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Major article

Decreased activity of commercially available disinfectants containing quaternary ammonium compounds when exposed to cotton towels

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Background: Health care-associated infections (HAIs) are a significant problem in hospitals, and environmental surfaces have been implicated as a source of HAIs in the hospital environment. Furthermore, Gram-negative and Gram-positive bacteria can persist on dry environmental surfaces for as long as several months. Poorly cleaned surfaces may serve as vehicles for microbes, which may then be transferred to patients.

Methods: Cotton and microfiber towels were both tested for their abilities to bind quaternary ammonium compounds (QACs). The towels were exposed to 3 commercially available disinfectants for 0.5, 30, and 180 minutes. Germicidal spray tests (GSTs) were performed for all towel eluates in accordance with the AOAC International method 961.02. Cotton towel eluates were analyzed for QAC concentration using high-performance liquid chromatography.

Results: QAC concentrations were reduced by up to 85.3% after exposure to cotton towels, resulting in failure of the disinfectants exposed to cotton towels in 96% of the GSTs.

Conclusion: The use of cotton towels with QAC-based cleansers should be reconsidered, particularly in hospitals where effective cleaning of the patient environment is needed to reduce the risk of HAIs.

Health care-associated infections (HAIs) are a significant problem, with an estimated 1.7 million cases reported annually in the United States.[1] Surfaces in the hospital environment have been implicated in the transmission of nosocomial infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Clostridium difficile*, and *Acinetobacter* spp.[2-4] Both Gram-negative (eg, *Acinetobacter* spp, *Escherichia coli*, *Klebsiella* spp, *Pseudomonas aeruginosa*) and Gram-positive bacteria (eg, *S aureus*, *Enterococcus* spp, *Streptococcus pyogenes*) can survive on dry environmental surfaces for several months, however, the ability of the bacteria to cause infection is unknown.[5] Bacteria have been detected not only in patient rooms, but also on high touch surfaces in communal hospital areas, including on escalator handrails and elevator buttons.[6]

It has been suggested that poorly cleaned surfaces may serve as vehicles for microbes, which may then be transferred to patients.[7] In fact, recent studies have reported an increased incidence of nosocomial infection among patients assigned to hospital rooms previously occupied by patients with VRE or MRSA.[2,3,8] Furthermore, the hands of health care workers have been shown to be a primary vehicle for HAI transmission, and several studies have confirmed that health care workers' hands can become contaminated with pathogens through contact with environmental surfaces in patient rooms.[9,10] One study found that health care workers' hands were contaminated with pathogens by touching environmental surfaces in rooms that had already been cleaned after patient discharge.[9]

Effective cleaning of patient rooms is necessary to reduce the risk of HAIs.[7] A reduction in disinfectant performance can be caused by the inactivation of quaternary ammonium compounds (QAC). A 2007 study compared the effectiveness of cleaning with cotton versus microfiber mops in combination with QAC disinfectants,

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Table 1
Summary of commercially available disinfectants used in this study and their active components

Disinfectant	Active components	Total active ingredients, %	Recommended use
A	Didecyl dimethyl ammonium chloride, n-alkyl dimethyl benzyl ammonium chloride	16.9	660 ppm; 14.8 mL disinfectant, 3,770.2 mL tap water
B	Didecyl dimethyl ammonium chloride, n-alkyl dimethyl benzyl ammonium chloride	16.9	660 ppm; 14.8 mL disinfectant, 3,770.2 mL tap water
C	Alkyl dimethyl ethylbenzyl ammonium chloride, alkyl dimethyl benzyl ammonium chloride	26.5	725 ppm; 10.4 mL disinfectant, 3,774.6 mL tap water

although no conclusion could be reached regarding the effect of the fabric type on QACs.[11] Guidelines adopted by the US Centers for Disease Control and Prevention (CDC), "Disinfection and Sterilization in Health Care Facilities," indicate that both high water hardness and exposure to cotton fibers can inactivate QACs.[12] A previous study demonstrated up to a 53% reduction in the original QAC concentration after exposure to cotton towels[13]; however, the effect of this reduction on disinfectant activity was not evaluated. This study measures the reduction of QAC concentrations resulting from reuse of cleaning towels and the ultimate impact of this reduction on disinfectant performance.

