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The effectiveness of antibacterial curtains in comparison with standard privacy curtains against transmission of microorganisms in a hospital setting

Jaffar A. Al-Tawfiq[1,2,3], Ali M. Bazzi[4], Ali A. Rabaan[5], Christopher Okeahialam[6]

[1]Specialty Internal Medicine, Johns Hopkins Aramco Healthcare, Dhahran, Saudi Arabia;
[2]Indiana University School of Medicine, Indianapolis, Indiana, USA;
[3]Johns Hopkins University School of Medicine, Baltimore, MD, USA;
[4]Microbiology Lab, Johns Hopkins Aramco Healthcare, Dhahran, Saudi Arabia;
[5]Molecular Diagnostic Lab, Johns Hopkins Aramco Healthcare, Dhahran, Saudi Arabia;
[6]Infection Control Unit, Johns Hopkins Aramco Healthcare, Dhahran, Saudi Arabia

SUMMARY

Studies have shown a correlation between a cleaner patient environment and lower infection rates and reduced risk of transmission. Privacy curtains are potentially important sites of bacterial contamination in hospitals. Privacy curtains integrated with antimicrobial properties have been shown to increase the time to first contamination compared with standard privacy curtains. In this study, we examined the difference in bacterial colonization of different curtains. We experimentally contaminated antibacterial Fantex protective curtains and compared the bacterial counts to natural contamination of privacy curtains. There was a significant reduction in the CFU/cm^2 on antibacterial Fantex protective privacy curtains after 24 hours of experimental contamination with *Pseudomonas aeruginosa, Acinetobacter baumannii,* methicillin-resistant *Staphylococcus aureus* (MRSA) or extended-spectrum-producing organisms (*Escherichia coli* or *Klebsiella pneumoniae*), compared to standard privacy curtains. Levels of environmental contamination with *S. epidermis, Streptococcus viridians, E. coli, S. haemolyticus, S. aureus, S. capitis*, non-fermenting Gram-negative bacteria, and *Bacillus* species were also significantly less on the Fantex curtains after two months hanging in the emergency department. Healthcare facilities may find that addressing environmental surfaces, including use of antibacterial privacy curtains, an effective horizontal strategy for addressing healthcare-associated infections across the board.

Keywords: curtain, privacy curtain, antibacterial agents

INTRODUCTION

According to the World Health Organization (WHO), healthcare-associated infections (HAIs) affect hundreds of millions of people annually, with significantly higher prevalence in low- and middle-income versus high-income countries [1, 2]. HAIs contribute to patient suffering and mortality, longer hospital stays and healthcare costs [1, 2]. The environment in healthcare facilities can contribute to HAI transmission [3]. Privacy curtains are among the environmental elements identified as important sites of bacterial contamination in hospitals [4, 5]. One study carried out in intensive care units and medical wards revealed that 95% of the examined curtains were contaminated with methicillin resistant *Staphylo-*

Corresponding author
Jaffar A. Al-Tawfiq
E-mail: jaffar.tawfiq@jhah.com; jaltawfi@yahoo.com

coccus aureus (MRSA) and vancomycin-resistant *Enterococcus* (VRE) [5]. Evidence suggests that bacteria from privacy curtains can be transferred to the hands and/or gloves of healthcare workers, for example in a recent study from the emergency department of a Canadian hospital [3, 6]. Others have shown that healthcare staff are less likely to observe hand hygiene practices after touching inanimate objects in the healthcare environment, such as curtains, than after direct contact with patients [7]. Although cleaning of privacy curtains, for example with improved hydrogen peroxide (IHP), can reduce antimicrobial load, it has also been shown that bacterial biofilms can develop even after terminal cleaning [8, 9]. Studies have indicated that antibacterial, sporicidal privacy curtains integrated with antimicrobial properties may play a cost-effective role in removing bioburden from the patient environment [10, 11]. In this study, we analyzed colonization levels of antibacterial Fantex protective privacy curtains compared to standard privacy curtains by experimental contamination, and also relative levels of bacterial contamination after two months of use of these curtains in the emergency department in a hospital in Saudi Arabia.

