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Linen: The New Frontier in Infection Control and Prevention

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OUTCOME

Learners will have an increase in or support of their nursing knowledge or skills related to best practices for infection prevention during linen processing.

OBJECTIVES

1. Describe at least two contributing factors for microbial contamination of linen.
2. Discuss three key steps involved in processing linens.
3. Identify at least two textile-based antimicrobials and discuss their effectiveness.

ACCREDITATION

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APPROVALS

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Debra Dunn, MSN, MBA, RN, CNOR, has no declared affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.

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PODCAST

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ABSTRACT

Personnel follow hospital policies and regulatory guidelines to prevent surgical site infections. However, a potentially contaminated item may be overlooked—the linen. When perioperative team members transport patients to the OR, the linen on the beds and transport carts can contain a variety of microorganisms. Textile surfaces can serve as reservoirs for microorganisms that can be transferred to health care providers, patients, and the environment. These pathogens may then infect patients, particularly those who are immunocompromised or have direct portals of entry (eg, catheters, incision sites). This article provides an overview of how microorganisms that cause health care–associated infections can survive and thrive on hospital linen and related equipment; discusses the linen laundering, transport, and storage processes and best practices; and discusses antimicrobial interventions—including a silver-ion laundering additive that was added as an infection prevention measure to the laundry production cycle at a medical center's contracted laundry facility.

Key words: linen laundering, antibiotic-resistant microorganisms, antimicrobial textiles, silver, copper.

Receiving a blanket fresh from the warmer is usually a welcome addition for a surgical patient during the perioperative period. Perioperative staff members may assume the laundered linen used in the OR is clean—but how clean is it? This article focuses on bed linen and patient gowns and the methods involved in the cleaning of these materials to ensure laundered linen is clean and does not transmit pathogens or lead to infection outbreaks.

HEALTH CARE–ASSOCIATED INFECTIONS AND BIOFILM

The US Centers for Disease Control and Prevention (CDC) estimates that 5% of hospitalized patients acquire a health care–associated infection (HAI), which can cost billions of dollars in added expenses.[1] National organizations, such as the CDC,[2] and professional organizations, such as AORN, provide recommendations and guidelines to direct patient care for the purpose of preventing surgical site infections. Perioperative nurses follow these requirements to provide optimal care, which includes

- instructing patients to perform preoperative skin cleansing at home;[3]
- preoperatively testing and treating patients for methicillin-resistant *Staphylococcus aureus* (eg, MRSA);[3]
- donning clean scrub attire;[4]
- intraoperatively maintaining patient normothermia,[5] ensuring antibiotic stewardship,[6] preparing the surgical site with an antiseptic,[3] applying sterile drapes, and employing sterile technique;[7]
- maintaining normothermia[5] postoperatively; and
- performing terminal cleaning.[8]

Humans live in a biodiverse world in which microorganisms are ever-present, naturally colonizing the intestines and living on the skin. Some microorganisms become

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pathogenic and invade and damage tissues or cause infections. Microorganisms that increase in number can upset the delicate biological balance inside the human body and carry the potential to cause death. Health care–associated infections are caused by bacteria and their endospores, fungi and their spores, and viruses. Bacterial endospores are formed when conditions are unfavorable to support life (eg, extreme fluctuations in temperature, lack of water and nutrients, low oxygen levels). These endospores can withstand heat, desiccation, chemicals, and radiation; they also can remain dormant for extended periods of time. After the environment reverts to more favorable conditions, endospores shed their dormant state and become vegetative again.[9] Microbes also can remain in this active state but hidden in biofilms.[10] A *biofilm* is a collection of different types of microorganisms that flourish as a group and produce a sticky substance composed of sugars, proteins, and nucleic acids used to attach themselves onto wet surfaces. Biofilms grow and thicken as layers are built upon layers.[11] They are hardy structures that are difficult to eradicate—microbicides either cannot penetrate the film[12] or are neutralized by the film.[11] Biofilms can develop on laundry equipment[10] and may contaminate linens.