MATERIALS AND METHODS

Cotton and microfiber towels

Unused cotton towels (RN 100021, 31.8 × 35.6 cm; Terry World Textiles, Suwanee, GA) and unused microfiber towels (Kimtech Wypall 83620, 35.6 × 43.2 cm; Kimberly-Clark, Neenah, WI), both commercially available in the United States, were evaluated to determine their ability to bind QACs. The towels were laundered before use by machine washing once with warm water (40°C) using Tide with Acti-Lift detergent (Procter & Gamble; Cincinnati, OH) for 30 minutes, including the spin cycle. The towels were then dried using the high heat (120°C) setting until all towels felt dry to the touch. No fabric softener was used during either the wash or the dry cycles. The cotton towels were washed a total of 3 times using this procedure and reexposed to the QAC disinfectants after each wash.

AOAC International method 961.02: Germicidal spray products as disinfectants

Germicidal spray tests (GSTs) were performed by Antimicrobial Test Laboratories (Round Rock, TX) in accordance with the Association of Analytical Communities (AOAC) 961.02 standard, using a 10-min contact time and Letheen broth as the neutralizer. Three bacterial species were tested: *S aureus* (American Type Culture Collection [ATCC] 6538), *Salmonella enterica* (ATCC 10708), and *P aeruginosa* (ATCC 15442). Three disinfectants—EcoLab Neutral Disinfectant Cleaner (Disinfectant A; Ecolab Health, St Paul, MN), Diversey Virex 256 (Disinfectant B; Diversey, Sturtevant, WI), and 3M HB Quat Disinfecting Cleaner (Disinfectant C; 3M, St Paul, MN)—were prepared by diluting 7.8 L of each disinfectant in an 11.4 L bucket using tap water according to chemical manufacturer specifications (Table 1). A 20-mL volume of prepared disinfectant was removed from each bucket and placed into a clean glass jar for efficacy testing. Ten towels of each type were then submerged in each bucket. After the appropriate contact time (0.5, 30, and 180 minutes), the top towel was removed and liquid from that towel was expressed into a clean glass jar by gently wringing the towel for approximately 30 seconds.

Quantitative analysis of QACs

The QAC concentrations of cotton towel eluates were analyzed via ultraviolet high-performance liquid chromatography (HPLC-UV) or evaporative light-scattering HPLC (HPLC-ELS), as appropriate. The HPLC system consisted of an Agilent 1100 module series (Agilent Technologies, Santa Clara, CA) with a Polymer Labs PL-ELS 1000 detector (Polymer Labs, Wilmington, DE). The HPLC method was performed using an analytical Agilent Eclipse XDB-C18 column (Agilent Technologies), 15 cm × 4.6 mm, and isocratic elution. The mobile phase consisted of 0.1 M ammonium formate:isopropyl alcohol (50:50 volume/volume) with 0.1% acetic acid, at a flow rate of 0.7 mL/minute. The injection volume was 100 μL, and UV detection was performed at 262 nm. The ELS detector settings were as follows: nebulizer temperature of 80°C; evaporator temperature of 90°C; and nitrogen flow of 1.0 L/min.

The n-alkyl dimethyl benzyl ammonium chloride and the n-alkyl dimethyl ethylbenzyl ammonium chloride compounds were distinguished by UV detection, whereas the didecyl dimethyl ammonium chloride was identified using ELS detection. The QACs in the 3 disinfectants were identified by comparing the retention times of the towel eluates with those of appropriate standards.

RESULTS

Disinfectant performance using AOAC International method 961.02

When exposed to the microfiber towels, all disinfectants passed the AOAC International GSTs for all tested bacteria (27/27 passing). However, when the disinfectants were tested using the AOAC International GST after exposure to the cotton towels, the failure rate was 96% (1/27 passing).

Reduction of QAC concentration after exposure to cotton towels

The cotton towel eluates were evaluated to assess the effects of the towel exposure on the QAC concentrations in the disinfectants. Each of the 3 QAC-based disinfectants showed an overall reduction of QAC concentration after exposure to the cotton towels for each of the tested durations. The rates of loss of individual QACs were monitored, but no trends were observed (data not shown).

