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Major article

Long-term efficacy of a self-disinfecting coating in an intensive care unit

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Key Words:
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Background: Cleaning and disinfecting fomites can effectively remove/kill pathogens on surfaces, but studies have shown that more than one-half the time, surfaces are not adequately cleaned or are recontaminated within minutes. This study evaluated a product designed to create a long-lasting surface coating that provides continuous disinfecting action.

Methods: This study was performed in an intensive care unit (ICU) in a major hospital. Various sites within the ICU were cultured before treatment and then at 1, 2, 4, 8, and 15 weeks after application of an antimicrobial coating. Samples were cultured for total bacteria, as well as *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococcus, and carbapenemase-resistant Enterobacteriaceae.

Results: The average bacterial count on all treated surfaces was reduced by >99% (2 logs) for at least 8 weeks after treatment. Overall, average levels of bacteria never returned to those observed before treatment even after 15 weeks. Antibiotic-resistant bacteria were found on 25% of the sites tested before treatment, but were isolated at only 1 site during the 15 weeks after treatment.

Conclusions: The product assessed in this study was found to have persisted over 15 weeks in reducing the total number of bacteria and antibiotic resistant bacteria on surfaces within an ICU.

Contamination of inanimate objects (fomites) and surfaces are known to contribute to the transmission of health care–associated infections (HAIs), especially those related to antibiotic-resistant bacteria.[1] Some infection control guidelines recommend the routine disinfection of patient care surfaces, especially high-touch objects. Such objects presumably contribute to the transmission of pathogens by contaminating the hands of health care workers who subsequently contact patients.[1,2]

Routine and terminal cleaning of surfaces using hospital-grade disinfectants is an accepted method for controlling the spread of infectious agents. Cleaning and disinfecting fomites can effectively remove/kill pathogens on surfaces, but studies have shown that more than one-half the time, surfaces are not adequately cleaned and may be recontaminated within minutes.[2,3]

Commonly used disinfectants (eg, chlorine, hydrogen peroxide, quaternary ammonium compounds) provide no persistent residual activity after their application to disinfect surfaces, because they are easily washed away. In addition, application of disinfectants needs to be closely monitored, because cleaning cloths may reduce the effective concentration during actual use by cleaning crews.[4] Self-disinfecting surfaces that act against microbes on a continuing basis would specifically address these limitations in current cleaning and disinfecting practices.[5] Recently, copper surfaces have been shown to reduce the rate of occurrence of methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococcus (VRE) colonization of patients in ICU rooms, as well as the numbers of the organisms on surfaces.[6,7] They also have been shown to continuously reduce the concentration of total bacteria on bed rails within intensive care unit (ICU) rooms.[8]

The present study was designed to assess the effectiveness of ABS-G2015 (Allied BioScience, Point Roberts, WA), a formulation of a quaternary ammonium organosilane compound that binds to surfaces and produces a residual (ie, long-term) disinfecting activity. Our initial laboratory work demonstrated ABS-G2015's effectiveness against a wide range of pathogenic bacteria (eg, MRSA, *Pseudomonas aeruginosa*) and viruses (eg, MS-2 virus). The goal of this study was to assess its efficacy in a practical application in a health care environment.

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Table 1
Culture methods used for microbial isolation and identification

Organism	Culture method	Incubation conditions	Further analysis	Reference
Total bacteria	Spread plating on R2A medium (BD Diagnostics, Sparks, MD)	24°C for 5 d		13
C difficile	Incubation for 7 days in 0.1% sodium taurocholate and cycloserine-cefoxin fructose broth	Anaerobic conditions at 37°C for up to 5 d	A 2-mL aliquot was mixed with equal amounts of absolute ethanol. Bacteria were concentrated by centrifugation and pellets were used to inoculate cycloserine-cefoxtin fructose agar.	14
MRSA	Trypticase soy agar amended with 5% sheep's blood, 10 mg/L colistin, and 25 mg/naladixic acid using spread plate method	35°C for 24-48 h	β-hemolytic colonies were isolated and subcultured on trypticase case soy agar with no amendments and incubated at 35°C for 24-48 h.	15
CRE	Modified Hodge test; Muller-Hinton agar	35°C for 24 h		16
VRE	Bile esculin azide agar	37°C in CO_2 incubator for 24-48 h	Gram stain, catalase test	17

NOTE. From an original volume of 4 mL of sponge stick eluate. A 0.1-mL volume of this eluate was used for each assay.