Microorganisms can live on hard surfaces (eg, medical equipment), soft surfaces (eg, linen), and human skin.[13] These microorganisms can then spread directly from person to person or indirectly via an intermediary item (eg, bed, privacy curtain) or air currents (eg, produced during bed making or ventilation). Performing frequent and proper hand hygiene and wearing appropriate personal protective equipment can reduce the spread of microorganisms.[14]

Microorganisms can live on hard surfaces (eg, medical equipment), soft surfaces (eg, linen), and human skin.

CONTAMINATION OF HEALTH CARE TEXTILES

Textiles are items made from fabric and may include privacy curtains, scrub attire, lab coats, reusable surgical gowns and drapes, patient gowns, and other linen (eg, sheets, pillowcases, blankets). Microorganisms can accumulate and proliferate on textiles and can cause HAIs via direct or indirect contact or aerosolization.[15-17] Privacy curtains in the holding area or postanesthesia care unit, for example, are often used for extended periods (ie, weeks or months) without being cleaned, during which time microorganisms on them may flourish. Health care workers regularly place their hands on the same curtain segment to open and close it, either contaminating the curtain with their hands or having their hands contaminated by the curtain, and then may touch the patient.[18] Research findings have shown that privacy curtains can be contaminated with a variety of microorganisms. In a study of cultures from 50 privacy curtains, researchers identified vancomycin-resistant enterococci (VRE) on 21 (42%) of the curtains, MRSA on 11 (22%) of the curtains, and *Clostridioides difficile* on two (4%) of the curtains.[19] Authors of another study involving 180 cultures obtained from 43 privacy curtains identified that 47 (26.1%) were positive for *S aureus*, 31 (17.2%) were positive for VRE, 12 (6.7%) were positive for MRSA, 79 (43.9%) were positive for enterococcus species, and 40 (22.2%) were positive for various aerobic gram-negative bacilli.[20]

Although linen is either laundered in-hospital or at a contracted laundering facility, the extent to which this laundering removes microorganisms is unknown. Textile surfaces serve as reservoirs for microorganisms capable of infecting patients,[10,21] especially when laundering or linen-storage processes are deficient.[10] Contaminated textiles may contain bacterial, viral, or fungal microorganisms or pathogens that can be transmitted to health care providers, patients, and the environment, causing infection and illness.[22-24]

Up to 90% of hospital laundry (in pounds washed) in the United States is outsourced to a centralized commercial linen service company.[25] Increasing scientific evidence, however, has revealed that contaminated linen is a problem and also may play an indirect but compelling role in the spread of antibiotic-resistant organisms[26] and multidrug-resistant organisms. Health care textiles can play a role in the transmission of pathogens and infection,[27-30] although the extent to which they contribute to HAIs is not yet known.[31] What is known, however, is that lower microbial loads on linen is best in the health care environment.[32] Patients with the highest risk of acquiring HAIs and having associated negative outcomes are those who

- have direct portals of entry (eg, catheters, incision sites),
- have cancer,
- are immunocompromised,
- receive chemotherapy,
- undergo organ transplantation, or
- have extensive burns or failing organs.[18]

Microorganisms proliferate rapidly on textiles when there is a large inoculum;[13] when the temperature and humidity are suitable;[13] and when dust,[33] spilled food or liquid,[33] emesis,[2,10,22] feces,[2,10,22] urine,[2,22] blood,[2,22] dead skin cells,[2,10,22] or other such items are present. Microorganisms residing on linen will grow in the warm, moist setting and can cross-contaminate the hands of hospital personnel. Depending on the microorganism, it can live on textiles from one day to several weeks and sometimes longer than three months.[15,34,35] The transfer rate of microorganisms from the fabric to a person or another object also will vary depending on a diverse set of variables, such as the microorganism (eg, strain),[36] conducive environmental factors to sustain the microorganism, and the type of fabric (ie, material).[37] Transfer rates will be lower when the fabric or the health care worker's hands are dry.[37]

