Soft-Surface Contamination in the Patient-Care Environment and Antimicrobial Textiles

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By Kelly M. Pyrek
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It is an area of growing interest among researchers. Kelly Reynolds, MSPH, PhD, associate professor in the Community, Environment and Policy Division at the Mel & Enid Zuckerman College of Public Health, University of Arizona will address the topic of “Decontaminating Textiles and Other Soft Surfaces: Evidence-Based Recommendations” at the annual meeting of the Association for the Healthcare Environment (AHE) in September. She says that the term “antimicrobial textiles” embodies a wide variety of antimicrobial agents and also a wide variety of delivery materials. “There is evidence of varying degrees relative to agent and materials alike that bacterial resistance can occur,” Reynolds says. “More research is needed to find the best antimicrobial agent at the most effective concentration along with the appropriate textile to deliver the agent for maximum efficacy to inactivate target pathogens.”

In terms of how antimicrobial textiles fit into an overall infection prevention program or intervention bundle, Reynolds says, “While their risk impact has not been quantitatively evaluated, I believe they are as important in infection control as any other surfaces vulnerable to contamination.”

The question is, how robust is the science behind antimicrobial textiles and how concerned should clinicians be about soft-surface contamination. As Reynolds notes, “Our research, and that of others, shows that soft surfaces play a key role in harboring microbial pathogens in healthcare and home settings. Just as microbes settle on hard surfaces, they also settle on soft surfaces and present an exposure hazard to anyone who comes into contact with them.”

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— Kelly Reynolds, MSPH, PhD
contact with that surface. While transfer from soft surfaces to hands does not appear to be as efficient as transfer from hard surfaces, soft surfaces are much more likely to not be cleaned and sanitized which further increases exposure risks. More research is needed to evaluate effective control strategies for soft surfaces as well as the cost/benefit for eliminating them from the hospital environment.”

Let’s take a closer look at the literature to determine what researchers are discovering.

**Healthcare textiles**

Neely (2000) sought to determine the length of survival of various gram-negative bacteria on fabrics and plastics commonly used in hospitals. Seven materials were tested: smooth cotton (clothing), cotton terry (towels), 60 percent cotton/40 percent polyester blend (scrub suits and lab coats), polyester (drapes), 75 percent nylon/25 percent spandex (pressure garments), polyvinyl (splash aprons), and polyurethane (keyboard covers). Neely used Pseudomonas aeruginosa, Escherichia coli, Klebsiella pneumoniae, Serratia marcescens, Proteus mirabilis, Acinetobacter species, and Enterobacter species to inoculate material swatches and then assayed them at regular intervals. Survival was dependent on the bacterium, its inoculum size, and the material tested. At 102 microorganisms per swatch, bacteria survived from less than one hour to eight days. At 10(4) to 10(5) bacteria per swatch, survival ranged from two hours to more than 60 days. Neely says her findings emphasize the need for careful disinfection and conscientious contact control procedures in areas that serve immuno-suppressed individuals.

In a separate study, Neely and Maley (2000) determined the survival of 22 gram-positive bacteria (vancomycin-sensitive and -resistant enterococci and methicillin-sensitive and -resistant staphylococci) on five common hospital materials: smooth 100 percent cotton (clothing), 100 percent cotton terry (towels), 60 percent cotton/40 percent polyester blend (scrub suits and lab coats), 100 percent polyester (privacy drapes), and 100 percent polypropylene plastic (splash aprons). Swatches were inoculated with 104 to 105 CFU of a microorganism, assayed daily by placing the swatches in nutritive media, and examining for growth after 48 hours. All isolates survived for at least one day, and some survived for more than 90 days on the various materials.

Neely and Orloff (2001) sought to determine if fabrics and plastics served as reservoirs or fomites for the transmission of fungi species such as Candida albicans, and the ability of some fungi to survive on common hospital items such as privacy curtains, towels, scrub suits, plastic splash aprons and computer keyboard covers. Swatches were inoculated, incubated and tested for fungal survival. The researchers reported that Aspergillus and Mucor survived 26 days; Candida, Fusarium, and Paecilomyces survived for five days. Within the Candida species, C. parapsilosis lived 30 days on all materials, compared to a four-day lifespan of C. albicans, C. tropicalis and C. krusei. The fungi tended to be viable for longer on 100 percent synthetic materials (polyester, spandex, polyethylene and polyurethane) with an average of 19.5 days than on fabrics with some natural fiber content (cotton, terry, and blends) for an average of five days.
Hospital furniture

Various studies have demonstrated that contaminated environmental surfaces, equipment, and healthcare workers’ hands have been linked to outbreaks of infection or colonization of VRE and Pseudomonas aeruginosa. And now experts believe that furniture upholstery, walls and flooring may act as reservoirs of pathogenic microorganisms.

