Infection Control Resource

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Prevention Strategies for IC Practitioners and Professional Nurses

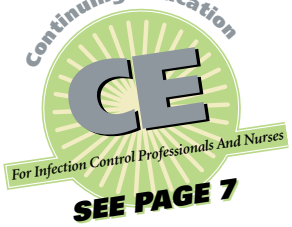
In this issue

The transfer of gram-positive bacteria, particularly methicillian-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE), among patients is a growing concern. In addition, newer viruses such as West Nile virus, SARS-associated coronavirus, and avian influenza have emerged in humans. One critical aspect of bacterial transfer is the ability of the microorganism to survive on various common hospital surfaces. There has been a resurgence of studies, several by Dr. Neely, examining the relationship between the environment, the microbe, and the host, with the aim being to better understand pathogenic processes so that we can design more and better ways of aborting them.

Prefilled syringes are now commonly used for routine flushing of all types of vascular access devices, and they offer numerous advantages. They provide a convenient unit-of-use dose, saving nursing time by avoiding having to draw up the flush solution from other fluid containers. Prefilled syringes prevent cross-contamination and infectious outbreaks from repetitive use of multiple-dose vials . Although these advantages encourage patient safety, there is the potential for misuse of prefilled saline syringes. Nurses have reported using these syringes in ways that encourage medication errors and contamination. In her article Ms. Hadaway discusses these inappropriate uses that could put patients at risk for serious complications.

Persistence of micro-organisms on common hospital surfaces

Strategies to control their dissemination



by Alice N. Neely, PhD

The primary role of the infection-control practitioner is to reduce the risk of both patients and healthcare workers (HCWs) acquiring infections. Over the past several years, it has become apparent that some microorganisms have increased their potential to cause serious infections; for example, virulent strains of bacteria such as *Clostridium difficile* and community-acquired methicillin resistant *Staphylococcus aureus* (CA-MRSA) have appeared within and outside medical facilities.[1,2] In addition, newer viruses such as West Nile virus,[3] SARS-associated coronavirus,[4] and avian influenza[5] have emerged in humans. Antimicrobial resistance has increased in all varieties of microbes, whether fungi,[6] viruses,[7] or bacteria.[8]

To gain some perspective on how we have arrived at this challenging point in our attempts to understand and combat infectious diseases, a brief digression into history might be helpful. In 1677, Antony van Leeuwenhoek assembled a crude microscope and began to describe the "little animals" he saw. For the next 200 years scientists studied the growth, survival, movement, metabolism, and all matters of function of these "animals." In 1882, with the publication of Koch's postulates to explain the etiology of anthrax, Robert Koch presented concrete rules to implicate "little animals" as the cause of disease, thereby solidifying what we now know as the germ theory of disease.[9] Meanwhile, there were efforts to control infections. In 1850, the infection-control hero Ignaz Semmelweis established that hand cleansing dramatically reduced puerperal fever. In 1867, Lister recognized the role of the environment in infections and introduced the use of antiseptics into the practice of surgery. Paul Ehrlich, speaking in Frankfurt in 1908, said that the compounds with which he was working "are exclusively 'parasitotrophic' and not 'organotrophic'and so it is not surprising that they seek out their targets like magic bullets."[9] Modern antimicrobial therapy with its search for "magic bullets" began. In 1929, Fleming published work about penicillin, which was followed in 1935 by Domagk's work with the first sulfa drug, and by the 1950s antibiotics were being widely used.

A subtle shift took place as the concept of the magic bullet developed. Much microbiologic research turned from studying basic properties of the microbes, such as their survival characteristics, to investigating the burgeoning pharmacologic science of antimicrobial development. Simultaneously, clinicians began more and more to rely on antibiotics for controlling infections—after all, if someone forgot to wash his hands or neglected to properly disinfect an area and someone else was infected, then he could always be given an antibiotic to cure the infection. For a number of years this philosophy worked; however, with time, antimicrobial-resistant strains emerged, and multiple-drug-resistant microorganisms (MDRO) are currently developing faster than new antibiotics are being discovered or synthesized.[6-8]