Common microorganisms found on hospital textiles include gram-negative bacteria,[38] coagulase-negative staphylococci,[38] *Bacillus* species,[38] *S aureus* and MRSA,[39] *C difficile*,[39] VRE,[35,39] *Acinetobacter baumannii*,[39] and skin flora.[38] *Clostridioides difficile* has been found to be the most common pathogen causing HAIs (12.1%); *S aureus* was the second most common (10.7%), followed by *Klebsiella pneumoniae* and *Klebsiella oxytoca* (9.9%) and *Escherichia coli* (9.3%).[40] In an audit of linen management practices at a 700-bed teaching hospital, the authors found that previously laundered linen located in storage rooms and on trolleys used for transporting the linen were contaminated with coagulase-negative staphylococci, *Bacillus* species (ie, mold), and viruses.[23] Hospital personnel should implement systematic cleaning protocols in their laundries or ensure their contracted facilities perform vigilant screening and cleaning practices to ensure microbial counts are as low as possible (Supplementary Sidebar 1).[22]

Researchers in the United Kingdom studied linen as a source of sporadic outbreaks of *C difficile* and examined the survival of *C difficile* spores on naturally contaminated bed sheets before and after washing at 65° C (149° F) for at least 10 minutes or at 71° C (159.8° F) for at least three minutes.[41] They found that combining heat and chemicals was more effective for decontaminating the linen than heat alone. They also found that even after processing linen in the commercial health care laundry facility using industrial detergent and disinfection-level temperatures, enough *C difficile* spores to pose a transmission risk still remained on the linen. They concluded that inadequate water temperature and disinfection conditions as well as the amount of time the linen spends passing through the various phases in the wash cycle could contribute to sporadic outbreaks of *C difficile*. Results of another study to evaluate the potential for cross-contamination of hospital linen during standard laundry procedures showed that *C difficile* spores can survive typical laundering temperatures and chemical treatments and can cross-contaminate other linen in the wash.[42]

Hospital personnel should implement systematic cleaning protocols in their laundries or ensure their contracted facilities perform vigilant screening and cleaning practices to ensure microbial counts are as low as possible.

In another study of linen, researchers purposely contaminated 19 fitted sheets and 17 top sheets with microorganisms and unexpectedly found that after laundering, the "clean" bed linen newly applied onto the patients' beds was still contaminated. The researchers concluded that the bacteria transfer most likely occurred when the health care worker's attire—which were contaminated from patient-care activities, such as touching patients and environmental surfaces—contacted the bed linen when making the bed.[43] Another theory, which the authors dismissed, indicated that contamination could have occurred anywhere along the continuum of the laundering and storage process. The authors accepted the belief that their textiles were free from contamination because of the statements made by the launderer. Results of an additional study showed that *S aureus* can survive a 10-minute wash at 54° C (129.2° F) with a drying cycle, and that *K pneumoniae* also can survive laundering that does not include a mechanical drying cycle (Supplementary Sidebar 2).[44]

PRODUCTION CYCLE FOR LAUNDERED LINEN

Two microbiological goals during the laundering process include the elimination or inactivation of pathogens on the linen and in the washing and drying devices and the prevention of biofilm formation inside the washing machine to prevent textile recontamination.[33]

Health care personnel should expect laundering to remove all soil from linen and eradicate or considerably reduce the number of microbes.[33] Laundry personnel should vigilantly and scrupulously adhere to regulatory requirements from national organizations (eg, Occupational Safety and Health Administration[45]) or laundry industry accrediting organizations (eg, International Organization for Standardization,[46] Healthcare Laundries Accreditation Council[47]) to help prevent HAIs. The acceptable limit standard for laundry contamination in the immediate postdrying phase is less than 20 colony-forming units per square decimeter and the absence of organisms, including *S aureus*, *E coli*, and *Candida albicans*.[18] Laundering facilities should provide standard washing, rinsing, drying, storing, and transporting of linen according to principles of hygiene, common sense, and consensus guidance from the CDC's Healthcare Infection Control Practices Advisory Committee and the Association for Professionals in Infection Control and Epidemiology.[22]

Washing

Transport personnel deliver hospital linen in closed bags to the laundry facility's soiled area where laundry personnel sort it by category (ie, sheets, blankets, surgical scrubs, patient gowns) before or after it is washed, according to the specific facility's protocols. During the wash phase, the washing mechanism removes dirt and either removes or kills microorganisms with heat, chemicals, and physical action. The water temperature should be 71° C (159.8° F) for at least 25 minutes to effectively destroy microorganisms.[2] Soap, detergents, and disinfectants also are used in the cleaning process to suspend soils and assist in eradicating microorganisms.[2] Disinfectants that destroy and inhibit microorganism growth include alcohols; quaternary ammonium cations; aldehydes; and oxidizing agents, such as sodium or calcium hypochlorite (bleach), hydrogen peroxide, and iodine.[14] Some of these compounds may result in bacterial resistance over time.[14] A mild acid is automatically added during the final step in the wash cycle (ie, a series of rinses) to neutralize the alkalinity in the water, soap, or detergent and kill microorganisms susceptible to rapid environmental pH shifts.[2] During the washing cycle, the following parameters must be in balance:

