American Journal of Infection Control 44 (2016) 1705-8

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Brief Report

Reduction in bacterial contamination of hospital textiles by a novel silver-based laundry treatment

John J. Openshaw MD [a,*], William M. Morris BS [b], Gregory V. Lowry PhD [c], Aydin Nazmi PhD [d]

[a] Division of Infectious Diseases and Geographic Medicine, Stanford University, Stanford, CA
[b] Applied Silver, Hayward, CA
[c] Civil & Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA
[d] Department of Food Science and Nutrition, California Polytechnic State University, San Luis Obispo, CA

Key Words:
Silver ion
Staphylococcus aureus
MRSA
Hospital-associated infections

Treating hospital patient textiles with ionic silver after each washing results in a significant decrease in microbial contamination. Although further study is needed to better understand the role textiles play in hospital-acquired infections and to quantify the influence of silver textile treatment on health care-associated infection risk and patient outcomes, ionic silver treatment of textiles may prove useful in hospital-acquired infection reduction strategies.

Textiles have been implicated in hospital outbreaks of fungal and bacterial pathogens.[1-4] The use of antimicrobial silver and copper in hospital textiles may mitigate the risk of hospital-acquired infections (HAIs). Silver kills bacteria by interacting with microbial proteins.[5] We evaluated the antimicrobial effectiveness of a silver-based textile treatment (SilvaClean, Applied Silver, Hayward, CA [Environmental Protection Agency No. 90335-1]) that treats textiles with ionic silver after each washing.

METHODS

The study was conducted at 3 community hospitals sharing an accredited laundry facility. After washing, textiles were treated with SilvaClean in accordance with Environmental Protection Agency label directions for use to provide 1.3-14 mg silver per kilogram textile.

Gowns and bottom sheets were sampled with contact plates containing 3 media types (ie, all aerobic bacteria, *Staphylococcus aureus* specific, and methicillin-resistant *S aureus* [MRSA] specific) pre- and postpatient use before and after silver treatment was initiated at the laundry facility. The onsite study team sampled a random selection of textiles from storage carts before patient use and from vacated hospital rooms after patient use. Two samples were collected from each textile: upper and lower areas on centerline of bottom fitted sheets and areas corresponding to center chest and suprapubic area of gowns.

Contact plates were incubated for 24 hours aerobically at 37°C, total colony forming units per plate were enumerated, and the 2 sampling sites were averaged to obtain a single measure for each textile.

The Wilcoxon rank-sum test was used to compare means in each group and Fisher exact tests were used to compare the proportions of textiles with bacteria isolated. Mixed-effects logistic models were used to control for different hospital sites and wards.

RESULTS

A total of 1,912 gowns and 2,074 sheets were included in the analysis. There was an 89% reduction in total aerobic bacterial colonies after silver treatment on prepatient-use gowns ($P < .0001$) and an 88% reduction on prepatient-use sheets ($P < .0001$). Among postpatient-use samples, there was a 45% reduction on gowns ($P < .0001$) and a 30% reduction on sheets ($P = .0001$) (Fig 1A). In *Staphylococcus aureus* cultures (Fig 1B), there was a 100% reduction in both prepatient-use gowns and sheets ($P < .0001$ and $P = .0009$, respectively), and an 89% and 74% reduction in postpatient-use gowns and sheets ($P < .0001$ in both cases). The average colony counts of MRSA (Fig 1C) were lower than colony counts on nonselective aerobic plates and the more general *S aureus* plates. Nevertheless,

* Address correspondence to John J. Openshaw, MD, Infectious Diseases and Geographic Medicine, Department of Internal Medicine, Stanford University School of Medicine, Lane Building, Ste 134, 300 Pasteur Dr, Stanford, CA 94305-5107.
E-mail address: jjo@stanford.edu (J.J. Openshaw).

Support for this study was provided by Applied Silver, Hayward, CA.
Conflicts of interest: GVL and WMM are shareholders with and JJO and AN are paid consultants for Applied Silver, Hayward, CA.