Two time points (Fig 1 and Table 2) reflected increases in detected QAC concentrations. For both time points, the concentrations of all QACs increased, suggesting that an equilibrium in charge may have been reached between the negative charge on the towel and the positive charge on the QAC. Furthermore, the number of wash cycles did not affect the magnitude of QAC reduction. An average 85.3% reduction in QACs was observed after exposure to the cotton towels (Table 2). The observed reduction in QAC concentration over such a relatively short period of time indicates that cotton towels may reduce the effectiveness of hospital disinfection procedures.

Table 2
Percent reduction in QAC concentrations after exposure to cotton towels

Disinfectant	Exposure time, min	Reduction compared with control, %			Average reduction from control, %, mean ± SD
		Wash 1	Wash 2	Wash 3	
A	0	NA	NA	NA	NA
	0.5	85.9	81.1	88.9	85.3 ± 3.9
	30	96.0	89.9	91.1	92.3 ± 3.2
	180	90.7	92.9	95.2	92.9 ± 2.2
B	0	NA	NA	NA	NA
	0.5	86.3	76.9	82.7	82.0 ± 4.7
	30	86.8	89.6	79.2	85.2 ± 5.4
	180	91.4	91.8	86.8	90.0 ± 2.8
C	0	NA	NA	NA	NA
	0.5	85.9	80.0	45.6	70.5 ± 21.8
	30	88.6	90.3	49.3	76.1 ± 23.2
	180	70.8	92.8	68.6	77.4 ± 13.4

NA, not applicable.

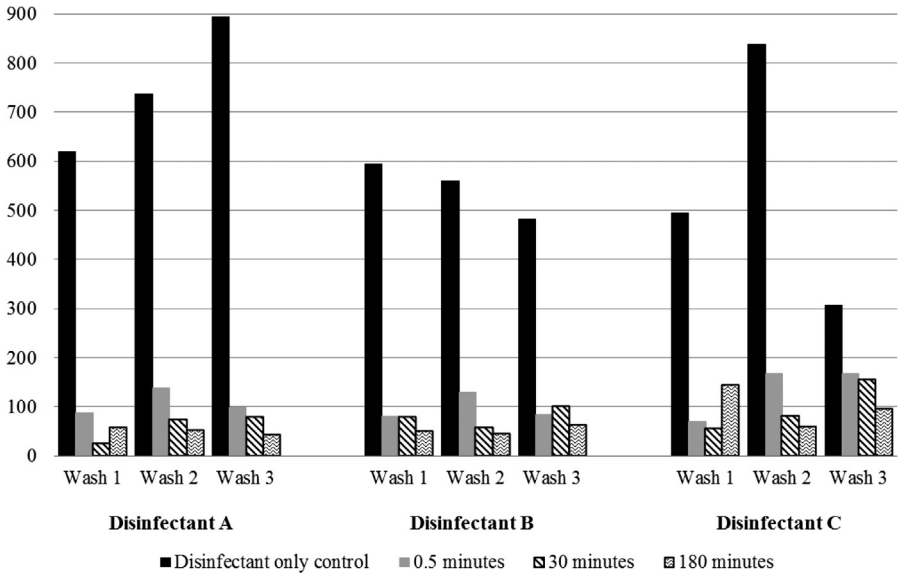

Fig 1. QAC concentrations in each of 3 commercially available substances before and after repeated exposure to cotton towels and laundering.

DISCUSSION

This study investigated the reduction of QAC concentrations in 3 commercial disinfectants after exposure to both cotton and microfiber towels. It has been previously established that cotton fibers have been shown to inactivate QACs, but characterization of the reduction in concentration and subsequent loss of disinfectant activity according to AOAC 961.02 GST has not been reported. Our results indicate that disinfectants exposed to microfiber towels retain their full germicidal activities, passing all GSTs. In addition, these evaluations demonstrated an 88.9% reduction of QAC concentrations within 30 seconds of exposure to the cotton towels, causing the disinfectants to fail the AOAC 961.02 GST.

A previous study reported a smaller reduction in QAC concentration[13]; however, the report did not list the specific disinfectants tested. This discrepancy suggests that QAC-based disinfectants may react differently with cotton towels depending on their specific formulations, but the effect of reduced QAC concentration on disinfectant activity was not evaluated in the previous study. The results of this study have implications with respect to the cleaning materials and procedures used by hospitals, suggesting that cotton towels should not be used in combination with QAC-based cleansers.

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