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Effect of copper-impregnated composite bed linens and patient gowns on healthcare-associated infection rates in six hospitals

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SUMMARY

Background: Hospital linens and patient gowns are frequently touched and contaminated, and may contribute to endogenous, indirect-contact, and aerosol transmission of nosocomial-related pathogens. Recently Sentara Healthcare adopted biocidal copper oxide-impregnated linens across its hospitals.

Aim: To assess whether the replacement of the linens resulted in the reduction of healthcare-associated infection (HCAI).

Methods: Rates of HCAI caused by *Clostridium difficile* and multidrug-resistant organisms (MDROs) were compared in six Sentara Healthcare hospitals with similar patient demographics (total of 1019 beds) in three parallel periods (90, 180 and 240 days) before and after (periods A1, A2 and A3, and periods B1, B2, and B3, respectively), replacing all the regular non-biocidal linens with the copper oxide-impregnated biocidal linens.

Findings: During periods B1, B2, and B3, compared with periods A1, A2 and A3, there were 61.2% ($P < 0.05$), 41.1% ($P < 0.05$) and 42.9% ($P < 0.01$) reductions in HCAI per 10,000 patient-days in hospital caused by *C. difficile*, respectively; 48.3% ($P > 0.05$), 36.4% ($P > 0.05$), and 19.2% ($P > 0.05$) reductions in HCAI per 1000 patient-days caused by MDROs; and 59.8% ($P < 0.01$), 39.9% ($P < 0.05$), and 37.2% ($P < 0.05$) in the reduction of HCAI per 1000 patient-days caused by *C. difficile* and MDROs combined.

Conclusion: The use of biocidal copper oxide-impregnated linens in the six analysed Sentara Healthcare hospitals resulted in significant reduction in both HCAI caused by *C. difficile*, and the combined metric of *C. difficile* or MDRO infection. Similar reductions in HCAI caused by MDROs were observed, although these reductions did not reach statistical significance, probably due to very low HCAI rates caused by these pathogens in the study facilities.

Introduction

Bed linens and patient gowns have been shown to be the surfaces most contaminated with meticillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile*, as well as being the most touched surfaces in a patient room [1–3].

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Copper has potent wide-spectrum biocidal properties, including efficacy against antibiotic-resistant bacteria [4,5]. The use in hospital environments of surfaces containing copper or copper oxide has been found to reduce bioburden and the transmission of healthcare-associated pathogens [4—10]. More recently, the use of linens, such as sheets, blankets, patient gowns, patient robes and pyjamas, towels, and washcloths with embedded copper oxide particles, has also been reported to reduce bioburden and healthcare-associated infection (HCAI) in several different clinical settings [10—13].

Sentara Healthcare System replaced the standard non-biocidal linens with biocidal copper oxide-impregnated linens in all 12 of its facilities. This study examined the effect of this deployment on HCAI rates, by comparing parallel time-periods before and after introduction of copper oxide-impregnated linens to six of the Sentara Healthcare hospitals with similar characteristics including patient demographics.

Methods

Study setting

This study was conducted in six Sentara Healthcare hospitals: Sentara Albermarle Hospital, Elizabeth City, NC (hereafter termed Facility 1); Sentara Halifax Regional Hospital, South Boston, VA (Facility 2); Sentara Martha Jefferson Hospital, Charlottesville, VA (Facility 3); Sentara Obici Hospital, Suffolk, VA (Facility 4); Sentara Rockingham Medical Center, Harrisonburg, VA (Facility 5); and Sentara Williamsburg Regional Medical Center, Williamsburg, VA (Facility 6). Demographic information for the six facilities is summarized in Table I.