http://dx.doi.org/10.1016/j.ajic.2016.06.021

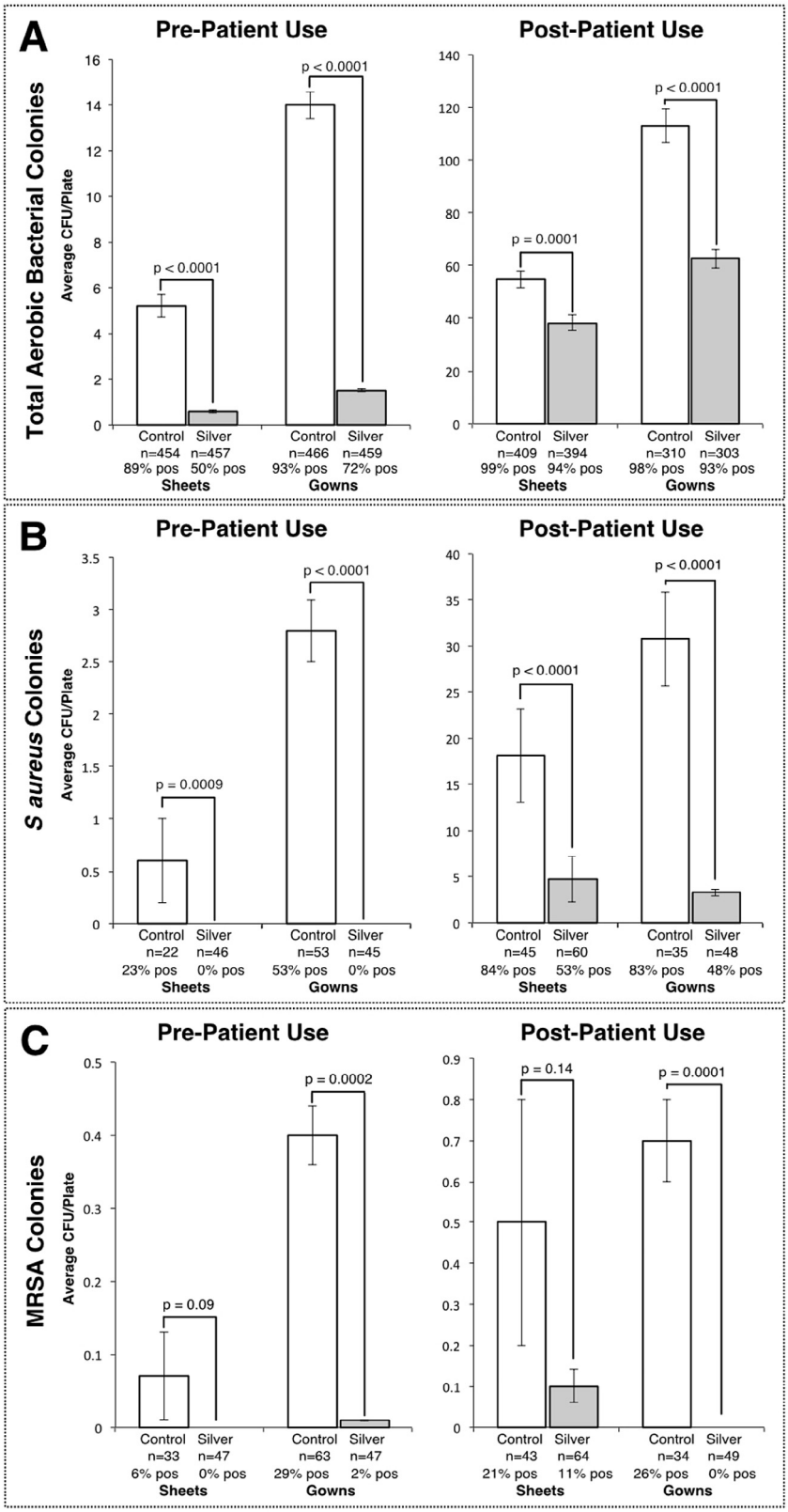

Fig 1. Average colony forming units per plate for (A) total aerobic bacterial colonies, (B) *Staphylococcus aureus* (*S aureus*) colonies, and (C) methicillin-resistant *S aureus* (MSRA) colonies before (control) and after silver application. Number of textiles per group and the percentage of cultures positive (having at least 1 colony) is shown below columns. Plates had a surface area of 28.27 cm^2. Colony counts > 300 (not clearly differentiated by counters) were recorded as 300 CFU/plate. Colony counts > 300 were seen on aerobic plates in 4% of postpatient-use gowns and 1% of postpatient-use sheets, but in <1% of all other groups. Three types of culture media were used: nonselective tryptic soy agar (Hardy Diagnostics, Santa Maria, CA) for total aerobic colony counts, Baird-Parker–based agar (Hardy Diagnostics) to quantify *S aureus*, and CHROM MRSA agar (Hardy Diagnostics) to quantify MRSA. A random number generator was used to ensure that approximately 20% of total samples would be on selective media (10% *S aureus* and 10% MRSA). Control groups included samples collected by the onsite study team between August 24, 2015, and September 18, 2015. Silver was introduced into the laundering process on December 8, 2015. Treatment groups include samples collected between December 14, 2015, and January 4, 2016.