With the recognition that antimicrobials alone are not going to control infections, there has been a re-emphasis on some of the pre-antibiotic means of reducing infections. For example, though the value of hand hygiene was shown back in 1850, it was not until 2002

Continued on page 4

Misuse of prefilled flush syringes

Implications for medication errors and contamination

by Lynn Hadaway, MEd, RN, BC, CRNI

Prefilled syringes are now commonly used for routine flushing of all types of vascular access devices, and they offer numerous advantages. They provide a convenient unit-of-use dose, saving nursing time by avoiding having to draw up the flush solution from other fluid containers. Prefilled syringes prevent cross-contamination and infectious outbreaks from repetitive use of multiple-dose vials and large-volume bags of normal saline.[1] In addition, they carry the proper label required by the National Patient Safety Goals of the Joint Commission.

Although these advantages encourage patient safety, there is the potential for misuse of prefilled saline syringes. While there have been no actual adverse events publicized so far, nurses have reported using these syringes in ways that encourage medication errors and contamination. A 2007 study[2] of injectable-medication errors reported that 99% of nurses (n = 1039) believed that there is serious risk to patients if errors occur, and that 48% of errors are most likely to happen during preparation and administration of medication. This article will discuss these inappropriate uses that could put patients at risk for serious complications.

Syringe sizes and catheters

The first step in medication administration through all catheters is to assess patency by aspirating and flushing. The type of intravenous (IV) catheter being flushed determines the syringe size and the volume of solution to be used. A short peripheral catheter is commonly flushed with a 3-mL syringe that contains either 2 or 3 mL of normal saline. Midline and all central venous catheters (CVC) are flushed with 5 or 10 mL of normal saline, usually in a 10- or 12-mL syringe.

The reason for catheter flushing also affects the volume of flush solution needed. According to the Infusion Nursing Standards of Practice,[3] catheters are flushed to maintain patency and to prevent contact between incompatible medications. To accomplish these goals, variations in quantity of flush solutions may be necessary.

Prior to administering a vesicant medication through a short peripheral catheter, a flush volume of 5–10 mL (rather than the usual 2–3 mL) may be required for proper assessment of catheter and vein patency. Drugs such as phenytoin and vancomycin can cause severe tissue damage if the drug leaks from the vein into the subcutaneous tissue; promethazine can cause such severe outcomes that the drug literature states it must be given through infusing fluids and not through a capped and locked peripheral catheter.[4] The pH of each of these drugs renders it not recommended for administration through a peripheral vein[3,5]; however, limited numbers of doses through a peripheral vein may be needed in some clinical situations. Methods to assess vein patency include a free-flowing gravity drip and the absence of localized edema when the catheter is manually flushed.

A volume of 10 mL may be necessary to thoroughly flush the tubing and catheter lumen between incompatible medications; however, for pediatric and neonatal patients with smaller-diameter catheters, smaller flush volumes are needed.

There are concerns about syringe size for flushing CVCs. Rising pressure inside the lumen can lead to a ruptured catheter, requiring its removal. Most catheter manufacturers have warnings about using small-size syringes or limiting the amount of pressure to be applied to the catheter.

On injection, as a rule, smaller syringes (e.g., 3 mL) generate greater pressure at the syringe tip than larger syringes (e.g., 10 mL); Smaller syringes do not automatically mean that catheter damage results from their use, but the greater pressure produced by most 3-mL syringes has led to the common practice of using only a 10- or 12-mL syringe for flushing a CVC; however, catheter damage can occur even with a large syringe if the conditions are right.[6] When you encounter resistance while attempting to flush any catheter, it is never appropriate to continue flushing the catheter. Applying force to the syringe plunger will result in dangerously high pressure inside the catheter. Nurses have no way to measure the amount of force being applied to the plunger. Stronger or larger hands can easily exert large amounts of force while smaller hands could not apply the same force.[6,7]

Resistance can come from many causes, including thrombus or drug precipitate inside the catheter lumen, fibrin and thrombus formation around the tip of the catheter, and mechanical obstructions to the catheter such as pinch-off syndrome.[7,8] Applying greater amounts of force to overcome this resistance can lead to a linear slit in the catheter, regardless of the syringe size. When resistance is noticed while attempting to flush a catheter, the nurse must stop the procedure and investigate the possible causes. This may be as simple as opening a closed clamp or removing the dressing to discover a kinked catheter, or it might require obtaining a contrast-agent injection under fluoroscopy to determine the problems with fluid flow through the catheter.