Lankford, et al. (2006) inoculated furniture upholstery, walls and flooring with VRE and Pseudomonas aeruginosa and assessed bioload at 24 hours, 72 hours, and seven days. Inoculated surfaces were cleaned utilizing manufacturers’ recommendations of natural, commercial, or hospital-approved products and methods, and samples were obtained. To assess potential for transmission, volunteers touched VRE-inoculated surfaces and imprinted palms onto contact-impression plates. Twenty-four hours following inoculation, all surfaces had recovery of VRE; 13 of 14 surfaces had Pseudomonas aeruginosa. After cleaning, VRE was recovered from seven surfaces and Pseudomonas aeruginosa from five surfaces.

Noskin, et al. (2000) assessed survival of VRE on fabric chairs in an attempt to determine the optimal upholstery for the healthcare setting. VRE was identified on three of 10 seat cushions sampled, including two chairs in a room of a patient with known VRE. After performing simulated contamination experiments, all samples were positive at 72 hours and one week after inoculation. Contamination of the upholstery could be prevented by placing a sheet folded four times or a bath blanket folded in half on the seat cushion. The researchers concluded that VRE is capable of prolonged survival on fabric seat cushions and can be transferred to hands, and that environmental surfaces such as chairs may serve as a potential reservoir for nosocomial transmission of VRE. They add that an easily cleanable, nonporous material is the preferred upholstery in hospitals.

It is clear that furniture and surfaces in the healthcare environment should receive thorough and regular cleaning and decontamination. Malik et al. (2006) used feline calicivirus (FCV) to mimic the properties of noroviruses in order to conduct disinfectant efficacy testing on various fabrics and carpets. The researchers applied FCV on fabrics and carpets and allowed it to dry, followed by treatment with a given disinfectant for a defined contact time of one, five and 10 minutes. The surviving virus was then eluted and titrated in Crandell-Reese feline kidney cells to determine virus inactivation. The researchers considered a disinfectant to be effective if it inactivated at least 99 percent of the applied virus. An activated dialdehyde-based product was found to be the most effective disinfectant on all types of fabric and carpet, inactivating more than 99.99 percent of the virus in one to 10 minutes. The researchers discovered that disinfection of carpets was more difficult than the disinfection of fabrics, and that 100 percent polyester was the least amenable to disinfection — only the activated dialdehyde-based product and a phenolic compound were able to inactivate 99 percent of FCV on 100 percent polyester.
Privacy curtains

Fabric can be found everywhere in the hospital, and sometimes the fabric used most often is the least likely to be cleaned regularly. Most notable are privacy curtains. Lambert, et al. (2006) point to the presence of multiple-resistant Acinetobacter species on fomite surfaces in the intensive care unit and on bed linen. The researchers point to the curtains surrounding patient beds as the major source of the bacterium. Typing by pulsed field gel electrophoresis demonstrated that the patients’ isolates and those from the environment were indistinguishable. Rigorous infection control measures including increased frequency of cleaning of the environment with hypochlorite and twice-weekly changing of curtains were implemented, along with restriction of meropenem use in the units. Isolation of the multiple-resistant Acinetobacter spp. subsequently diminished and it was not detected over a follow-up period of 18 months. This outbreak also highlights environmental sources, particularly dry fabrics such as curtains, as an important reservoir for dissemination of acinetobacters.