Table 1
Predictors of bacterial isolation on textiles

	All aerobic bacteria			*Staphylococcus aureus*			Methicillin-resistant *S aureus*		
		Unadjusted	Adjusted		Unadjusted	Adjusted		Unadjusted	Adjusted
Predictor	% (n)	OR (95% CI)*	OR (95% CI)†	% (n)	OR (95% CI)*	OR (95% CI)†	% (n)	OR (95% CI)*	OR (95% CI)†
Ward type									
Nonmonitored	83% (2191)	Ref	–	34% (94)	Ref	Ref	9% (27)	Ref	–
Monitored	95% (569)	4.1 (2.8-6.1)‡	–	79% (61)	7.2 (3.9-13.3)‡	3.9 (2.1-7.8)‡	21% (19)	1.6 (0.8-3.2)	–
Patient exposure									
Preuse	76% (1298)	Ref	Ref	20% (33)	Ref	Ref	11% (21)	Ref	–
Postuse	96% (1362)	7.9 (5.9-10.6)‡	9.5 (7.1-13.0)‡	65% (122)	9.7 (5.7-16.7)‡	11.9 (6.1-23.4)‡	13% (25)	1.5 (0.8-2.9)	–
Textile type									
Sheet	82% (1414)	Ref	Ref	43% (75)	Ref	–	10% (18)	Ref	–
Gown	87% (1346)	1.5 (1.2-1.8)‡	1.8 (1.5-2.3)‡	44% (80)	0.9 (0.6-1.4)	–	14% (28)	1.2 (0.6-2.4)	–
Silver treatment									
Absent	94% (1547)	Ref	Ref	64% (100)	Ref	Ref	22% (38)	Ref	Ref
Present	75% (1213)	0.1 (0.1-0.2)‡	0.1 (0.1-0.2)‡	27% (55)	0.2 (0.1-0.3)‡	0.1 (0.05-0.2)‡	4% (8)	0.3 (0.1-0.9)‡	0.3 (0.1-0.9)‡

CI, confidence Interval; *OR*, odds ratio; *Ref*, reference category.
*In mixed-effects logistic models, the dependent variable was the isolation of bacteria on the specific medium type. Models controlled for differences among the 3 hospital sites as a random effect.
†Multivariable mixed-effects logistic models were built using information-theoretic model selection to generate all possible combinations of the independent variables. The dependent variable was the isolation of bacteria on the specific medium type. The model with the lowest corrected Akaike information criterion was selected. Models controlled for differences among the 3 hospital sites as a random effect.
‡$P < .05$.

MRSA colonies isolated per plate decreased after silver treatment, with a 97% and 100% reduction in prepatient-use gowns and sheets ($P = .0002$ and $P = .09$, respectively), and a 100% and 80% reduction in postpatient-use gowns and sheets ($P = .0001$ and $P = .14$, respectively).

Silver treatment was associated with fewer positive cultures (Fig 1). The proportion of cultures with at least 1 aerobic colony fell from 93% (432 out of 466) to 72% (330 out of 459) after silver treatment in prepatient-use gowns (Fisher exact test $P < .0001$). The proportion of prepatient-use gowns from which at least 1 colony of *S aureus* was isolated fell from 53% (28 out of 53) to 0% (0 out of 45; $P < .0001$) after silver treatment and from 83% (29 out of 35) to 48% (23 out of 48; $P = .001$) in postpatient-use gowns. The proportion of sheets with at least 1 colony of *S aureus* decreased from 23% (5 out of 22) to 0% (0 out of 46; $P = .002$) in the prepatient-use group and from 84% (38 out of 45) to 53% (32 out of 60; $P = .0008$) in the postpatient-use group.

In mixed-effects logistic models controlling for hospital site clustering (Table 1), the presence of silver was associated with decreased isolation of total aerobic bacteria, *S aureus*, and MRSA. Bacteria were more likely to be isolated after textile use: identification of any aerobic colony was 9 times higher after use and identification of *S aureus* was 12 times higher after use. Isolation of aerobic colonies was more likely on gowns (adjusted odds ratio, 1.5; 95% CI, 1.5-2.3). Although textiles in critical care areas appeared to be more likely to have aerobic colonies isolated in the unadjusted model, this factor did not improve model fit in the fully adjusted model. *S aureus* was more likely to be isolated on textiles in critical care settings (adjusted odds ratio, 3.9; 95% CI, 2.1-7.8). In the best-fit multivariable mixed-effects logistic model for isolation of MRSA, only the presence or absence of silver was predictive of MRSA isolation.