Medication errors

Prefilled flush syringes are intended solely for catheter flushing, and use for other purposes can lead to medication errors. According to the National Coordinating Council for Medication Error Reporting and Prevention, medication error is defined as "any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use."[9]

A 2005 study[10] reported that 49% of all IV medication administration resulted in a medication error, with most mistakes occurring with IV-push medications, often from too-rapid injection. An assessment of the current literature reveals that human factors are a leading cause of medication errors. Human factors include performance deficits, knowledge deficits, dosage miscalculations, improper drug preparation, and not adhering to procedures and protocols.[10-12] In the 2007 study mentioned above, 78% of nurses reported that being too busy or rushed was a factor in injectable medication errors, and 60% reported that working with too many medications was another risk factor.[2]

The most frequent improper use, and the one that produces the greatest risk, is adding medication to a prefilled saline syringe, usually for the purpose of reconstituting or diluting the medication. The saline may be injected into a vial of medication and then

drawn back into the prefilled syringe, or a small amount of saline can be forced out of the syringe to allow a medication to be drawn into it. While the intention of saving time or money for the hospital may be a noble one, the outcome can be serious problems for your patients. The Institute for Safe Medication Practices was the first to sound an alarm about this, in 2006.[13]

Incorrect dosing

Volume markings on prefilled saline and heparin-lock syringes are not the same as those on regular syringes. On a standard 10- or 12-mL syringe, there is a mark at each milliliter and smaller marks every 0.2 mL. On a prefilled syringe designed for catheter flushing, the gradations are only at the half and full milliliter points; this makes it impossible to accurately measure a small dose of medication.

Prefilled syringes are often used with high-alert medications such as morphine and other narcotics; digoxin; and corticosteroids such as hydrocortisone, dexamethasone, and methylprednisolone. These medications must frequently be drawn in fractions of a milliliter, which is impossible to do accurately with a prefilled flush syringe. One manufacturer (Covidien) has widened the gradations on its prefilled syringes of saline and heparin-lock solutions (MONOJECT PreFill™) to discourage adding medication to the syringes.

Using prefilled saline syringes to dilute medications is also considered to be an off-label use, as no manufacturer provides instructions for this. Thus nurse and employer would bear the legal liability for any adverse events occurring from this practice.

Incorrect labeling

Administration of IV medications is performed using the SASH (Saline Administer Saline Heparin) or SAS method. Saline is injected first to assess catheter patency and to aspirate for blood return, followed by administration of the medication. Then the catheter is again flushed with saline to ensure that all medication was infused; heparin may or may not be administered after the saline flush. This multiple-step procedure mandates the use of appropriately labeled syringes and control of all human factors.

The majority (68%) of nurses participating in the 2007 study[2] of injectable-medication errors believed that more consistent syringe labeling would reduce such errors. The American Hospital Association includes "lack of appropriate labeling as a drug is prepared and repackaged into smaller units" in its list[9] of most common causes of medication errors. In response to The Joint Commission's National Patient Safety Goals for 2006, all fluid containers, including syringes, are now required to have a label specifying drug name, strength, amount, and expiration date (or time if the expiration will occur in less than 24 hours).[14] This goal pertains to ambulatory-care providers, critical-access hospitals, hospitals, and office-based surgery centers. It applies to all patient-care areas where procedures are performed. Labeling is required when a syringe is prepared and its contents are administered slowly over time, if a medication dose is prepared by one staff member and used by another, if medication doses are prepared in bulk for a series of procedures, or if the staff member participates in any other activity prior to administering the medication in the syringe.

Labeling is part of the medication preparation process. Therefore, labeling syringes in advance is not appropriate; however, preprinted labels may be applied to a syringe during its preparation. It is not acceptable to tape the empty vial of medication to the syringe in place of a proper label.