Ohl, et al. (2012) performed a longitudinal study to determine the prevalence and time course of bacterial contamination on privacy curtains. Over a three-week period, swab cultures (n = 180) were obtained twice weekly from the leading edge of 43 curtains in 30 rooms in two intensive care units and a medical ward. Curtains were marked to determine when they were changed. Contamination with Staphylococcus aureus, methicillin-resistant S aureus (MRSA), Enterococcus spp, vancomycin-resistant enterococcus (VRE), or aerobic gram-negative rods was determined by standard microbiologic methods. To distinguish persistence of pathogens on curtains from recontamination, all VRE and MRSA were typed using pulsed-field gel electrophoresis. Twelve of 13 curtains (92 percent) placed during the study showed contamination within one week. Forty-one of 43 curtains (95 percent) demonstrated contamination on at least one occasion, including 21 percent with MRSA and 42 percent with VRE.

Schweizer, et al. (2012) report on a study in which 21 rooms in a surgical intensive care unit (ICU) and nine rooms in a medical ICU were randomly selected to receive either a new standard curtain or a new identical-looking antimicrobial-fabric curtain. Fifteen rooms received antimicrobial-fabric curtains and 15 received standard curtains. Cultures were performed of samples that were collected from curtains twice a week for four weeks (23 days). Contamination was determined according to standard microbiologic methods. The median time to first contamination was seven times longer for antimicrobial-fabric curtains than for standard curtains (14 vs. two days). Antimicrobial-fabric curtains were significantly less contaminated than standard curtains according to earlier culture results but not significantly different for later culture results. Fourteen antimicrobial-fabric curtains and 13 standard curtains were contaminated at least once. The adjusted rate of contamination was
29 percent lower among antimicrobial-fabric versus standard curtains, but this was not statistically significant. The researchers say that the use of privacy curtains with antimicrobial properties could increase the time between washings and may potentially play a role in decreasing pathogen transmission. They add that further clinical research in antimicrobial textiles could increase our understanding of the potential impact of these products in healthcare environments.

In a culture survey Trillis, et al. (2008), found that 42 percent of hospital privacy curtains were contaminated with vancomycin-resistant enterococci, 22 percent with MRSA, and 4 percent with Clostridium difficile. By direct plating culture, 10 (20 percent) of 50 curtains were positive for VRE, and 11 (22 percent) of 50 were positive for MRSA. For VRE, the median number of colonies obtained by direct plating culture was two. For MRSA, the median number of colonies obtained by direct plating was three. Hand imprint cultures were positive for MRSA for five (45 percent) of the 11 curtains that were contaminated with MRSA; only one or two colonies of MRSA were recovered from hand imprint cultures for each of these five curtains. Hand imprint cultures were positive for VRE for two (20 percent) of the 10 curtains that were contaminated with VRE; only one colony of VRE was recovered after contact with each curtain. Hand imprint cultures were positive for C. difficile for two (100 percent) of the two curtains that had broth enrichment cultures positive for C. difficile. Of the 50 curtains sampled for culture, 14 (28 percent) were in MRSA isolation rooms. There was a trend toward a higher rate of detection of MRSA on curtains in isolation rooms, compared with curtains in non-isolation rooms; the same trend was seen for the rate of detection of VRE. For VRE and MRSA, the proportion of curtains with positive culture results was highest on the medical wards and lowest in the intensive care units.

Klakus, et al. (2008) concluded after culturing hospital curtains for MRSA that curtains are frequently handled both directly before and after examination of patients by healthcare workers, and are probably an overlooked vehicle for MRSA transmission within hospitals.

Das, et al. (2002) report that multiple-antibiotic-resistant Acinetobacter was first isolated from a patient in the general intensive care unit of a tertiary-referral university teaching hospital in Birmingham in December 1998. Similar strains were subsequently isolated from 12 other patients, including those on another intensive care unit within the hospital. The outbreak followed an increase in the use of meropenem in both the units. Environmental screening revealed the presence of the multiple-resistant Acinetobacter species on fomite surfaces in the intensive care unit and bed linen. The major source appeared to be the curtains surrounding patients’ beds. Typing by pulsed field gel electrophoresis demonstrated that the patients’ isolates and those from the environment were indistinguishable. Rigorous
infection control measures including increased frequency of cleaning of the environment with hypochlorite (1000 ppm) and twice-weekly changing of curtains were implemented, along with restriction of meropenem use in the units. Isolation of the multiple-resistant Acinetobacter spp. subsequently diminished and it was not detected over a follow-up period of 18 months.

Palmer (1999) reported that of the 28 curtains sampled for bacteria, all plates yielded bacteria; 22 of the 28 yielded Staphylococcus aureus.