- water temperature,
- duration of the wash and rinse cycle(s),
- mechanical agitation, and
- type and amount of detergent and disinfectants.[10]

If one of the parameters is inadequate, one or more of the other parameters must be increased to achieve hygienically cleaned linen.[22] Microorganisms may survive washing cycles if the water temperature is not hot enough or the wash or rinse cycles are too short.[10] In a study conducted to investigate laundry contamination after washing at reduced water temperatures (ie, 22° C [71.6° F] versus 71.1° C [159.9° F]), researchers produced a satisfactory reduction in microbial contamination at lower water temperatures when they used bleach in larger quantities.[48]

Microorganisms may survive washing cycles if the water temperature is not hot enough or the wash or rinse cycles are too short.

Laundry supervisors should ensure that washing machines are cleaned properly and undergo maintenance on a regular schedule to prevent the buildup of biofilm.[10] An outbreak of *K oxytoca* occurred in a hospital because the microorganism had colonized inside the door seals of the washing machines. When large numbers of microorganisms survive the wash cycle, they can be transferred onto other items in the same wash cycle or when drying.[10]

Drying

Drying linen at high temperatures is another method for killing any remaining microorganisms. Personnel use drying machines or mechanical irons to dry linen. Appropriate dryer temperatures, cycle times, and load capacities (ie, size or weight) are dependent on the type of fabric.[10] Synthetic fibers (eg, polyester, polyester blends) require shorter drying times and lower temperatures than natural fibers (eg, cotton).[2] Dryers also need to undergo regular maintenance and temperature checks to ensure they are functioning correctly.

Transporting and Storing

Environmental services leaders in hospitals and surgery centers and laundry supervisors in commercial laundry facilities employ control measures for the transportation and storage

of cleaned linen. According to The Joint Commission, leaders of organizations that process laundry

> *are expected to develop their linen cleaning, storage and management requirements in accordance with evidence-based sources … such as the CDC, the National Association of Institutional Linen Management and/or the local or state authority having jurisdiction.*[49]

Cleaned linen should be transported in covered bins or trolleys or on carts and conveyor belts when being delivered to storage areas, which should be clean and free of soil, dust, and microorganisms (eg, mold) and are dry, with proper airflow and limited traffic.[18] Linen must be completely dry before being bundled or covered because residual moisture contributes to microbial growth.[50] Personnel overseeing transportation services and storage facilities of laundered linen at the laundry facility or in the hospital's laundry area should disinfect and air dry transportation and storage devices (eg, bins, carts, shelves, trolleys) on a regular basis to avoid contaminating the cleaned linen.[50,51] Researchers have identified that clean linen and the racks on which they are stored can be contaminated with both *S aureus* and MRSA.[23] Transporting and storing linen involves many touchpoints because of the numerous personnel handling the linen and the many pieces of equipment used—all of which pose a contamination risk. For both health care organizations and commercial laundries, these touchpoints include the transport of laundry out of the laundry area and into the central storage area. For health care facilities contracting commercial vendors, linen transport also includes vehicular transportation from the laundry facility to the health care facility, transportation from the arrival dock to the central storage zone, and transportation from the central repository point to the patient care units and onto ancillary storage carts.

The risk for contamination is greatest during the transport of cleaned linen from the laundry facility back to the hospital (Supplementary Sidebar 3). Cleaned and contaminated linen should be transported in vehicles (eg, trucks, vans, carts) that permit separation of clean and contaminated items. Clean and contaminated items may be transported together in the same vehicle as long as physical barriers or space separators are in place and shown to be effective in contamination prevention.[2] Supervisors should ensure that the carts, bins, plastic containers, or bags as well as the trucks or vans transporting the linen are cleaned on a regular schedule. After the linen arrives at the hospital, transport personnel drop it off at a loading dock where it is then transported for storage in a central location. Environmental services staff members will then dispense and store the linen on clinical units. All storage sites need to be clean areas, and the linen should be kept dry and free from soil and body-substance contamination (ie, via the hands, arms, and fronts of attire).