Color coding is another idea for syringe identification; however, current processes are controversial, with very little data supporting a decrease in medication errors. The Infusion Nursing Standards of Practice[3] state that "color coding, color differentiation, and color matching shall not be used for product or medication identification."

Proper labeling poses a significant problem when medication has been added to a prefilled syringe. The manufacturer's label is permanently affixed to the syringe barrel and contains product codes and barcode as well as specific information about the fluid and its volume. If a second medication is added to this syringe, there is no adequate method to amend the manufacturer's label. Consider what might happen if the nurse who prepared it was then distracted or briefly relinquished control of it: The newly prepared syringe could easily be confused with one containing only the prefilled solution, resulting in a serious medication error.

Contamination

Manufacture of commercially available prefilled flush syringes incorporates one of two sterilization methods: aseptic processing or terminal sterilization. Both methods are strictly determined by good manufacturing practices defined by the US Food and Drug Administration.[15]

Manufacturing

Aseptic processing involves multiple products and steps, consequently introducing a greater risk of contamination. The syringe, tip cap, and fluid are all sterilized individually and then brought together. The sterilization process for each component requires multiple environmental and personnel controls and strict validation of each step. Manipulation of the sterile component during assembly could introduce contamination.[15] When syringes are aseptically filled, sterilizing the final assembled product is not done.

With terminal sterilization, the fluid, syringe, and tip cap initially have a low bioburden but are not sterile. Once the syringe is filled and sealed under high-quality environmental conditions, it is then sterilized. The probability of a nonsterile unit is greater than one in a million.[15]

Packaging

Packaging of prefilled flush syringes can be either clean or sterile. Most prefilled syringes have a clear plastic overwrap that acts as a dust cover. With terminal sterilization, the syringe is filled, sealed, sterilized, and then packaged in the overwrap. The fluid and fluid pathway are sterile, but the outside of the syringe is not and therefore cannot be added to a sterile field.

Removal of packaging should occur immediately prior to use of the syringe. The entire internal surface of the syringe barrel is sterile. However, the distal portion of the barrel is not inside the sealed fluid pathway, so pulling the plunger back to the very end of the barrel could bring the fluid into contact with a clean but not necessarily sterile area. In addition, the syringe may contain an air bubble. Before the syringe is attached to the catheter hub, the air bubble must be expelled, which leaves 1–2 mL of space in the syringe barrel for aspiration.

Certain brands of prefilled flush syringes—MONOJECT PreFill™ Advanced (Covidien), Syrex™ (Excelsior Medical), and BD PosiFlush SF™ (BD Medical)—are filled, sealed, and packaged, and then the package is sterilized and overwrapped with sterile material. Thus the syringes can be dropped onto a sterile field.

Re-use

All prefilled flush syringes are single-use devices and do not contain a preservative agent. This means that they should be attached to a catheter hub only once, used, and then discarded. In an attempt to save time and money, some nurses may think it is appropriate to use 5 mL of the saline in a prefilled 10-mL syringe to flush a catheter

MONOJECT PreFill™ (Covidien, Sharps Safety Division)

before medication is given, to reapply the tip cap, and then to use the remaining 5 mL to flush after the medication has been infused. This practice raises the risk of contamination by excessive manipulation of the tip cap and the syringe tip.

Assessing catheter function requires aspirating for a brisk blood return. Syringes that have been exposed to blood should not be reserved for later use. The tip cap should not be used to cover the end of an intermittent IV administration set, since this could also introduce microorganisms to the system.

Safety first

Patient safety is now receiving well-deserved attention. Proper use of prefilled syringes is a convenient way to enhance patient safety while saving nursing time and costs. Policies and procedures should be written to include the points about proper use made in this discussion.

Training for all staff using prefilled syringes is imperative. Appropriate use of prefilled flush syringes and preventing their misuse will reduce the risk of medication error and infection.

