant Enterobacteriaceae colonization or infection.

to have been hospitalized in a Sentara Healthsystem hospital within the prior 180 days.

A small minority (<1%) of admitted patients had a prior known history of *C difficile* infection and/or MDRO colonization or infection through the study periods. Although there was no difference in the incidence of prior MDRO colonization/infection in patients hospitalized in either wing during the assessment period compared with the baseline period, more patients had a history of *C difficile* infection in the old wing compared with the baseline period. During the assessment period, individuals admitted to either the old or the new hospital wing spent a portion of their admission in the intensive care unit compared with the baseline period. Finally, patients admitted to the new wing were more likely to die during their admission compared with the baseline period, whereas those admitted to the old hospital wing were less likely to die compared with the baseline period.

The baseline period included a total of 46,391 patient-days. The assessment period included a total of 33,656 patient-days distributed between the new wing (14,479 patient-days; 43%) and the old wing (19,177 patient-days; 57%). Overall, IR of pooled MDRO and CDI was 6.25 events per 10,000 patient-days during the baseline period (95% CI, 6.21-6.30). During the assessment period, IR of pooled MDRO and CDI fell to 1.38 events per 10,000 patient-days in the new wing (95% CI, 1.32-1.44; $P = .023$; Table 2). By comparison, IR of pooled MDRO and CDI was unchanged at 8.34 events per 10,000 patient-days in the old wing (95% confidence interval [CI], 8.29-8.40; *P* = not significant) (Table 2). Incident rate ratios for the new wing and the old wing compared with historic data were 0.221 and 1.335, respectively.

Subanalysis demonstrated a reduction in IR of CDI in the new wing, with 0.69 (95% CI, 0.65-0.73) events per 10,000 patient-days during the assessment period ($P = .048$) (Table 2) compared with 4.10 (95% CI, 4.05-4.14) events per 10,000 patient-days during the baseline period, whereas the IR of CDI in the old wing during the assessment period remained stable at 4.69 (95% CI, 4.62-4.76) events per 10,000 patient-days (*P* = not significant) (Table 2) compared with the baseline period. IRs of pooled MDRO in the new and old wings were 0.69 (95% CI, 0.65-0.73) and 3.65 (95% CI, 3.58-3.72) events per 10,000 patient-days, respectively, during the assessment period, compared with an IR of 2.16 (95% CI, 2.12-2.19) events per 10,000 patient-days during the baseline period (both *P* = not significant) (Table 2). IRs of CLABSI and CAUTI were not different during the assessment period for either the new wing or the old wing compared with the baseline period (Table 3).

Hand hygiene compliance was 94% of all observed hand hygiene opportunities during the baseline period and was 88% and 87% for the new wing and the old wing, respectively, during the assessment period. A total of 10 patients hospitalized in new wing

Table 2
Incidence rates of *Clostridium difficile* infections (CDIs) and multidrug-resistant organisms infections (MDROs) during the baseline period (November 15, 2012-November 16, 2013), before installation of copper-containing hard surfaces and linens, and during the assessment period (March 1-December 31, 2014), after installation of copper-composite hard surfaces and linens in the new hospital wing

Health care-associated infection category	Baseline period (n = 46,391 patient-days)	Assessment period: New hospital wing, copper (n = 14,479 patient-days)		Assessment period: Old hospital wing, no copper (n = 19,177 patient-days)	
	Incidence rate[*] [95% confidence interval] (events)	Incidence rate[*] [95% confidence interval] (events)	*P* value	Incidence rate[*] [95% confidence interval] (events)	*P* value
Clostridium difficile	4.10 [4.05-4.14] (19)	**0.69 [0.65-0.73] (1)**[†]	**.048**[†]	4.69 [4.62-4.76] (9)	.736
MDROs					
Methicillin-resistant *Staphylococcus aureus*	(3)	(0)		(2)	
Vancomycin-resistant *Enterococcus*	(5)	(1)		(3)	
Extended spectrum β-lactamase Enterobacteriaceae	(1)	(0)		(1)	
Multidrug-resistant *Acinetobacter* spp	(0)	(0)		(0)	
Carbapenem-resistant Enterobacteriaceae	(1)	(0)		(1)	
Total	2.16 [2.12-2.19] (10)	0.69 [0.65-0.73] (1)	.252	3.65 [3.58-3.72] (7)	.280
Total *Clostridium difficile* + MDROs	6.25 [6.21-6.30] (29)	**1.38 [1.32-1.44] (2)**[†]	**.023**[†]	8.34 [8.29-8.40] (16)	.352

[*] Incidence rates are expressed per 10,000 patient-days.
[†] Boldface type indicates *P* value ≤ .05.