Table 2
Average (arithmetic mean) total bacterial numbers (cfu) isolated on 100 cm^2 from fomites and percent reduction after treatment

		Weeks after treatment				
Variable	Baseline*	1	2	4	8	15
Number of samples	95	81	64	64	64	45
Average number of bacteria	233,064	98	80	43	2,247	3,320
Range	10-7,000,000	10-2,500	10-840	10-2,500	10-44,000	10-57,000
% reduction	NA	99.96	99.97	99.98	99.04	98.58

NA, not applicable.
*Before treatment.

Table 3
Percent cfu of total bacteria per 100 cm^2 exceeding values indicated

		Weeks after treatment				
Count, cfu per 100 cm^2	Baseline*	1	2	4	8	15
>100	71.5	11.1	17.2	12.8	51.2	33.3
>1,000	51.5	2.4	1.5	0	17.1	24.4
>10,000	25.2	0	0	0	4.6	11.1

*Before treatment.

MATERIALS AND METHODS

This study was conducted in a 24-bed ICU of a community hospital in Los Angeles County, California, between May 10 and September 30, 2013. Initial microbial sampling of various fomites was conducted to assess the levels of bacteria on various hospital surfaces before selection of study sites. After review, 95 sites in the ICU were selected for study.

In each patient room of the ICU, cultures were collected from the following sites: bed rails, bed controls, tray table, and wall above the sink. Samples also were collected from the 2 ICU nursing stations and waiting lobby, including countertops, phones, computer keyboards, chair armrests, and end tables. All movable items were inconspicuously tagged and coded over the course of the study so that the same objects (ie, surfaces) could be sampled.

Each of the sites was cultured before application of the ABS-G2015 product and at 1 week (6-8 days), 2 weeks (13-17 days), 4 weeks (29-32 days), 8 weeks (59-62 days), 15 weeks (104-107 days) after application. Some objects were removed and were not available for culture at some of the subsequent time points. The ABS-G2015 coating comprises both quaternary ammonium silyl oxide and titanyl oxide moieties, and is not commercially available at present.

The ABS-G2015 coating was applied with an electrostatic spray applicator on all surfaces in the ICU, including hard surfaces (eg, beds, tray tables, bed rail, walls.) and soft surfaces (eg, drapes, cloth- and vinyl-covered chairs), and left wet to dry. Surface preparation and application were done by trained certified technicians following a structured protocol. All applications were monitored for quality control by a manufacturer's representative. During the course of the study, hospital staff maintained their normal daily cleaning schedule, which involved disinfecting with reusable cloths containing bleach and/or reusable disposable quaternary ammonium wipes (PDI Sani-cloth; Professional Disposables International, Orangeburg, NY) containing dimethyl ethylbenzyl ammonium chloride and dimethyl benzyl ammonium chloride as active ingredients. No clinical interventions (eg, changes in hand hygiene practices) were instituted during the study period.