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Persistence of microorganisms on common hospital surfaces — Continued from page 1

that the US Centers for Disease Control and Prevention (CDC) issued guidelines about hand hygiene,[10] and the Joint Commission then made proper hand hygiene a National Patient Safety goal.[11] Also, while at times the role of inanimate surfaces in the spread of infections has been questioned,[12] there has been a resurgence of studies examining the relationship between the environment, the microbe, and the host, with the aim being to better understand pathogenic processes so that we can design more and better ways of aborting them.

Controlled studies of the transfer of microorganisms

A number of studies have demonstrated that fomites in the environment can play a significant role in the nosocomial transmission of microorganisms.[13-15] For example, laboratory tests have shown[16] that simply touching a metal disk that had 10^4 plaque-forming units of rotavirus dried onto it 20 minutes earlier resulted in 10^3 infectious viruses transferred to the fingertip. Various species of the yeast *Candida* dried onto a hard plastic surface were transferred to the hands of 18 of 20 volunteers who contacted the plastic.[17] In another permutation[18] of a controlled experiment to investigate microbial transmission, investigators donned sterile gloves and then touched the bedrails and bedside tables of patients with documented vancomycin-resistant enterococci (VRE) in their stools. Direct culturing of the surfaces showed that 12 of the 13 surfaces (92%) were positive for VRE and 6 of the glove cultures (46%) were positive. Such transfer is also possible when soft surfaces, such as fabrics or plastics, are involved. For example, Scott and Bloomfield[19] demonstrated transfer of *Escherichia coli*, *Klebsiella aerogenes,* and *S aureus* from contaminated cloths to fingertips or to a laminated surface. Noskin[20] showed that VRE could be transferred to upholstery cushions and from the fabric cushions to people. Garments of healthcare workers are an important aspect of the environment that can easily become contaminated. Boyce et al[21] reported that 65% of nurses who had performed care activities on patients with MRSA in a wound or urine contaminated their nursing uniforms or gowns with MRSA.

Epidemiologic evidence linking fomites and transmission of microbes

Besides controlled studies of microbial transfer, numerous epidemiologic investigations have linked microbial contamination

> These microorganisms can survive on inanimate objects in the environment long enough for an instrument to move bacteria from one patient to another.

of surfaces and fabrics to an infectious outbreak. Cheesbrough et al[22] provided evidence that an outbreak of severe nausea and diarrhea in carpet installers was caused by small round structured viruses in the carpet, and Desenclos et al[23] documented transmission of hepatitis C virus by spring-loaded fingerstick devices. A cluster of hospital-acquired fungemia in neonates was connected with intravascular pressure-monitoring devices,[24] an outbreak of *Pseudomonas aeruginosa* infections was associated with flexible bronchoscopes,[25] an outbreak of multiresistant *Klebsiella pneumoniae* was associated with contaminated roll boards in operating rooms of a large teaching hospital,[26] and an epidemiologic investigation showed urine jugs to be the point source of contamination in an outbreak of *Serratia marcescens* bacteriuria in an intensive care unit.[27] In three separate studies,[15,28,29] recurrent patient acquisition of *Acinetobacter baumannii*, *P aeruginosa*, and MRSA has been linked to widespread environmental contamination by these bacteria. Just as a reminder that nosocomial acquisition affects not only patients: a recent study from Johns Hopkins suggested that fomites played a role in the transmission of CA-MRSA to two healthcare workers in their outpatient clinic area.[30]

Microbial survival

One critical factor for transmission of a microorganism from a patient or healthcare worker to the environment and then to another person is the ability of that microbe to survive on that environmental surface. If the microorganism dies on the surface, then the transfer cannot occur.

A number of factors have been shown to affect the survival of microbes on surfaces. For the purpose of this article, only persistence on dry surfaces, such as those found in a typical hospital room, will be considered.