**Healthcare worker apparel**

Patient-to-patient transmission of nosocomial pathogens has been linked to transient colonization of healthcare workers, and studies have suggested that contamination of healthcare workers’ clothing, including white coats, may be a vector for this transmission.

Morgan, et al. (2012) sought to assess the role of environmental contamination in the transmission of multidrug-resistant bacteria to healthcare workers’ clothing. A prospective cohort study was conducted in six intensive care units at a tertiary-care hospital. Study participants included registered nurses, patient care technicians, respiratory therapists, occupational/physical therapists, and physicians. The researchers found that 120 of 585 (20.5 percent) healthcare worker/patient interactions resulted in contamination of healthcare workers’ gloves or gowns. Multidrug-resistant Acinetobacter baumannii contamination occurred most frequently, 55 of 167 observations (32.9 percent), followed by multidrug-resistant Pseudomonas aeruginosa (15 of 86 or 17.4 percent), vancomycin-resistant Enterococcus, (25 of 180 or 13.9 percent) and methicillin-resistant Staphylococcus aureus (21 of 152 or 13.8 percent). Independent risk factors associated with healthcare worker contamination with multidrug-resistant bacteria were positive environmental cultures, duration in room for >5 minutes, performing physical examinations, and contact with the ventilator. Pulsed field gel electrophoresis determined that 91 percent of healthcare worker isolates were related to an environmental or patient isolate. The researchers concluded that contamination of healthcare workers’ protective clothing during routine care of patients with multidrug-resistant organisms is most frequent with A. baumannii. Environmental contamination was the major determinant of transmission to healthcare workers’ gloves or gowns. Compliance with contact precautions and more aggressive environmental cleaning may decrease transmission.

Bearman, et al. (2012) sought to determine the effectiveness of antimicrobial scrubs on hand and apparel bacterial burden. In a prospective, crossover trial, 30 healthcare workers were randomized to study versus control scrubs in an intensive care unit. Weekly microbiology samples were obtained from scrub abdominal area, cargo pocket, and hands. Mean
log colony-forming unit (CFU) counts were calculated. Compliance with hand hygiene practices was measured. Apparel and hand mean log CFU counts were compared. Adherence measures were 78 percent for hand hygiene and 82 percent for scrubs. Culture compliance was 67 percent. No differences were observed in bacterial hand burden or in healthcare workers with unique positive scrub cultures. No difference in vancomycin-resistant enterococci (VRE) and gram-negative rod (GNR) burden was observed. A difference in mean log methicillin-resistant Staphylococcus aureus (MRSA) CFU count was found between study and control scrubs for leg cargo pocket, abdominal area, leg cargo pocket at the beginning of shift, and abdominal area pocket at the end of shift. The researchers say study scrubs were associated with a 4–7 mean log reduction in MRSA burden but not VRE or GNRs. A prospective trial is needed to measure the impact of antimicrobial impregnated apparel on MRSA transmission rates.

Munoz-Price, et al. (2012) sought to aimed to determine the association between the bacterial contamination of healthcare workers’ hands and uniforms (white coats and scrubs). Healthcare personnel working in five intensive care units had cultures obtained from their hands and uniforms (white coats or scrubs). Pathogens were defined as any gram-negative bacilli, Staphylococcus aureus, and enterococci. Bacterial growth was detected on 103 hands (86 percent); 13 (11 percent) grew S aureus, 7 (6 percent) grew Acinetobacter spp, two (2 percent) grew enterococci, and 83 (70 percent) grew only skin flora. The presence of pathogens on the hands was associated with a greater likelihood of the presence of pathogens on white coats, but not on scrubs. Similarly, the presence of Acinetobacter on healthcare workers’ hands was associated with a greater likelihood of Acinetobacter contamination of white coats but not of scrubs. Contamination of provider’s hands with pathogens or Acinetobacter baumannii was associated with contamination of white coats. This association was not observed between hands and scrubs, however.