Cleaned and contaminated linen should be transported in vehicles (eg, trucks, vans, carts) that permit separation of clean and contaminated items.

Providing hygienically clean linen is a complex task. Laundry supervisors in commercial laundry facilities and environmental services staff members in health care facilities should ensure the cleanliness of linen storage areas, transport devices, and transportation vehicles to prevent contamination of these items. Laundry or facility maintenance personnel should document daily temperatures and humidity readings of the storage space in the laundry facility, and they should also inspect the ventilation system for cleanliness.[18] The frequency of cleaning the transport carts or bins also is pertinent, as is determining if the lowest racks on the carts are solid and covered so that the cart's wheels do not splatter dirt onto the linen.[18]

POTENTIAL FOR CONTAMINATION OF LINEN DURING USE

Microorganisms on linen may become airborne and settle onto surfaces and contaminate them. This transfer can occur when the OR bed is made, when the sheets are shifted, or when the patient transfers to the OR bed along with his or her hospital gown and top layer of linen.[22,24,52,53] For example, MRSA becomes a bioaerosol that contaminates the air and causes respiratory infections during bed making.[53,54] Researchers collected baseline air samples from the environment around 13 patients currently infected or colonized with MRSA.[53] They then collected air samples during the bed-making process and found aerosolized MRSA counts (ie, particulates collected on air samplers) that were significantly (approximately 25 times)

higher than the baseline MRSA counts (P = .01). One hour later, MRSA counts on the sheets were lower than before bed-making. The researchers also found that the aerosolized MRSA particles colonized the patients' nasal cavities or passed into their lungs.[53]

Environmental contamination by patients also was the focus of a study of isolation rooms housing 25 patients colonized or infected with MRSA.[26] More than half of the surfaces sampled, including the bed linen, tested positive for MRSA, suggesting that patients with MRSA contaminated their environment. The surfaces most commonly contaminated with MRSA are the patients' gowns, the front of health care workers' attire,[43] and the bed linen.[51,55] In a literature review, bed linen may have been the cause of the spread of MRSA, *Pseudomonas aeruginosa*, and VRE.[52] Thirty-seven studies were discussed, with a focus on determining contaminated bed components. Other researchers also were able to isolate *Bacillus stearothermophilus*,[52] *P aeruginosa*,[56] and *Burkholderia*[57] pathogens from the air during linen changes.

Contamination of health care workers and patients can also occur when an individual touches a contaminated surface (ie, direct transfer) and then touches another surface or individual (ie, indirect transfer), thereby infecting that surface or individual. Although hand hygiene eventually breaks the spread of infection, it cannot stop the "nosocomial infection loop" alone because it is of little use in a heavily contaminated hospital environment.[32] Because of the growing number of microorganisms resistant to antibiotics, administrators from patient care units, infection control, quality, and environmental services must improve the infection prevention and cleaning protocols in their health care facilities to decrease microbial proliferation.

TEXTILE-BASED ANTIMICROBIAL INTERVENTIONS

Creating antimicrobial surfaces and coatings using inorganic materials such as copper or silver on top of or woven into textiles is one approach to providing a cleaner environment.[32] Through a technological application, the antimicrobial coatings are diffused into the fabric to prevent microorganism adhesion to the fabric. A potential problem, however, is that diffusible antimicrobials could inadvertently cause microbial resistance over time because they continuously release active compounds into the environment. At present, however, few microorganisms show resistance to silver or copper.[32]