Table 1. **Factors that affect microbial survival**

Microbial factors
- specific microorganism: genus, species, and strain
- concentration of the microorganism on the surface

Environmental factors
- light, UV radiation
- temperature
- humidity
- medium in which the microbe is suspended
- surface on which the microbe is deposited

This distinction is important, because some microbes—for example, *P aeruginosa*—will survive for months or longer in a wet environment,[31,32] but only for a matter of a few hours to a few days on dry surfaces.[19,33]

Factors that affect the survival of microbes on dry surfaces can be divided into two main groups: those related to the microorganism and those related to the environment (Table 1). The specific microorganism (genus, species, and even particular strain) is a determining factor in how long it will persist on a surface; data in Table 2 support this statement. These data were all generated under the same conditions of room temperature and humidity, and the microorganisms were all suspended in the same medium (10% saline) and inoculated onto the materials at the same concentrations (10^4–10^5 CFU).[33-35] The following common hospital fabrics and plastics were used: 100% cotton (clothing, towels), a blend of 60% cotton-40% polyester (scrub suits, lab coats, clothing), 100% polyester (privacy curtains, clothing), 100% polyethylene plastic (splash aprons), and 100% polyurethane (keyboard covers). Different microorganisms exist for different amounts of time on these materials. Coagulase-negative staphylococci persisted for 8-21 days on cotton, while *P aeruginosa* lived for only 2-24 hours on the same surface. Also, species of the same genus may persist for different periods; for example, the *Candida* species *albicans*, *tropicalis*, and *krusei* tended to die sooner on these materials than did *C parapsilosis*. Even within the same genus and species, individual strains survived for different periods, as indicated by the ranges of survival times recorded. These results hold for viruses also. For example, Mahl and Sadler[36] showed that adenovirus 2 lived for 3-8 weeks on various surfaces, while coxsackievirus B3 survived for only 2 weeks under exactly the same circumstances. Dixon et al[37] showed that different strains of the same virus, poliovirus 2, lived for a range of 1 to 4 weeks under similar conditions.

The concentration of the microbe on the surface can also influence its persistence. All other factors being equal, the greater the microbial load, the longer the survival. This is generally true for both gram-positive and gram-negative bacteria,[33,34,38] fungi,[35] and viruses.[39] For example, shortly after the SARS outbreak, investigators in public-health laboratories in Hong Kong inoculated cotton gowns with increasing concentrations (10^4, 10^5, and 10^6 $TCID_{50}$/mL) of the SARS-associated coronavirus, and they found that the higher the microbial load on the gown, the longer the viruses survived (5 minutes, 1 hour, and 24 hours, respectively).[39]

Environmental variables can also influence microbial viability (Table 1). Visible light and ultraviolet (UV) radiation are generally detrimental to microbes; for instance, both the yeast *C albicans*[40,41] and viruses[42] tend to live longer in the dark and when UV radiation is low.

Temperature can affect microbial viability. Human pathogens are often most functional at about 37°C. High temperatures (> 50°C) will kill most *Candida* species[43] and are generally detrimental to viral survival.[42] Low temperatures (4°C to 6°C), on the other hand, actually increase survival times for many bacteria.[44]

Humidity can have varying effects on the persistence of microorganisms on surfaces. Most bacterial pathogens survive longer under humid conditions, though *S aureus* persists longer at low humidity.[44-46] Considering that *Candida* species thrive in moist, often mucocutaneous environments, it is not surprising that the one study available indicates that these yeast survive better at higher humidity.[47] A number of studies have examined the effects of humidity on viral persistence, and the results are quite viral-specific; for example, hepatitis A virus and enterovirus 70 survived longer at higher relative humidity,[48,49] while herpesvirus 1 and rotavirus lived longer on surfaces at lower humidity.[36,50]

The medium in which the microbe is suspended also influences how long the organism lives once it is dried on a surface. Jawad et al[46] reported that *Acinetobacter* species suspended in bovine serum albumin survived considerably longer than did strains in distilled water, and Lai et al[39] found that SARS-associated coronavirus suspended in respiratory fluids lived longer than when suspended in stool. Sattar and Springthorpe[42] postulated that the menstruum in which the virus is suspended may be the most important of all parameters for survival of the virus once dried, because this medium could potentially provide nourishment and/or protection for the microorganism. The same could probably also be said for bacteria and fungi.

Microbial survival can be greatly affected by the surface on which the microorganism is deposited. This conclusion is true for viruses[39,51-53] and for bacteria and fungi, which tended to survive longer on plastics than on fabrics (Table 2).