MATERIALS AND METHODS

Experimental contamination of privacy curtains

For experimental contamination, we contaminated samples of both antibacterial Fantex Disposable Curtains, which are non-woven polypropylene curtains treated with Fantex, which is a unique antimicrobial protective agent on cationic quaternary compounds and polymers (Statina Healthcare, Hornsby, Australia) and control standard polycotton privacy curtains with known organisms. Survival of the organisms on the curtain fabrics was analyzed. Curtains were inoculated with a known concentration (approximately 50 organisms/cm^2) of *Pseudomonas aeruginosa, Acinetobacter baumannii,* Methicillin Resistant *Staphylococcus aureus (*MRSA) or Extended Spectrum Producing (ESBL) organisms (*Escherichia coli* or *Klebsiella pneumoniae*). Curtain samples were then cultured to determine the survival of these microorganisms. For each organism, a 1 ml suspension of 0.5 McFarland equivalent to 1x10^8 was prepared, followed by a series of ten-fold dilutions to give a concentration of 1000-2000 organisms/ml. 150-250 µl from each organism suspension (approximately 250 total organisms) was placed on a 5 cm^2 sample of antibacterial or control curtain fabric (approximately 50 organisms/cm^2) and allowed to air dry for one hour. This was sufficient to allow the bacterial organisms to establish growth on the fabric and for the antimicrobial properties to work. Each sample was then divided into five equal pieces (1 cm^2 each). Thus, there was a total of 20 pieces of curtain for each type of curtain and each of the four bacteria was tested on five pieces of 1 cm curtain. Each piece of 1 cm^2 was placed in 1 ml of 0.9% saline solution, vortexed for 1 min to remove the organisms from the fabric, and the full amount was cultured on blood agar plates. The plates were incubated and colonies were counted at 24 hours. Growth was continued for a further 24 hours to ensure no further colonies grew. Mean colony forming units (CFU) and standard deviations (SD) were calculated for each individual organism and for the overall bacterial counts, and results of CFU for antibacterial curtains were compared to those of the control curtains using one-tail Student's t-test; $p<0.05$ was taken as significant.

Naturally acquired curtain contamination

Antibacterial Fantex disposable curtains or standard polycotton control curtains were hung in December 2016 in patient cubicle in the emergency department. The cubicle is 2m x 2m containing one bed and there were other cubicles in the area. A total of five curtains of each type were used. Then, a 20 cm^2 area was marked on the leading edge of the most frequently touched area of the Fantex disposable curtains or standard control curtains for collection for microbiological testing. After two months the marked sample areas were collected and placed in 20 ml 0.9% saline solution. Samples were vortexed vigorously for 5 min, the fabrics were removed, and samples were centrifuged at 3600 rpm for 15 min at 50^{0}C. The supernatant was discarded and the pellet was re-suspended in normal saline to a final volume of 1 ml and cultured into blood agar plate for 48 hrs. Mean and standard deviations were calculated for total CFU and results for CFU for Fantex antibacterial curtains. It was hypothesized that fewer colonies would be found on the Fantex curtains, therefore mean ± SD were compared to those for control curtains using one-tail Student's t-test; $p<0.05$ was accepted as significant.

RESULTS

Table 1 shows the CFU/cm² for *P. aeruginosa*, *A. baumannii*, MRSA or ESBL organisms (*E. coli* or *K. pneumoniae*) 24 h following experimental contamination of antibacterial Fantex disposable curtains and control standard polycotton privacy curtains at approximately 50 organisms/cm². For each individual bacterial type and for the group overall, Student's t-test comparison indicated that the CFU/cm² was significantly lower for the Fantex versus the standard control curtains. For *Pseudomonas aeruginosa*, the mean ±SD was 1.2±0.4 vs. 22.2±5.2, respectively (P<0.0001), and 2.0±0.9 vs. 28.4±1.6 (P<0.00001) for *Acinetobacter baumannii*, 2.4±0.8 vs. 31.8±5.6 for MRSA (P<0.00001) and 1.8±1.1 vs. 27.3±5.7 (P<0.00001) for all organism, respectively. Table 2 shows the CFU/20 cm² for environmental contamination of Fantex versus the control curtains over two months in patient rooms in the emergency department. Contamination with *S. epidermidis, Streptococcus viridans, E. coli, S. haemolyticus, S. aureus, S. capitis*, non-fermenting Gram-negative bacteria (GNB), and *Bacillus* spe-

Table 1 - Comparison of experimental contamination of antibacterial Fantex protective and control curtains.

Microorganism	*Non protective curtain CFU/cm²**	*Fantex Protective curtain CFU/cm²*	*P value (two-tail)*
Pseudomonas aeruginosa	28	1	
Pseudomonas aeruginosa	23	2	
Pseudomonas aeruginosa	27	1	
Pseudomonas aeruginosa	14	1	
Pseudomonas aeruginosa	19	1	
Mean ± SD	22.2 ± 5.2	1.2 ± 0.4	< 0.0001
Acinetobacter baumannii	31	2	
Acinetobacter baumannii	28	3	
Acinetobacter baumannii	28	1	
Acinetobacter baumannii	29	3	
Acinetobacter baumannii	26	1	
Mean ± SD	28.4 ± 1.6	2.0 ± 0.9	< 0.00001
MRSA	34	1	
MRSA	36	1	
MRSA	36	2	
MRSA	32	1	
MRSA	21	1	
Mean ± SD	31.8 ± 5.6	2.4 ± 0.8	< 0.00001
E. coli ESBL	29	2	
E. coli ESBL	34	5	
E. coli ESBL	27	4	
KPN ESBL	22	2	
KPN ESBL	22	1	
Mean ± SD	26.8 ± 4.5	2.8 ± 1.5	< 0.00001
All organism CFU (Mean ± SD)	27.3 ± 5.7	1.8 ± 1.1	< 0.00001

*Each cm² was seeded by approximately 50 organisms as per ASM. recommendation; MRSA= Methicillin Resistant *Staphylococcus aureus;* ESBL= Extended Spectrum B-lactamase; KPN= *Klebsiella pneumoniae.*

Table 2 - Comparison between Antibacterial Fantex and control curtains environmental contamination after two months in an emergency room.