Microbicide-Releasing Surfaces: Copper and Silver

Copper incorporated into hospital linen reduces microbial loads 46% to 50% compared with standard linen.[58] In a quasi-experimental study on a chronic-care head-injury unit, patients who received copper-impregnated linen experienced 24% fewer HAIs, a 47% reduction in the number of days of fever, and a 32.8% reduction in the total number of days of antibiotic use compared with patients who received standard linen.[58] Further, in another study there was a reduction in *E coli* and *S aureus* within two hours of exposure to copper-impregnated fabrics, and the fabrics retained their activity against *S aureus* after 35 washes at 85° C (185° F) and remained active against dermatophytes and yeasts such as *C albicans*.[59] Cotton fibers can be plated and synthetic fibers (eg, polyester and nylon) and cotton-synthetic blends can be impregnated with copper oxide,[60] allowing copper to be permanently bound into the fibers.[59] After 100 washes, there was minimal loss of copper oxide from the cotton fibers, and its biocidal efficacy (ie, ability of a chemical substance or microorganism to destroy, make harmless, or control harmful organisms via chemical or biological means) remained intact.[59] In a study on copper oxide–impregnated textiles, patients slept on nonimpregnated sheets (ie, regular sheets) for one night and then on 90% cotton/10% copper oxide–impregnated sheets (ie, copper sheets) the next night. Researchers found that bacterial colonization on the sheets where the patients' feet had rested was significantly lower on the copper sheets than on the regular sheets (P < .05).[60] They concluded that HAIs can be reduced by using copper oxide in linen because bed sheets and pillowcases come into direct contact with the patient's skin.[60]

Creating antimicrobial surfaces and coatings using inorganic materials such as copper or silver on top of or woven into textiles is one approach to providing a cleaner environment.

Silver and silver-embedded surfaces serve as broad-spectrum antimicrobials to which bacteria have shown little resistance, even with low silver concentrations.[32] Silver ions kill microbes by binding to their surface proteins, causing their cell walls to rupture, which permits deeper ion penetration. Once inside the cell, silver ions interrupt metabolic

Key Takeaways

- Microorganisms can accumulate and proliferate on linen (eg, privacy curtains, scrub attire, gowns and drapes, sheets, pillowcases, blankets) and can cause health care–associated infections via direct or indirect contact or aerosolization. Increasing scientific evidence has revealed that contaminated hospital linen is a problem and may play an indirect role in the spread of antibiotic-resistant organisms.
- Laundering facilities should provide standard washing, rinsing, drying, storing, and transporting of linen according to principles of hygiene, common sense, and consensus guidance (ie, Centers for Disease Control and Prevention's Healthcare Infection Control Practices Advisory Committee, Association for Professionals in Infection Control and Epidemiology).
- Inadequate laundering parameters (eg, water temperature, duration of wash and rinse cycles) could contribute to sporadic outbreaks of microorganisms and infection. Laundry supervisors should ensure that washing machines are cleaned properly and undergo maintenance on a regular schedule to prevent the buildup of biofilm.
- Textile surface applications and antimicrobial coatings that diffuse into the fabric are technologies employed to prevent microorganism adhesion to fabric. Creating antimicrobial surfaces and coatings using materials such as copper or silver on top of or woven into textiles is one approach toward providing a cleaner environment.

activity, suffocating the cell. They also bind to DNA strands, preventing cell replication.[56] Silver ions also produce oxygen radicals, causing DNA and RNA damage and protein denaturization, resulting in bacterial cell death.[17]

Ionic silver is a more effective antimicrobial than a silver compound.[61] Through a charge-based interaction, silver ions bond and adhere to fibers and remain active throughout the duration of patient use.[62] Silver ions are released from textile threads in the presence of moisture, providing ongoing protection from contamination via health care workers' hands, surgical attire, and lab coats.[18,62] In a study involving 2,074 sheets and 1,912 patient gowns from three community hospitals with a focus on *Staphylococcus* and MRSA, researchers found that treating linen with a silver-ion solution reduced total aerobic bacterial colonies for bed linen by 88% and patient gowns by 89%.[63]

Silver, silver ions,[64] copper, and copper ions are used in health care products and water treatment devices. Silver and silver ions are used in surgical dressings, wound and device dressings, and indwelling urinary and vascular catheters to reduce the risk and rate of infection.[18] Copper has mostly been used on surfaces (eg, door handles, bed railings, light switches, and inhalation systems).[65] Two drawbacks to silver are that it lacks permanence, making replenishment a requirement,[66] and carries the possibility of human cell cytotoxicity.[66,67] Silver ion toxicity continues to be a debatable issue.[68,69]

PRACTICAL EXPERIENCE USING A RESIDUAL SILVER-ION LAUNDRY ADDITIVE

On February 1, 2020, Holy Name Medical Center, a community hospital in New Jersey, began laundering bed linen and patient gowns with a residual silver-ion additive dispensed during the rinse cycle each time the linen was washed. Health care providers' reusable isolation gowns and the scrub attire worn by staff members caring for patients with coronavirus disease 2019 (COVID-19) were added to this protocol in early March 2020 when the hospital became an epicenter for patients with COVID-19.