DISCUSSION

The levels of bacteria identified on clean laundry in our study are consistent with other studies, suggesting that this is a general problem in health care settings.[1,6] As would be expected, textiles sampled postpatient use had increased bacterial contamination, consistent with the transfer of the patient's colonizing bacteria to textiles. The reduction in bacterial contamination with silver in postpatient-use textiles indicates that silver treatment continues to reduce bacteria, including *S aureus*, over the extent of the patient's hospitalization. The low prevalence of MRSA at the study sites limited our ability to draw statistically significant conclusions regarding reductions in MRSA contamination. Our results show a trend toward decreased MRSA isolation in both sheets and gowns after silver application, but this reduction was statistically significant only on gowns.

The level of bacterial contamination on textiles that increases the risk of HAIs is not known.[7] Studies on hard surface environmental contamination have used < 2.5 CFU/cm^2 aerobic colonies and < 1 CFU/cm^2 for specific indicator organisms, including *S aureus* (corresponding to < 70.6 CFU/plate and 28.2 CFU/plate in this study).[7,8] It is not clear that acceptable levels for contamination on hard surfaces can be extended to sheets and gowns because textiles have unique properties: they are always in contact with patients, have large contacted surface areas, and can lead to bacterial aerosolization. Despite questions of applicability, if these levels are applied to textiles, postpatient-use gowns without silver exceeded cutoffs for both total aerobic colony counts and *S aureus* isolation in our study. Studies of copper-coated surfaces and textiles suggest that the addition of the metal reduced HAIs.[9,10] Although further studies are needed, given successes with copper and reductions below the hard surface cutoffs in this study, it is likely that silver textile treatment would decrease HAIs.

Acknowledgments

The authors thank the sample collection team, including Stephen Albertolle, Austin Carey, and Sean Rodgers.

References

1. Fijan S, Turk SŠ. Hospital textiles, are they a possible vehicle for healthcare-associated infections? Int J Environ Res Public Health 2012;9:3330-43. doi:10.3390/ijerph9093330.
2. Duffy J, Harris J, Gade L, Sehulster L, Newhouse E, O'Connell H, et al. Mucormycosis outbreak associated with hospital linens. Pediatr Infect Dis J 2014;33:472-6. doi:10.1097/INF.0000000000000261.
3. Sasahara T, Hayashi S, Morisawa Y, Sakihama T, Yoshimura A, Hirai Y. *Bacillus cereus* bacteremia outbreak due to contaminated hospital linens. Eur J Clin Microbiol Infect Dis 2011;30:219-26. doi:10.1007/s10096-010-1072-2.
4. Cheng VCC, Chen JHK, Wong SCY, Leung SSM, So SYC, Lung DC, et al. Hospital outbreak of pulmonary and cutaneous zygomycosis due to contaminated linen items from substandard laundry. Clin Infect Dis 2015;doi:10.1093/cid/civ1006.

5. Maillard J-Y, Hartemann P. Silver as an antimicrobial: facts and gaps in knowledge. Crit Rev Microbiol 2013;39:373-83. doi:10.3109/1040841X.2012.713323.
6. Pinon A, Gachet J, Alexandre V, Decherf S, Vialette M. Microbiological contamination of bed linen and staff uniforms in a hospital. Adv Microbiol 2013;3:515-9. doi:10.4236/aim.2013.37069.
7. Dancer SJ. How do we assess hospital cleaning? A proposal for microbiological standards for surface hygiene in hospitals. J Hosp Infect 2004;56:10-5.
8. Claro T, O'Reilly M, Daniels S, Humphreys H. Surface microbial contamination in hospitals: a pilot study on methods of sampling and the use of proposed microbiologic standards. Am J Infect Control 2015;43:1000-2. doi:10.1016/j.ajic.2015.05.009.
9. Salgado CD, Sepkowitz KA, John JF, Cantey JR, Attaway HH, Freeman KD, et al. Copper surfaces reduce the rate of healthcare-acquired infections in the intensive care unit. Infect Control Hosp Epidemiol 2013;34:479-86. doi:10.1086/670207.
10. Lazary A, Weinberg I, Vatine JJ, Jefidoff A, Bardenstein R, Borkow G, et al. Reduction of healthcare-associated infections in a long-term care brain injury ward by replacing regular linens with biocidal copper oxide impregnated linens. Int J Infect Dis 2014;24:23-9. doi:10.1016/j.ijid.2014.01.022.