Table 2. **Survival of common nosocomial pathogens on hospital fabrics and plastics at ambient temperature and humidity**[33-35,a]

Microorganism (number tested)	Survival time on fabric				
	Cotton	Blend	Polyester	Polyethylene	Polyurethane
Gram-positive bacteria					
Coagulase-negative staphylococci (6)	8-21 d	6-28 d	7-16 d	41->90 d	ND
Staphylococcus aureus (6)	4-21 d	1-21 d	1-56 d	22->90 d	ND
Enterococcus sp (10)	11->90 d	18->90 d	43->90 d	68->90 d	ND
Gram-negative bacteria					
Pseudomonas aeruginosa (2)	2-24 h	12 h-3 d	1-2 d	2-10 d	2-7 d
Serratia marcescens (2)	1-2 d	14 h-3 d	4-7 d	3-8 d	7-10 d
Proteus mirabilis (2)	4 h-9 d	2 h-8 d	2-4 d	4-8 d	8-26 d
Escherichia coli (2)	1-2 d	2 d	3-9 d	11-25 d	15-36 d
Klebsiella pneumoniae (2)	4-6 d	6-14 d	4-11 d	9-27 d	11-32 d
Acinetobacter sp (2)	2-9 d	9-11 d	4-14 d	>60 d	53-60 d
Enterobacter sp (2)	10-35 d	13-49 d	5-26 d	19-33 d	15-35 d
Fungi					
Candida albicans/ tropicalis/krusei (6)	1-3 d	1-5 d	1-8 d	3-18 d	4-12 d
Candida parapsilosis (2)	9-27 d	>30 d	27->30 d	>30 d	>30 d
Aspergillus sp (12)	1->30 d	2->30 d	1->30 d	>30 d	2->30 d
Fusarium/Mucor/ Paecilomyces sp (3)	<1-21 d	<1-20 d	5-24 d	4->30 d	6-20 d

Abbreviations: sp, species; ND, not done; d, days; h, hours
aThe same numbers of test organisms (10^4–10^5 CFU) were placed on each surface.

Given all of these variables, can any other generalizations be made? First, it must be noted that for every generalization made in this article, there are exceptions. Second, despite all of the variables mentioned above, it is clear that most common pathogenic microorganisms are capable of living on fabrics, such as those of uniforms or lab coats, long enough to be transported by a HCW from one patient to another or from the hospital environment to the healthcare worker's home. Likewise, these microorganisms can survive on inanimate objects in the environment long enough for an instrument such as a stethoscope to move bacteria from one patient to another,[54] for a contaminated keyboard in a patient-care area to serve as the source of an outbreak,[55,56] or for a contaminated toy to serve as a fomite, moving pathogens from one child to another.[57,58]

Various authoritative bodies have recognized the risk to patients caused by microbial survival on surfaces and have included recommendations in their guidelines to minimize these risks. For example, CDC/HICPAC Guidelines for Environmental Infection Control in Health-care Facilities,[59] NIOSH/CDC Selecting, Evaluating, and Using Sharps Disposal Containers,[60] and CDC/HICPAC Guidelines for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings 2007[61] each contain recommendations targeted at preventing the transfer of microorganisms by decreasing their presence, either by removing the microbes from the surface by cleaning or by decreasing their survival with disinfectants or sterilization.

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Controlling microorganisms on surfaces in the healthcare environment

How do we protect ourselves and our patients from microbes on surfaces? The following rules are basic and well known. The trick is to follow them and, as infection-control practitioners, to convince and encourage others to do so. The *APIC Text of Infection Control and Epidemiology*[62] has entire chapters on many of these topics and can serve as a good resource for any of these rules.

Do a risk assessment and control surface microorganisms accordingly. All surfaces, whether fabric or solid, are contaminated with microbes, but not all microbes present a risk for all patients. For example, a HCW in a well-child clinic will generally not need the same amount of personal protective equipment (PPE) as a HCW who enters the room of a bone-marrow transplant patient.