All six facilities replaced their regular linens with copper oxide-impregnated woven linens (Cupron Medical Textiles; Cupron, Inc., Richmond, VA, USA) during the month of April 2017. The linens replaced included all patient gowns, pillowcases, fitted and flat sheets, washcloths, bath towels, bath blankets, and thermal blankets. Data taken from three different periods (90, 180 and 240 days) from all six hospitals before and after the replacement of the linens were analysed and compared. The 90 days analysed (period A) are a subset of the 180-day analysis (period B), which in turn are a subset of the 240-day analysis (period C). The study time-periods compared were a 90-day control period pre-intervention from May 1st to July 31st, 2016 (period A1) with an interventional 90-day time-period post intervention of biocidal linens of May 1st to July 31st, 2017 (period B1). Additionally, a 180-day control pre-intervention time-period from May 1st to October 31st, 2016 (period A2) was compared with a test post-intervention period of May 1st to October 31st, 2017 (period B2); and a 240-day control pre-intervention time-period between May 1st to December 31st, 2016 (period A3) with a test post-intervention period of May 1st to December 31st, 2017 (period B3).

Infection prevention and control programme

Similar HCAI prevention measures and practices according to Sentara standard operation procedures were implemented consistently in all facilities during both 2016 and 2017. These practices included: isolation precaution practices in accordance with professional guidelines, room cleaning and disinfection with validation education, cleaning checklists and monitoring of cleaning thoroughness using Dazo fluorescent marking gel (Ecolab, St Paul, MN, USA) in 2016, and the AccuPoint® ATP monitoring system (Neogen, Lansing, MI, USA) in 2017. Routine daily and terminal cleaning used quaternary ammonium disinfectants, except for patients with *C. difficile* infection, where a hypochlorite product was used. Processes for insertion, maintenance, and removal of urinary and vascular catheters were comparable across the facilities.

Surveillance cultures for MRSA, vancomycin-resistant enterococci (VRE) or other MDRO colonization were not routinely performed. Neither ultraviolet light nor hydrogen peroxide was used for environmental decontamination. Unit-level hand hygiene compliance rates were assessed through an ongoing, anonymous cross-auditing programme by infection prevention and unit-based staff; no major changes in the hand hygiene programme occurred during the study. Hand hygiene compliance rates were as follows: Facility 1: 97% vs 98%; Facility 2: 99% vs 99%; Facility 3: 98% vs 90%; Facility 4: 98% vs 99%; Facility 5: 99% vs 99%; Facility 6: 98% vs 97%. During the study, educational efforts were undertaken across both years, namely to reinforce best practices for disinfection by Environmental Services Department personnel (2016), and for testing for *C. difficile* infection (2017).

The Det Norske Veritas/Germanischer Lloyd (DNV GL) infection risk certification programme was in place in all six facilities by 2016.

HCAI surveillance and definitions

HCAI surveillance was performed retrospectively through the existing Infection Prevention and Control Programme of the hospital. The primary endpoint was the incidence rate of hospital-onset infections, using National Healthcare Safety Network (NHSN) definitions, due to an MDRO or *C. difficile* infection. MDROs included MRSA, VRE, extended-spectrum β-lactamase, multidrug-resistant *Acinetobacter baumannii*, and carbapenem-resistant Enterobacteriaceae. Hospital onset was

Table I
Hospitals' and patients' demographic information

Facility	Location	No. of staffed beds	Bed use rate (%)	Average daily census	Total acute days	Adjusted patient-days	Average length of stay (days)	Medical CMI	Surgical CMI	CC/MCC rate
1	Rural	142	41.8	59.4	22,721	57,954	4.3	1.19	2.55	0.64
2	Rural	192	21.0	40.3	15,633	48,758	4.2	1.24	2.49	0.64
3	Urban	150	59.3	89.0	36,095	124,556	3.9	1.19	2.54	0.60
4	Urban	158	56.3	88.9	35,929	92,075	4.0	1.20	2.72	0.61
5	Rural	238	57.9	137.8	53,917	172,321	4.0	1.18	2.86	0.62
6	Urban	139	50.0	69.6	27,587	72,733	3.8	1.15	2.43	0.58

CMI, case-mix index; CC/MCC rate, comorbidity and medical complication rate.

defined as events that occurred on or after hospital day 3, using NHSN rules. The location of attribution of the infection was assigned to the inpatient location where the hospital-onset infection occurred, following (when applicable) the NHSN transfer rule for events that occurred on the day of or after a patient transfer or discharge.