Wierner, et al. (2011) investigated the rate of potentially pathogenic bacteria present on uniforms worn by hospital staff, as well as the bacterial load of these microorganisms. Cultures were obtained from uniforms of nurses and physicians by pressing standard blood agar plates at the abdominal zone, sleeve ends, and pockets. Each participant completed a questionnaire. A total of 238 samples were collected from 135 personnel, including 75 nurses (55 percent) and 60 physicians (4 percent). Of these, 79 (58 percent) claimed to change their uniform every day, and 104 (77 percent) defined the level of hygiene of their attire as fair to excellent.Potentially pathogenic bacteria were isolated from at least one site of the uniforms of 85 participants (63 percent) and were isolated from 119 samples (50 percent); 21 (14 percent) of the samples from nurses’ gowns and six (6 percent) of the samples from physicians’ gowns included of antibiotic-resistant bacteria. The researchers concluded that up to 60 percent of hospital staff’s uniforms are colonized with potentially pathogenic bacteria, including drug-resistant organisms. It remains to be determined whether these bacteria can be transferred to patients and cause clinically relevant infection.
Treakle, et al. (2009) performed a cross-sectional study involving attendees of medical and surgical grand rounds at a large teaching hospital to investigate the prevalence of contamination of white coats with important nosocomial pathogens, such as methicillin-sensitive Staphylococcus aureus, MRSA and VRE. Each participant completed a brief survey and cultured his or her white coat using a moistened culture swab on lapels, pockets, and cuffs. Among the 149 grand rounds attendees’ white coats, 34 (23 percent) were contaminated with S aureus, of which 6 (18 percent) were MRSA. None of the coats was contaminated with VRE. S aureus contamination was more prevalent in residents, those working in inpatient settings, and those who saw an inpatient that day.

Perry (2001) found that 52 percent of the nurses uniforms he cultured grew MRSA and VRE, while Osawa (2003) found that 79 percent of the white coats cultured grew MRSA.

Loh, et al. (2000) proposed that medical students’ white coats are more likely to be bacteriologically contaminated at points of frequent contact, such as the sleeve and pocket. The researchers identified organisms which were principally skin commensals, including Staphylococcus aureus. The researchers note that the coat’s cleanliness, as perceived by the student, was correlated with bacteriological contamination, yet despite this, a significant proportion of students only laundered their coats occasionally. Loh et al. say this study shows white coats as a potential source of cross-infection and its design should be modified to facilitate handwashing. They add that teaching hospitals should provide freshly laundered coats to medical students.

Physicians’ ties have come under scrutiny as well. Steinlechner, et al. (2002) tested the ties of its orthopedic department staff for pathogenic organism carriage and found that all ties were colonized by bacteria that are frequently cultured from swabs taken from discharging wounds of its orthopedic patients. Nurkin (2004) sampled 42 physician neckties and found that 20 of them had one or more pathogenic microorganisms, including 12 that carried Staphylococcus aureus, five with a gram-negative bacteria, one with Aspergillus and two ties with multiple pathogens.

Long sleeves and the link to the carriage of bacteria was the impetus behind a new “bare below the elbows” rule issued by the British National Health Service, which prohibited physicians from wearing long sleeves and ties. The United States currently has no restrictions on physicians’ apparel, but some experts wonder if the British are on to something. One study conducted at a Connecticut hospital demonstrated that if a HCW entered a room containing a patient with MRSA colonization or infection, the bacteria would be found on the HCW’s clothes approximately 70 percent of the time — even if the HCW did not touch the patient.
Taking into consideration studies like Cristomo (2002) which found that 65 percent of medical personnel say they change their lab coats less than once a week, and 15 percent change it less than once a month, some research indicates that clean uniforms can reduce the spread of infections. St. Mary’s Health Center in St. Louis reduced infections after Cesarean births by more than 50 percent by providing all caregivers with hospital-laundered scrubs as well as requiring them to double-glove. In Connecticut, Stamford Hospital recently banned the wearing of scrubs outside of the hospital, citing a spike in Clostridium difficile infections. But the bugs return quickly. Burden, et al. (2011) found that bacterial contamination occurs within hours after donning newly laundered uniforms.