Microbial methods

Areas of 100 cm^2 were sampled using a sponge stick containing Letheen broth (3M, St Paul, MN) to neutralize any residual disinfectant. After collection, the samples were immediately placed on ice packs and sent overnight to the University of Arizona. On receipt, the broth was extracted from the sponge stick by manual agitation, and 4 mL of extracted broth was assayed using selective media for isolation of the various bacteria. Samples were cultured for total bacteria, *Clostridium difficile*, MRSA, VRE, and carbapenemase-resistant *Enterobacteriaceae* (CRE). Test methods for each organism are presented in Table 1. Total bacteria were measured using R2A medium and 5 days of incubation, which have been found to be sensitive for detecting bacteria in environmental samples.[9,10]

Data analyses

The data on bacterial concentrations did not demonstrate a normal distribution. Even after log transformation, the data did not meet the conditions of normality and homogeneity. Thus, we used bootstrapping techniques to conduct analysis of variance for each stage between the baseline concentrations of the sampled fomites and the intervention concentrations of the same fomites to determine statistical significance differences, based on a rejection region of 5%.[11,12]

RESULTS

The average numbers of total bacteria detected per 100 cm^2 at all locations and percent reductions in total bacterial numbers after

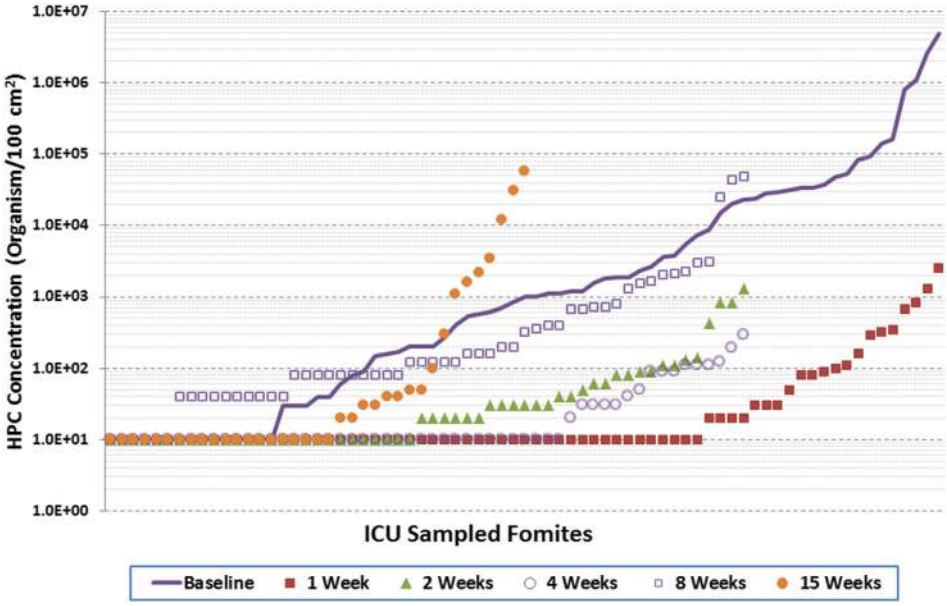

Fig 1. Total bacterial concentrations on sampled sites before and after treatment. Each dot represents the value at an individual sample site, from lowest value to highest value.

treatment are presented in Table 2. As shown in the table, bacterial numbers were always 99.9% (3 logs) less at 4 weeks after the treatment, 99% (2 logs) after 8 weeks, and still almost 99% (2 logs) after 15 weeks. Moreover, significantly, the number of sites containing >10,000 colony-forming units (cfu)/100 cm^2 was reduced from 71.5% of the sites before treatment to 0 for the next 8 weeks, and after even 15 weeks, only 11.1% of the sites exceeded this level (Table 3).

Bootstrapping analysis of variance was conducted for each stage between the baseline concentrations for the sampled fomites and the intervention concentrations for the same fomites to determine statistical significant differences based on a rejection region of 5%. Based on the *P* values (<.0005), there was a statistical significance difference between the baseline concentrations and the fomite concentrations during the entire 15 weeks of the study.

Colony counts of total bacteria per 100 cm^2 surface area for baseline samples (before treatment) and those collected after the application of the ABS-G2015 for fomites sampled in the ICU are represented graphically in Figure 1. This figure represents the distribution of bacterial numbers detected at each site before and after the intervention. Of note, peak values 15 weeks after treatment were still 100-fold (2 logs) less than those measured before treatment (baseline).