Incidence rates of hospital-onset infections due to MDROs and/or *C. difficile* were calculated based on the total number of patient-days of acute care unit occupancy.

Statistical analysis

The three types of infection analysed were *C. difficile*, all MDROs, and total infections. The infection rates were calculated using patient-days. The infection rates at baseline were compared to the infection rates at the assessment using a Fisher's exact test performed with SAS version 9.4 (Cary, NC, USA). The actual counts and patient days were used for the statistical testing. The infection rates were normalized to 1000 or 10,000 patient-days in hospital.

Results

Table II summarizes the number of *C. difficile*, MDROs, and *C. difficile* and MDROs combined, HCAI incidences, and incidence rate per patient-days during the studied periods.

During periods B1, B2, and B3, compared with periods A1, A2 and A3, there were 61.2% ($P < 0.05$), 41.1% ($P < 0.05$) and 42.9% ($P < 0.01$) reductions in HCAIs per 10,000 patient-days in hospital caused by *C. difficile*, respectively; 48.3% ($P > 0.05$), 36.4% ($P > 0.05$), and 19.2% ($P > 0.05$) reductions in HCAIs per 1000 patient-days caused by MDROs; and 59.8% ($P < 0.01$), 39.9% ($P < 0.05$), and 37.2% ($P < 0.05$) in the reduction of HCAIs per 1000 patient-days caused by *C. difficile* and MDROs combined (Figure 1).

Discussion

Microbially contaminated surfaces play an important role in transmission of nosocomial pathogens [14]. The higher the bioburden, the higher the risk of nosocomial transmission of the pathogens. Surfaces in close proximity to the patients become readily contaminated [14]. Patients, for example, shed bacteria via bodily secretions or from intact or breached skin into their linen. Whereas micro-organisms may persist and survive for long periods on inanimate surfaces [14,15], without an appropriate micro-environment, such as appropriate moisture and temperature, they cannot proliferate. Such a micro-environment exists between patients and their gown, sheets and other patient-contacting textiles. Linens thus can contribute to HCAI via significant endogenous, indirect-contact, and aerosol transmission of nosocomial pathogens [16]. Accordingly it has been hypothesized that the use of biocidal textiles may contribute to the reduction of HCAI [16].

Indeed, several studies have indicated that the use of biocidal medical textiles can help reduce HCAI rates. Lazary *et al.* [11] completed a before-and-after study of copper oxide-impregnated linens introduced into a head injury ward. The six-month baseline period was followed by a six-month intervention period. There was a 24% reduction in incidence rate from 27.4 to 20.8 per 1000 patient-days ($P = 0.046$). Marcus *et al.* conducted a non-randomized cross-over study in two chronic ventilator-dependent patient wards [12]. For three months, one ward received copper oxide-impregnated textiles while the other received untreated textiles. After a one-month wash-out period, the wards were alternated for another three-month period. Staff members were masked to the treatment and control groups by colour-coding the linen. HCAI indicators were assessed: antibiotic treatment initiation events, fever days (axillary temperature >37.6°C), days of antibiotic treatment and antibiotic defined daily dose (DDD) per 1000 hospitalization days. There were reductions of 29.3% ($P = 0.002$), 55.5% ($P < 0.0001$), 23.0% ($P < 0.0001$), and 27.5% ($P < 0.0001$) in antibiotic treatment initiation events, fever days, days of antibiotic treatment and antibiotic DDD per 1000 hospitalization days, respectively.

Based on these studies, and as part of the strong desire of the Sentara Healthcare System to improve healthcare and give the best possible protection to patients, it was decided to replace the linen in all its facilities to biocidal copper oxide-impregnated linen as well as to replace hard surfaces, such as bed rails, patient and staff countertops, with copper oxide biocidal composite surfaces.

Sifri *et al.* investigated the effect of using both copper oxide-containing linens and composite hard surfaces on HCAI rates in a 204-bed acute care Sentara hospital located in Norfolk, Virginia [10]. They compared the HCAI rates obtained from a copper-containing new hospital wing (14,479 patient-days; 72 beds) with those from the baseline (46,391 patient-days; 204 beds) and with an unmodified hospital wing (19,177 patient-days; 84 beds). The new wing had 78% ($P = 0.023$) fewer HCAIs due to MDROs or *C. difficile*, 83% ($P = 0.048$) fewer cases of *C. difficile* infection, and 68% ($P = 0.252$) fewer infections due to MDROs relative to the baseline period.