Silver-ion antimicrobial textile treatments kill infectious microorganisms through residual antimicrobial activity that is continuously effective during linen use, storage, and handling.[63,70] The product is approved by the United States Environmental Protection Agency (Reg. No. 90335-1) and the manufacturer states it is safe for all types of patients (eg, immunocompromised, neonatal, pediatric), can be used in a magnetic resonance imaging suite, and does not change the look or feel of the linen.[71] The manufacturer of the residual silver-ion laundry additive or the manufacturer's contracted partners incorporated good laboratory practices (ie, a set of principles followed in nonclinical laboratory research to ensure the quality and integrity for products regulated by government agencies) when performing laboratory studies and the results showed that residual silver ions applied to linen reduced levels of the following pathogens by 99.9% over time:

- *S aureus* and *C albicans* after six hours of contact;
- *K pneumoniae*, vancomycin-resistant *Enterococcus faecalis*, extended-spectrum beta-lactamase–positive *E coli*, and *A baumannii* after three hours of contact; and
- MRSA after nine hours of contact.[70]

Holy Name Medical Center entered into an agreement with a third-party laundry facility to use the silver-ion additive with a cost-savings guarantee (ie, percent decrease in HAIs). The silver-ion additive system was installed at Holy Name Medical Center's contracted laundry facility. The laundry facility sends clean linen samples to an independent third-party laboratory contracted by the silver-ion additive manufacturer to ensure efficacious levels of silver ions are on the linen. The additional cost of using the silver-ion additive is about $0.10 per pound, which translates to approximately $150,000 per year. According to the CDC, HAIs total more than $28.4 billion per year in direct medical costs as well as $12.4 billion in societal costs as a result of premature deaths and lost productivity.[72] Compared to the cost of HAIs, the additional expenditure for the residual silver-ion laundry additive is justifiable.

IMPLICATIONS FOR PRACTICE

It is difficult to establish a cause-effect relationship between contaminated linen and HAIs because the types of microorganisms to be studied are numerous and their interaction with humans is complex. Infection control and environmental services departments should work closely together with contracted (or internal) laundering facilities to periodically ascertain cleanliness of the facility and culture samples of laundered linen for cleanliness. As Bloomfield[10] states, it is not possible to attain zero HAIs, but that does not mean that health care providers should not continue to strive to reach this goal. The "seemingly 'harmless' microbial reservoirs of pathogens (e.g., in laundry)" or on stored linen "may become an important contributing factor to severe infections or the spread of microorganisms."[10(p10)] This is especially relevant for antibiotic-resistant bacteria.

CONCLUSION

Although it seems simple to provide hygienically clean linen for the OR—wash it, dry it, fold it, and store it—this process is much more complex than at first glance. This article provided evidence cited in various studies demonstrating correlations between contaminated linen and HAIs. Many perioperative practices revolve around maintaining a sterile environment and using aseptic technique to prevent surgical site infections. Perhaps it is time to take a closer look at linen and the role it plays in infection control and prevention.

Facility leaders should ensure routine cleaning practices are in place, proper equipment maintenance is performed, and proper processes are followed when washing, drying, transporting, and storing linen to prevent infection breaches and curtail poor work practices that may lead to contaminated environments. Facility leaders also should trial new technologies that focus on decreasing HAIs by eradicating microorganisms. The time has come to question what happens to linen at the laundering facility, in storage at the hospital, and in the OR. The greater the number of hands that touch the linen and the more bodies against which it is held, the greater the number of contamination sources that are introduced. This is a frontier that health care providers have mostly overlooked.

SUPPORTING INFORMATION

Additional information may be found online in the supporting information tab for this article.