Some studies call into question the effectiveness of antimicrobial healthcare worker apparel. In a prospective, randomized, controlled trial conducted in a university-affiliated, public safety net hospital, Burden, et al. (2013) sought to compare the extent of bacterial contamination of uniforms and skin when healthcare workers wore one of two types of antimicrobial scrubs or standard scrubs. Study participants were 105 hospitalist physicians, nurse practitioners, physician assistants, house staff, and nurses working on internal medicine units. Bacterial colony counts in cultures taken from the healthcare workers’ scrubs and wrists after an eight-hour workday. The median total colony counts was 99 (66-182) for standard scrubs, 137 (84-289) for antimicrobial scrub type A, and 138 (62-274) for antimicrobial scrub type B. Colony counts from participants’ wrists were 16 (5-40) when they wore standard scrubs and 23 (4-42) and 15 (6-54) when they wore antimicrobial scrubs A and B, respectively. Resistant organisms were cultured from three healthcare workers (4.3 percent) randomized to antimicrobial scrubs and none randomized to standard scrubs. Six participants (5.7 percent) reported side effects to wearing scrubs, all of whom wore antimicrobial scrubs. The researchers concluded that they found no evidence that either antimicrobial scrub product decreased bacterial contamination of healthcare workers’ uniforms or skin after an eight-hour workday.

Hospital gowns

Gowns worn by healthcare providers other than surgeons have been implicated in the spread of microbes. Pilonetto (2004) analyzed the microbiota from the uniforms of 31 HCWs in a general intensive care unit. After total viable counts of microorganisms were determined, various parts of gowns were analyzed for microbial contamination at the beginning and end of a work shift. Pathogens were isolated from 48 percent of the gowns; samples from the abdominal region revealed the presence of Staphylococcus aureus, Acinetobacter baumannii, Klebsiela pneumoniae and Serratia rubidae. Pilonetto (2004) also noted that gowns can pick up bacteria from patients and disseminate it within the environment or even to other patients, with increased opportunities for transmission as the HCWs’ shift progressed. Pilonetto (2004) observes, “We found that there is a considerable population of microorganisms in the gowns of medical staff, and this population grows during the work period. This is evident from the rise of bacteria counts from 45.1 CFU/plate (2.2 CFU/cm2) in the first evaluation, to 97.6 CFU/plate (4.9 CFU/cm2)
in the second count.” Pilonetto (2004) observes further, “It is known that the more a gown is re-utilized the greater the susceptibility to contamination and, by inference, the less protection afforded to the user and to the patients. The use of reusable cotton gowns should also be analyzed to determine if they are really economical or if the adoption of synthetic, semi-synthetic or even disposable materials would have greater cost-benefit, resulting in a better quality of service for the patient. We believe that a re-education program applied to health professionals would help to diminish bacterial contamination through hospital gowns, especially in the ICUs where the rate of hospital infections is very high.”

Researchers have also discovered that certain bacterium adhere to particular fabrics in distinct ways. Hsieh and Merry (1986) examined the adherence of the Staphylococcus aureus, Staphylococcus epidermidis and Escherichia coli on cotton, polyester and their blends through contact in aqueous suspensions. The researchers discovered that Staph epidermidis adhered to fabrics much more so than Staph aureus, and that the adherence of Staph epidermidis and Staph aureus to fabrics increased as the content of polyester fibers in the fabrics increased. The attachment of E. coli to all fabrics was very low and was not affected by the fiber contents. The total numbers of adherent bacteria on cotton and polyester fabrics were related directly to the concentrations of the bacterial suspensions. The extents of adherence, expressed by the percentage of adherent bacteria from the suspension, however, were independent of the concentration. The length of contact with bacteria was also found to affect the adherence of bacteria on fabrics studied.

Just how bacteria is transferred from fabrics to hands and then to other fabrics again was the focus of study by Sattar, et al. (2001), who developed and applied a quantitative protocol for assessing the transfer of bacteria from bleached and undyed fabrics of 100 percent cotton and a 50-50 cotton/polyester blend to fingerpads or other pieces of fabric. Each fabric piece was inoculated with 10⁵ CFU of Staphylococcus aureus. Transfer from fabric to fabric was performed by direct contact using moist and dry fabrics. Transfers from fabrics to fingerpads of adult volunteers were tested using moist, dry and re-moistened pieces of the fabrics, with or without friction during the contact. Bacterial transfer from fabrics to moistened fingerpads was also studied. After the transfer, the fabric pieces were eluted, the eluates spread-plated, along with appropriate controls, on tryptic soy agar and the percentage transfer calculated after the incubation of the plates for 24 hours at 37 degrees C. The researchers concluded that bacterial transfer from moist donor fabrics using recipients with moisture was always higher than that to and from dry ones. Friction increased the level of transfer from fabrics to fingerpads by as much as fivefold. Bacterial transfer from poly/cotton was consistently higher when compared with that from all-cotton material. The researchers say this kind of data could help in the development of better models to assess the role fabrics may play as vehicles for infectious agents.
Antimicrobial Textile Technology