Table II
Number of healthcare-associated infection incidences normalized to the number of hospitalization days

Period		Hospitalization days	*C. difficile* alone		MDROs alone		*C. difficile* and MDROs combined	
Days	Name		No. of incidences	Infection rates[a]	No. of incidences	Infection rates[a]	No. of incidences	Infection rates[a]
90	A1	29,865	20	6.70	5	0.17	25	0.84
	B1	34,625	9	2.60	3	0.09	12	0.34
180	A2	59,662	36	6.03	12	0.20	48	0.80
	B2	70,326	25	3.55	9	0.13	34	0.48
240	A3	81,448	47	5.77	15	0.18	62	0.76
	B3	94,125	31	3.29	14	0.15	45	0.48

MDRO, multidrug-resistant organism.
[a] Per 10,000 patient hospitalization days.

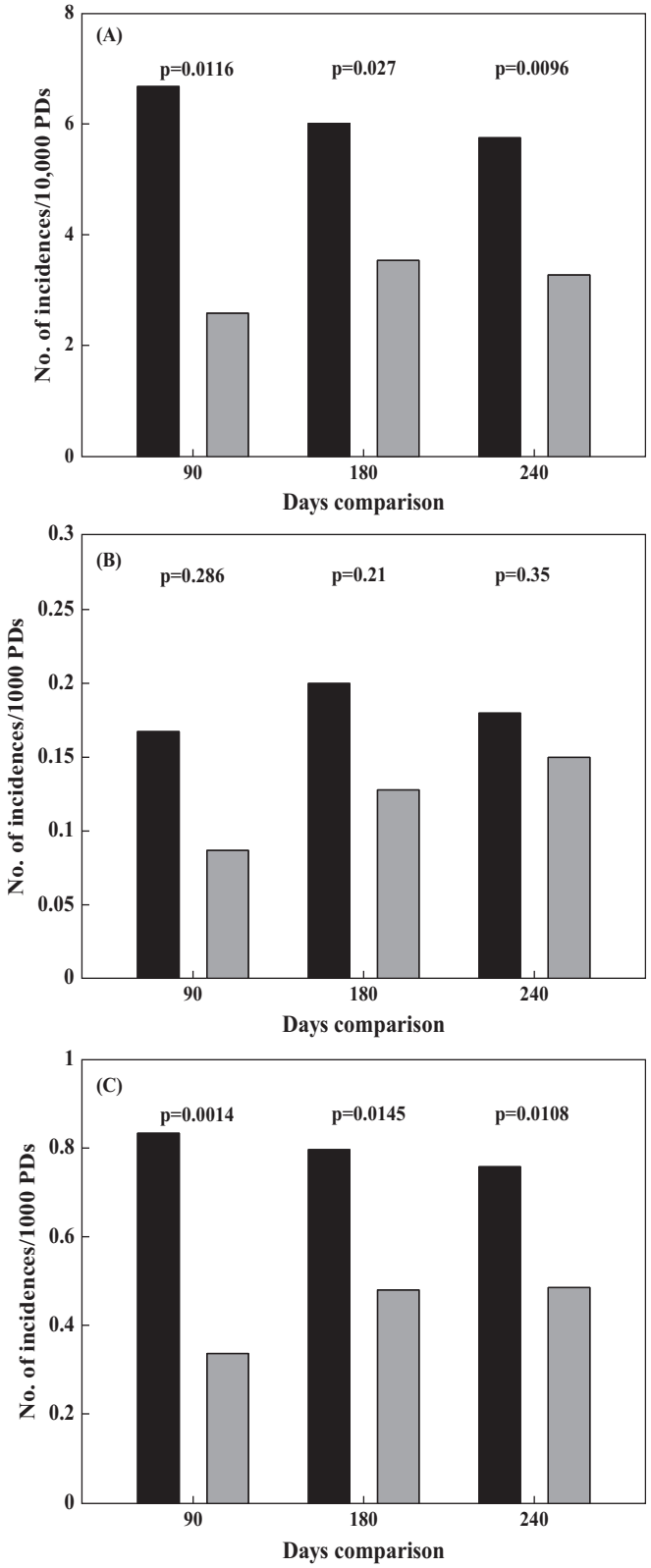

Figure 1. Healthcare-associated infection rates in 2016 (black bars) and 2017 (grey bars) caused by (A) *Clostridium difficile*, (B) multidrug-resistant organisms (MDROs), and (C) *C. difficile* and MDROs combined. PDs, patient-days in hospital.

Burke and Butler analysed potential confounding factors in the Sifri *et al.*'s study, such as of new construction and DNV-MIR accreditation to mitigate risk of HCAI, by undertaking a retrospective analysis of three hospitals within the Sentara Healthcare System [10,13]. DNV-MIR is a new certification programme from DNV GL (Oslo, Norway) that certifies facilities as Centres of Excellence in Managing Infection Risk, which recognizes exceptional processes and an approach to mitigating infection risk that exceeds current standards. Facilities 1 and 2 shared the circumstance of new construction. Facilities 1 and 3 shared the processes of DNV-MIR. Only Facility 1 undertook the intervention of copper-impregnated products. They compared incidence rate following their normalization per 10,000 patient-days before and after complete implementation of copper-impregnated products. Facility 1 had 28% reduction in total *C. difficile* and MDROs incidence rate, while Facilities 2 and 3 had 103% and 48% increases in total incidence rate respectively [13]. This analysis supported the contention that the copper-impregnated products contributed to the reduction in incidence rate.

In the current study the contribution of the copper oxide-impregnated linens to the reduction of HCAI before the introduction of the biocidal hard surfaces was analysed. This was done by examining the incidence rate caused by *C. difficile* and MDROs in six small- to medium-sized hospitals of the Sentara Healthcare System (between 138 and 238 beds per hospital), by comparing 240-day parallel periods before and after replacing the