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EXAMINATION

Continuing Nursing Education Activity

Linen: The New Frontier in Infection Control and Prevention

1.8 CH https://aorn.us/Apr22-cea

OUTCOME

Learners will have an increase in or support of their nursing knowledge or skills related to best practices for infection prevention during linen processing.

OBJECTIVES

1. Describe at least two contributing factors for microbial contamination of linen.
2. Discuss three key steps involved in processing linens.
3. Identify at least two textile-based antimicrobials and discuss their effectiveness.

The Examination and Learner Evaluation are printed here for your convenience. To receive contact hours, you must complete the online Examination and Learner Evaluation at *https://aorn.us/Apr22-cea*.

QUESTIONS

1. A biofilm is a collection of different types of microorganisms that flourish as a group and _____ laundry equipment; they may contaminate linens.
   a. are easy to eradicate from
   b. attach to dry surfaces on
   c. produce an oily substance on
   d. produce a sticky substance on

2. Microorganisms can accumulate and proliferate on textiles and can cause health care–associated infections via direct or indirect contact or aerosolization.
   a. true b. false

3. Textile surfaces serve as _____ microorganisms capable of infecting patients, especially when laundering or storage processes are _____.
   a. sources of; adequate
   b. sources of; deficient
   c. reservoirs for; adequate
   d. reservoirs for; deficient

4. During the laundering cycle for linen, inadequate _____ could contribute to sporadic outbreaks of *Clostridioides difficile*.
   1. air temperature
   2. water temperature
   3. sterilizing conditions
   4. disinfection conditions
   a. 1 and 3 b. 2 and 4
   c. 2, 3, and 4 d. 1, 2, 3, and 4

5. During standard laundry procedures, *C difficile* spores can survive typical laundering temperatures and chemical treatments and cross-contaminate other linen in the wash.
   a. true b. false

6. During the wash phase, the water temperature should be _____ for at least ____ minutes to effectively destroy microorganisms.
   a. 71° C (159.8° F); 40 b. 60° C (140° F); 40
   c. 71° C (159.8° F); 25 d. 60° C (140° F); 25

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7. Drying linen at high temperatures is another method for killing any remaining microorganisms. Synthetic fibers (eg, polyester) require _____ drying times and ____ temperatures than natural fibers (eg, cotton).
   a. longer; higher
   b. longer; lower
   c. shorter; higher
   d. shorter; lower

8. Cleaned linen should be transported in covered bins or on carts when being delivered to storage areas, which should be
   1. in a separate building.
   2. clean and free of soil, dust, and microorganisms.
   3. dry and have proper airflow.
   4. dry and have limited traffic.
   a. 1 and 3
   b. 1 and 4
   c. 2, 3, and 4
   d. 1, 2, 3, and 4

9. Copper incorporated into hospital linen reduces microbial loads ___% to __% compared with standard linen.
   a. 35; 40
   b. 46; 50
   c. 50; 62
   d. 53; 60

10. Silver and silver-embedded surfaces serve as broad-spectrum antimicrobials that are effective against multidrug-resistant organisms.
   a. true
   b. false

LEARNER EVALUATION

Continuing Nursing Education Activity

Linen: The New Frontier in Infection Control and Prevention

1.8 CH https://aorn.us/Apr22-cea

This evaluation is used to determine the extent to which this continuing nursing education activity met your learning needs. The evaluation is printed here for your convenience. To receive contact hours, you must complete the online Examination and Learner Evaluation at *https://aorn.us/Apr22-cea*. Rate the items as described below.

OUTCOME

Learners will have an increase in or support of their nursing knowledge or skills related to best practices for infection prevention during linen processing.

OBJECTIVES

To what extent were the following objectives of this continuing nursing education activity achieved?

1. Describe at least two contributing factors for microbial contamination of linen.
   Low 1. 2. 3. 4. 5. High
2. Discuss three key steps involved in processing linens.
   Low 1. 2. 3. 4. 5. High
3. Identify at least two textile-based antimicrobials and discuss their effectiveness.
   Low 1. 2. 3. 4. 5. High

CONTENT

4. To what extent did this article increase or support your knowledge of the subject matter?
   Low 1. 2. 3. 4. 5. High
5. To what extent did this article increase or support your skills related to the subject matter?
   Low 1. 2. 3. 4. 5. High

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