Table 3
Incidence rates of central line-associated bloodstream infections (CLABSIs) and catheter-associated urinary tract infections (CAUTIs) during the baseline period (November 15, 2012- November 16, 2013), before installation of copper-containing hard surfaces and linens, and during the assessment period (March 1-December 31, 2014), after installation of copper-composite hard surfaces and linens in the new hospital wing

Health care-associated infection category	Baseline period		Assessment period: New hospital wing, copper			Assessment period: Old hospital wing, no copper		
	Device use (catheter-days)	Incidence rate [95% confidence interval] (events)	Device use (catheter-days)	Incidence rate [95% confidence interval] (events)	*P* value	Device use (catheter-days)	Incidence rate [95% confidence interval] (events)	*P* value
CLABSI	0.156 (7,250)	6.90 [6.79-7.00] (5)	0.181 (2,620)	3.82 [3.63-4.00] (1)	.584	0.176 (3,368)	8.91 [8.80-9.01] (3)	.726
CAUTI	0.187 (8,672)	6.92 [6.82-7.02] (6)	0.231 (3,344)	0 (0)	.128	0.138 (2,649)	3.78 [3.59-3.96] (1)	.569

NOTE. Incidence rates are expressed per 10,000 catheter-days.

developed skin rashes with a concern for a copper-associated skin hypersensitivity reaction. Nine were evaluated by dermatology and determined to have an alternative etiology for their skin rash. One patient was discharged before the reaction could be assessed.

DISCUSSION

In this study, we demonstrate that a newly constructed hospital wing with broad deployment of copper-composite hard surfaces and linens had 78% fewer HO infections due to MDROs or *C difficile* relative to the baseline period. Compared with historic data, use of copper-composite hard surfaces and linens was also associated with 83% fewer HO CDI and 68% fewer HO MDRO infections, although the latter did not reach statistical significance. By contrast, no significant changes in HO total MDRO or *C difficile* infections, HO CDIs, or total MDRO infections were observed in patients admitted in parallel to the old hospital wing compared with the baseline period. Together, these results suggest that antimicrobial surfaces and linens may have substantial influence in reducing HAIs due to problematic MDROs in a hospital that has already employed aggressive infection control measures and has low rates of HAIs. However, no differences were observed in device-associated infections in patients cared for in room outfitted with the copper-containing products.

Contaminated environmental surfaces in hospitals are increasingly being recognized as potential reservoirs for health care-associated pathogens that may be transmitted to patients, for example through unclean hands, contaminated medical equipment, or direct interactions with the environment by a patient.[2-4,6,17] Hospital staff, even when using protective equipment such as gloves, may contaminate themselves by touching contaminated surfaces and then may transfer microorganisms to other patients, either directly or indirectly by contaminating other surfaces.[18,19] Similarly, textiles in hospitals have been hypothesized to be an important source of cross-contamination and transmission of MDROs in clinical environments.[13] Textiles are an excellent substrate for bacterial and fungal growth under appropriate moisture and temperature conditions, and studies have shown that bacteria and fungi can survive for prolonged periods (in some cases up to 3 months) on hospital fabrics.[20] Microbial shedding from the body occurs continuously and may be greater in hospitalized or ill individuals. Thus a bacterium, when shed onto a textile fabric between the patient and the bed, can survive and proliferate in the warm, moist setting of the textile microenvironment.[21] Like hard surfaces, contaminated textiles can then cross-contaminate the hands of hospital personnel or shared medical equipment.[19] Moreover, activities such as bed making and undressing may release microbes into the air that contaminate adjacent hospital surfaces.[22]

Copper has potent intrinsic biocidal activity for a broad spectrum of microorganisms.[12] Several recent studies have demonstrated that copper-containing surface materials, including the copper-composite hard surfaces used in this study, can reduce microbial loads on various clinical surfaces by 60%-100%.[14,23] Copper incorporated into hospital textiles has also been demonstrated to have potent biocidal properties, resulting in hospital linens with 46%-50% reduced microbial loads compared with standard linens.[15]

This study represents the largest clinical trial of copper or copper-containing antimicrobial surfaces reported to date, with more than 14,000 patient care days in 72 copper-furnished acute care hospital beds. The largest previous clinical trial of copper antimicrobial hard surfaces was a randomized control trial performed in 16 medical ICU rooms (8 copper and 8 control) in 3 hospitals in New York and South Carolina. The study compared the clinical outcomes of persons hospitalized in copper-furnished rooms (294 patient-days) to persons hospitalized in noncopper control rooms (320 patient-days) and found a 58% reduction in HAIs and a 42% reduction HAIs and/or new MRSA or VRE colonization in patients in the copper-furnished rooms.[24] Antimicrobial linens containing copper oxide particles have also been evaluated in a clinical setting. In a quasiexperimental study conducted at an Israeli chronic care head injury ward across 2 6-month time periods, patients exposed to copper-impregnated linens (3,940 patient-days) had 24% fewer HAIs, fewer days of fevers, and reduced antibiotic use than patients who were using standard linens (4,337 patient-days).[15] The reduced incidence of HAIs observed in this investigation are comparable to those reported in these earlier studies; however, in contrast to prior studies, this investigation occurred with patients admitted to an acute care hospital with low rates of HAI at baseline.