regular linen with the biocidal linen. Subsets of these 240-day periods were also compared, i.e. 90- and 180-day periods before and after replacement of the linens. This approach was taken to assess whether the observed differences occur also shortly after the intervention, and whether the effect is long-lasting. These six hospitals were chosen as they have very similar profiles geographically, similar size, number of beds, and patient demographics and case-mix index. All of these hospitals adhere to the same HCAI prevention guidelines and standard operating procedures established in the Sentara Healthcare System. As the HCAI incidence rate in each hospital is very low, the data of all six hospitals were analysed as one set. We choose to compare parallel periods in order to 'neutralize' potential seasonal effects on the HCAI incidence rate.

The primary comparison, in terms of understanding the effect of the intervention, is the 240-day comparison. It showed a statistically significant reduction of $\sim$43% ($P < 0.01$) in the HCAIs per 10,000 patient-days in hospital caused by *C. difficile*. This is in accordance with the reductions of HCAI caused by *C. difficile* reported for other Sentara Hospitals [7,10]. Since the 240-day period was significant, the 90- and 180-day subsets were also examined. Similar such reductions were observed also at the 90- and 180-day comparisons performed. Our analysis indicates that the effect of the antimicrobial linens and patient gown was not reduced over time. No statistically significant reductions were observed for MDRO-caused HCAIs, probably due to the very low incidences of such HCAIs, but there were clear trends of reduction observed in all three analysed periods, also in accordance with the reductions observed in the other Sentara Hospitals analysed [7,10].

This was a quasi-experimental trial and therefore some factors were not controlled, such as the continuous education efforts undertaken to reinforce best practices for disinfection,

which may have also contributed to the reduction of the HCAI rates. The study supports the notion that the use of the copper oxide-impregnated biocidal linens may contribute to a reduction of HCAI caused by *C. difficile* and MDROs, and that the use of biocidal linen may be an important additional measure in the fight against nosocomial infections in clinical settings.

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Conflict of interest statement
None declared.

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