Antimicrobial textile technology — and the soft-surface contamination challenge it is designed to address — has continued to evolve and advance in the last several years, providing a parallel to hard-surface antimicrobial technology in the healthcare setting. A number of companies have developed and are marketing textiles in which a proprietary alloy of established antimicrobial elements such as silver are woven into the fabric and are designed not to wear off or wash out. These antimicrobial textiles are being incorporated into the manufacturing of healthcare worker apparel such as scrubs and white coats, as well as bed linens, privacy curtains and other soft-surfaces.

A number of studies have looked at the effectiveness of antimicrobial textiles. For example, Mariscal, et al. (2011) evaluated the antimicrobial action of a silver-treated fabric for use in healthcare environments. The researchers note, “Unlike other biocides used in hospital fabrics, the prolonged use of silver has not been related to the appearance of resistant bacteria or cross-resistance to antibiotics, in spite of being extensively used in some treatments. Thirty-three hospital strains of bacteria were tested. This study showed the capacity of (silver-treated fabric) for significantly reducing the number of microorganisms present, compared with the reduction observed in control fabrics (CF). The antimicrobial action of (silver-treated fabric) was expressed as log(10) reduction (LR) from an initial inoculum of about 10^(5) colony-forming units (cfu). According to the bacterial species, an LR of between 2.6 and 5.0, and 4.1 and 5.0 (5.0 indicating total inhibition of bacterial growth) were observed, respectively, after 24 and 48 hours for (silver-treated fabric). Acinetobacter strains were the most resistant to CF after 72 hours (0.8 LR). All of the microorganisms, except two strains of Enterococcus faecalis, were totally inhibited after 72 hours on (silver-treated fabric).”

Let’s look to what the current literature reports about challenges relating to antimicrobial textiles.

Windler, et al. (2013) acknowledge that numerous antimicrobial technologies are available for textiles, used in many different applications to prevent the growth of microorganisms. They point to safety of the biological activity of the antimicrobial compounds as an ongoing subject of research and regulatory scrutiny. As Windler, et al. (2013) explain, “Triclosan, silane quaternary ammonium compounds, zinc pyrithione and silver-based compounds are the main antimicrobials used in textiles. On the technical side the application rates of the antimicrobials used to functionalize a textile product are an important parameter with treatments requiring lower dosage rates offering clear benefits in terms of less active substance required to achieve the functionality. The durability of the antimicrobial treatment has a strong influence on the potential for release and subsequent environmental effects. In terms of environmental criteria, all compounds were rated similarly in effective removal in wastewater treatment processes. The extent of published information about environmental behavior for each compound varies, limiting the possibility for an in-depth comparison of all

A number of companies have developed and are marketing textiles in which a proprietary alloy of established antimicrobial elements such as silver are woven into the fabric and are designed not to wear off or wash out.
textile-relevant parameters across the antimicrobials. Nevertheless, the comparative evaluation showed that each antimicrobial technology has specific risks and benefits that should be taken into account in evaluating the suitability of different antimicrobial products. The results also indicated that nanoscale silver and silver salts that achieve functionality with very low application rates offer clear potential benefits for textile use. The regular care of textiles consumes lots of resources (e.g. water, energy, chemicals) and antimicrobial treatments can play a role in reducing the frequency and/or intensity of laundering which can give potential for significant resource savings and associated impact on the environment."