Organism	*Normal curtain (average CFU/20cm^2*	*Antibacterial Curtain (average CFU/20cm^2)*	*P value (one-tail)*
S. epidermidis	14	3	0.036
Streptococcus viridans	4	0	
E. coli	3	1	
S. haemolyticus	3	1	
S. aureus	2	0	
S. capitis	2	0	
Non fermenting GNB	1	0	
Bacillus species	1	1	
Total CFU (Mean ± SD)	3.75 ± 3.9	0.75 ± 0.9	0.036

GNB=Gram negative bacilli.

cies was detected. Comparison of mean CFU/20 cm^2 for total bacterial species indicated that CFU/20 cm^2 was significantly lower for the Fantex versus the control curtains (p=0.036).

DISCUSSION

In this study, we demonstrated that antibacterial curtains were significantly resistant both to experimental contamination with a range of bacterial organisms, including *P. aeruginosa*, *A. baumannii*, MRSA and ESBL organisms and to environmental contamination in the emergency department of our hospital, when compared to standard privacy curtains.

The role of privacy curtains in environmental contamination in hospitals, and in transmission of contamination via the hands of healthcare workers, especially when coupled with sub-optimal hand hygiene practices, has been documented [3, 6, 7]. The emergency department of busy hospitals can be particularly vulnerable, as they are typically over-crowded and limited in resources, and privacy curtains are frequently used in separation of patient beds or trolleys. Privacy curtains can be rapidly contaminated with a range of bacteria including MRSA, vancomycin-resistant enterococci (VRE) and *C. difficile* in a range of hospital settings including emergency departments, intensive care units (ICUs), general wards and outpatient clinics [4-6, 11, 12]. Curtains have also been occasionally associated with outbreaks of HAIs, for example in an outbreak of carbapenem-resistant *Acinetobacter* in the ICU of a hospital in the UK and an outbreak of group A *Streptococcus* (GAS) infections in an ear, nose and throat (ENT) ward in a tertiary referral centre also in the UK [13, 14]. Privacy curtains are difficult to effectively clean and are often left in place until visibly soiled or contaminated [8, 9]. These factors have increased interest in privacy curtains with integrated antimicrobial properties, such as the Fantex disposable curtains used in this study. These are made from 100% non-woven polypropylene 100 gsm and are coated with a polymer based biocide called Fantex [15]. They are designed to provide an effective cross-contamination barrier for six-twelve months against a range of bacteria including MRSA, VRE, *Clostridium difficile*, *Candida*, *C. albicans* and *E. coli*, and to have anti-viral properties against herpes viruses, coronaviruses (CoVs) such as Middle East respiratory syndrome (MERS)-CoV, norovirus, rotavirus, influenza viruses and Ebola [15]. Sporicidal disposable curtains have been shown to be efficient and cost-effective in reduction of MRSA, VRE, carbapenem-resistant *Enterobacteriaceae* and *Clostridium difficile* growth on privacy curtains in a busy ICU environment [11]. In a double-blinded randomized control trial (RCT) carried out in two ICUs, curtains treated with an antimicrobial complex element compound (CEC) were shown to reduce the time to first contamination when compared to standard curtains [10].

There were different bacterial population between experimental contamination (MDR pathogens chosen per protocol) and environmental contamination. The observed and recovered bacteria from

the study were not multidrug resistant. This difference is related to the environmental bacteria recovered from the environment and represent a lower risk in the environment than the experimental study. The rate of MRSA in our hospital was reported to be 6% of all *S. aureus* isolates and the rate was lower than other areas of the country [16, 17]. There is also a likely difference in the rate of MDR organisms in the emergency room compared to other areas of the hospital such as the intensive care units. This difference is a contributor to the limitation of the study. There seems to be a difference between experimental study and real-life effect of the antibacterial curtain on the contaminating organisms. In real-life scenario, there was more contamination of the curtains with *S. epidermidis* than other organisms. The low inoculum effect may be due to the low prevalence of MDR organisms in the emergency room thus not allowing for better comparison between the two types of the curtains. However, experimental data showed significant reduction of other organisms in reference to antibacterial curtains. The data suggest that if there is a high inoculum of any given organism then antibacterial curtains are better in reducing microorganisms.

Another limitation of the study is the contact time of 1 hr in the artificially inoculated curtains. This means that while the bacteria are initially killed on contact not all of the organisms are killed for any of the bacterial species tested. These surviving bacteria might well grow and multiply over the next 7 days or subsequent days.

In our study, we confirmed that use of the Fantex curtains in an emergency department environment significantly reduced environmental contamination. We did not study cross-contamination of healthcare workers' hands, which would be a valuable topic for future studies. However, our results indicate that consideration should be given to introduction of antibacterial curtains in hospitals.

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