The percentage of samples in which antibiotic resistant bacteria were isolated at the various sites sampled is shown in Table 4. Antibiotic-resistant bacteria (except *C difficile*) were isolated from all study areas during the baseline sampling. VRE was the most commonly isolated organism. Before treatment, antibiotic-resistant bacteria were isolated from 25% of the sites (surfaces) sampled. After treatment, no antibiotic-resistant bacteria were isolated until week 8, when VRE was found in 1 of 64 samples (1.5%; from a chair armrest).

Table 4
Isolation of antibiotic-resistant bacteria (percent of positive sites)

		Weeks after treatment				
Variable	Baseline*	1	2	4	8	15
Number of samples	95	81	64	64	64	45
VRE	14	0	0	0	1	0
MRSA	7	0	0	0	0	0
CRE	3	0	0	0	0	0
C difficile	0	0	0	0	0	0
Overall percentage	25	0	0	0	1.5	0

*Before treatment.

DISCUSSION

Fomites and surfaces in the health care environment are known to play roles in the transmission of pathogens.[1] This knowledge has led to the study and development of self-sanitizing surfaces as a means to improve on usual cleaning and disinfecting practices.[5]

The present study demonstrates that the application of ABS-G2015 is capable of reducing the numbers of bacteria on surfaces by >99% (2 logs) for 8 weeks after a single treatment (Table 2). Levels of bacteria were reduced by 99.9% (3 logs) at 4 weeks after treatment. Overall, average levels of bacteria never returned to those observed before treatment. Bacterial numbers increased between 8 and 15 weeks posttreatment, but the average bacterial count on all treated surfaces was still <90% (1 log) after 15 weeks. No values >10,000 cfu/100 cm^2 were detected for 4 weeks after treatment, compared with 25.2% of value measured before treatment, and even after 15 weeks, only 11.1% of the values exceeded this level.

No antibiotic-resistant bacteria were isolated until 8 weeks after the treatment, and then at levels below those measured before the treatment (Table 4). No MRSA or CRE were isolated even after 15 weeks posttreatment, and VRE was isolated only at 8 weeks posttreatment. *C difficile* was not isolated at baseline or after the treatment; however, *C difficile* was isolated in the initial screening used to select the sampling sites (data not shown).

In a recently published study, Boyce et al[18] evaluated two organosilane-based quaternary products for their residual activity in patient rooms in a rehabilitation ward. Neither demonstrated any residual activity over a 4-wk period. The differences found in the present study could be related to the method of application (Boyce et al[18] used microfiber clothes rather than spray application as in the present study), product formulation (formulation of

quaternary ammonium disinfectants plays a major role in their activity against microorganisms and ability to adhere to surfaces[19]), daily cleaning methods by staff, or microbial assay methods (contact plates vs swab and dilution assay).

Based on the results of this study, we recommend applying the treatment every 3-4 months to ensure effective reduction of bacteria on the treated fomites. Copper surfaces are also antimicrobial and have been demonstrated to reduce exposure to bacteria on surfaces in patent wards.[7] Although directly comparing studies is difficult, the organosilane quaternary ammonium formulation used in the present study appears to be at least as effective in reducing the numbers of bacteria on surfaces and perhaps more effective in reducing the isolation of antibiotic-resistant bacteria on surfaces. Advantages of this treatment over copper surfaces is that it can be easily applied to existing facilities without the need to replace existing equipment, and that its spray application allows treatment of all surfaces (including fabrics), including hard-to-reach surfaces (eg, wall corners, crevices).

A limitation of the study was that some treated items were moved to other locations and could not be found. In addition, the number of rooms occupied by patients over time varied. Strengths of the study include the large area sampled (100 cm^2), use of media designed to optimized recovery of stressed bacteria, and long study duration.

In conclusion, the product assessed in this study was found to have persisted over 15 weeks in reducing the total number of bacteria and antibiotic resistant bacteria on surfaces within an ICU.

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