Borkow, et al. (2008) acknowledge that “The rates of nosocomial infections, especially by those caused by antibiotic resistant bacteria, are increasing alarmingly over the globe. Although more rigorous infection control measures are being implemented, it is clear that the current modalities to reduce nosocomial infections are not sufficient. Textiles are an excellent substrate for bacterial growth under appropriate moisture and temperature conditions. Patients shed bacteria and contaminate their pajamas and sheets. The temperature and humidity between the patients and the bed are appropriate conditions allowing for effective bacterial proliferation. Several studies have found that personnel in contact with contaminated textiles were the source of transmission of the micro-organisms to susceptible patients. Furthermore, it has been reported that bed-making in hospitals releases large quantities of micro-organisms into the air, which contaminate the immediate and non-immediate surroundings. Contaminated textiles in hospitals can thus be an important source of microbes contributing to endogenous, indirect-contact, and aerosol transmission of nosocomial related pathogens.” Borkow, et al. (2008) note further that “the use of antimicrobial textiles, especially in those textiles that are in close contact with the patients, may significantly reduce bioburden in clinical settings and consequently reduce the risk of nosocomial infections. These textiles should possess broad-spectrum biocidal properties. They should be safe for use and highly effective against antibiotic resistant micro-organisms, including those that are commonly involved in hospital-acquired infections, and they should not permit the development of resistant microorganisms to the active compound.”

Kramer, et al. (2006) acknowledge that the antimicrobial impregnation of textiles is intended to provide protection of healthcare fabrics against microbial corrosion and therapy of infections and caution, “For every biocidal product a careful risk assessment for humans and the environment has to be performed. The advantage of antimicrobially active textiles has to be documented for every agent as well as for every application, and a balance has to be found between a textile’s quality rating and the potential risks, e.g., sensitization, disturbance of the ecology of the skin, toxic side effects by means of systemic absorption, cytotoxicity, genotoxicity, carcinogenicity, teratogenicity and ecotoxicity.” The researchers stress further, “It has to be emphasized that there are no objections against the use of antimicrobially active textiles if their use is equal or superior to other preventive or therapeutic measures. This applies to the amelioration of the course of dermatological diseases with disturbed skin flora, in particular atopic..."
dermatitis, the prevention and therapy of acute and chronic wound infections by wound dressings, the use of impregnated surgical suture material as well as special indications in the prevention of infection in medical facilities ... Presently, from a hygienic point of view, the following questions have to be clearly determined: declaration of any antimicrobial impregnation; development of international standards for in vitro testing and preclinical evaluation of efficacy and tolerance; and evaluation of the advantage of the antimicrobial properties for the intended use including the risk-benefit assessment.”

Höfer (2006) concurs, adding that proper test systems to evaluate the effectiveness and the safety of antimicrobial textiles must be devised to record qualitative and quantitative data on the in-vitro degree of effectiveness of antimicrobial textiles. Test systems based on testing the biocompatibility of medical devices are suitable to evaluate the safety of antimicrobial textiles.

Several studies have raised the question of selection for resistance. As McArthur, et al. (2012) summarize, “Bacteria have evolved unique mechanisms that allow them survive in the presence of strong selection pressures. Included in these mechanisms is the ability to share genetic determinants among and between species of bacteria thus spreading metal or antibiotic resistance traits quickly. The textile industry in response to demand has developed antimicrobial fabrics by the addition of bactericidal compounds during production. Some of these antimicrobials include metal nanoparticles, quaternary ammonia compounds, and broad spectrum compounds like triclosan. Bacteria have already expressed resistance to each of these bactericides. We predict that continued use of such materials could result in increased and widespread resistance to specific antimicrobials, especially metals, with an increased resistance to antibiotics. Such increases have the potential to find their way into other bacterial populations of human pathogens leading to serious and unintended public health consequences.”

Benefits must be weighed with potential drawbacks, requiring further research. Researchers continue to ascertain what the real level of risk that soft-surface contamination presents to patients and healthcare workers. “More studies are needed to evaluate the risk of soft surface contamination to patients and healthcare workers,” says the University of Arizona’s Kelly Reynolds says. “We know very little about the relative role of these environments in the actual survival and transmission of disease-causing organisms.”

Within this evolving frame of reference, clinicians and infection preventionists must evaluate these antimicrobial textiles and determine how they may play a role in a healthcare institution’s overall infection prevention and control program. Reynolds suggests they look to the science to help them better understand potential issues such as selecting for resistance. “Metal-based antimicrobials tend to have less association with developing resistance,” Reynolds says. “Clinicians and infection preventionists should consider which antimicrobial textiles have the greatest bactericidal effect (considering bactericidal agent and also efficiency of agent delivery from the textile) compared to a bacteriostatic effect. Information relative to noted side effects (i.e., reported skin/lung irritation) should also be considered.”

“Metal-based antimicrobials tend to have less association with developing resistance.”
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