An unexpected finding was that the single largest reduction in HAIs observed in persons hospitalized in rooms with copper-impregnated biocidal products was the reduction in CDI. *C difficile* endospores are intrinsically resistant to contact killing by copper, which has led some experts to question whether copper and copper-containing products could reduce *C difficile* in hospital environments.[2,25] However, vegetative *C difficile* is readily killed by copper, which could reduce the time available for vegetative *C difficile* to successfully undergo sporulation and thereby reduce environmental contamination by *C difficile* endospores.[25] Moreover, the copper-composite hard surfaces used in this study have some activity against *C difficile* endospores. Under experimental conditions, exposure to the copper-composite hard surfaces used in this study leads to a 1.6 $\log_{10}$ reduction in viable *C difficile* endospores over 24 hours of exposure (A. Monk, personal communication), which is similar to what has been previously reported for copper and copper alloys.[26]

The study has several strengths. It is largest clinical trial of copper or copper-containing antimicrobial surfaces reported to date, with more than 67,000 patient-care days distributed between the different arms of the study, including nearly 14,500 patient care days in copper-furnished acute care hospital beds. To our knowledge, it is also the first study to explore the combined use of both self-disinfecting hard surfaces and linens in the same investigation. Deployment of antimicrobial hospital linens as well as antimicrobial hard surfaces in patient rooms and common work areas provides perhaps the most comprehensive use of self-disinfecting surfaces used to date. Finally, it reports the real-world experience of using these products in an institution with low rates of MDRO and device-associated infections.

However, there are several important limitations to this study. Differences in patient characteristics, demographic characteristics, or risk factors for HO *C difficile* and/or MDRO infection in individuals hospitalized the new hospital wing and/or the old hospital wing may have influenced the study results. Notably, the admission types of the new wing and old wing were markedly different: A majority of admissions to the new wing were surgical patients, whereas those hospitalized in the old wing were nearly exclusively medicine patients. Perhaps reflecting this difference in admission type, patients admitted to the old wing were more likely to have medical comorbidities, whereas those admitted to the new wing were generally less likely to have medical comorbidities. Furthermore, those admitted to the old wing were also more likely to have been admitted to the hospital in the prior 180 days. Although these could be predicted to influence exposure to MDROs before hospitalization, no difference was noted in MDRO colonization/infection of patients hospitalized in either wing during the assessment period compared with the baseline period. However, patients in the old wing but not the new wing were more likely to have a history of *C difficile* infection in the prior 6 months. Unfortunately, some patient-specific risk factors, such as antibiotic consumption based on geographic location of admission, could not be obtained for this analysis. As a quasi-experimental study with a control group, other potential confounders may not have been recognized between patient populations over time or by hospital geography.

In addition to patient-specific factors, differences in the physical configuration and furnishings of the newly constructed wing and the rest of the hospital not associated with the use of copper-composite surfaces may have been another confounder. For example, the rooms in the new wing were 112% larger than those in the existing hospital. Interestingly, Jou et al[27] recently reported a positive association between hospital room square footage and risk of CDI. The authors speculate that this association is the consequence of increased environmental cross-contamination and/or inadequate room cleaning. In this study, the lowest rates of CDI observed were in rooms of the new wing, which were the largest acute care rooms in Sentara Leigh Hospital.

It should also be noted that data were collected retrospectively by the IPC program personnel during the study. Although no significant changes were made in the IPC program for the duration of the study, we cannot guarantee that recall bias did not occur as a consequence of the retrospective review. Lack of blinding may have also led to reporting bias among staff or even patients. The study did not assess new colonization of MDROs during hospitalization; consequently, a thorough evaluation of the effect of copper-impregnated composite materials on MDRO transmission could not be performed. Finally, the relative contribution of specific hard surfaces or linens to potential protection from HAIs cannot be determined from this study.

Conclusions

This study demonstrates that broad deployment of biocidal copper-composite hard surfaces and linens was associated with fewer HAIs, notably including CDI, in a population of acute care hospitalized patients. As constitutively active, horizontal infection prevention measures, self-disinfecting surfaces and linens represent a novel approach to limiting transmission of MDROs and reducing HAIs. Like no-touch automated decontamination technologies, these technologies should not be viewed as replacement for proper environmental hygiene practices, but rather as means to augment infection prevention in hospitals. Additional studies using more rigorous methods and trial designs are needed to better determine the efficacy of copper-containing hard and soft surfaces for infection prevention in modern clinical environments.

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