Use proper hand hygiene. Effective hand hygiene means educating staff, patients, and often families as to the correct way to wash hands with soap and water and with alcohol products. Some caveats about alcohol products should be kept in mind: visible dirt needs to be removed before using the alcohol; spore-forming microorganisms (such as *C difficile)* and non-enveloped viruses (such as norovirus) are not as readily killed as some other microbes, so washing with soap and water would be the preferred means of hand hygiene when dealing with these pathogens.

Use isolation precautions. Standard precautions will protect against bloodborne pathogen splash exposures. For certain microbes, such as MDROs, contact control with isolation precautions might be needed in addition. Use PPE appropriately. It is important that all HCWs know how to properly put on and take off the PPE so that this garb protects while being worn and does not contaminate the person in the process of being removed.

Disinfect appropriately. Just as microorganisms are different as to their survival times, so are they also different as to their susceptibility to various types of disinfectants. The Environmental Protection Agency (EPA) tests all potential disinfectants for their capacity to kill microorganisms, especially some of the types of microbes that are more difficult to kill—for example, mycobacteria such as *M tuberculosis* and bacterial spores such as *Clostridium* species. When a disinfectant is needed, use EPA-approved disinfectants or detergent disinfectants; note if the agent has the required action (e.g., virucidal, tuberculocidal, sporicidal, etc.); and heed correct-use concentrations and exposure times.

Launder appropriately. Just as disinfectants are used to kill and/or remove microbes from surfaces, laundering can be an effective means of removing contaminants from fabrics. Here I am referring not to industrial laundries but to laundering that HCWs might be doing—for example, some HCWs launder their own uniforms. Conventional automatic washers and driers can be effective if the following conditions are met: Use detergent to loosen the dirt and microbes from the fabric and bleach to kill the microbes. Use a high enough level of preferably warm water, because the water will dilute the microbes and carry them out of the washer. Use a clothes drier, because heat has been shown to further decrease microbial load.

Purchase equipment, furniture, and other items that can be easily disinfected. Nooks and crannies might be great for English muffins, but they are not for medical equipment or other hospital surfaces. Examine potential products for crevices and blind ends that might be difficult to clean. Smooth surfaces are preferable for furniture as well as equipment. While microbes tend to live longer on plastics than fabrics (Table 2), a smooth plastic chair covering that can be easily wiped with disinfectant would be preferable to a cloth covering unless the cloth can be removed and laundered frequently. Today many products are sold with "antimicrobial" surfaces. Used in the right circumstances and in the right way, some of these antimicrobial products can be helpful; however, some have been shown not to work[54] and the potential for misuse or overuse is a concern. Ehrlich's magic bullets have not cured infectious diseases but rather have generated some highly antibiotic-resistant organisms, so we need to weigh the potential benefit of purchasing these products against the risk of adding more antimicrobials to the environment and possibly generating more resistant organisms.

Apply your knowledge to work outside the box. For example, even using disinfectants effective against *S aureus,* we were unable to remove all MRSA from cases used to carry suction equipment for patients with tracheostomies. The bottoms of the cases were made of particle board that was covered with a synthetic fabric, so they could not be immersed in disinfectant. We knew that the MRSA would persist on the synthetic covering for many days if not removed or killed. We also knew that if the cases were made of materials that could be laundered, the proper laundering would remove the MRSA. A prototype case was constructed of denim, contaminated with MRSA, laundered, and tested; the surface contamination problem was solved.[63]

Communicate and collaborate. As with all other aspects of infection control, communication with other departments such as patient care services, environmental services, and purchasing is critical in preventing the transfer of microbes from surfaces. Solving the case-contamination problem above in-

volved personnel from respiratory therapy, a seamstress from rehabilitation services, and an infection-control practitioner. Collaboration among infection control and other departments can yield synergistic effects.

Conclusion

Some microbes can survive on surfaces for long times. These environmental surfaces can be involved in the transfer of microorganisms to patients and subsequently in the development of hospital-associated infections. Following the suggestions above to reduce microbial transfer will help to protect you, your patients, your fellow HCWs, and your family.

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Provider approved by the California Board of Registered Nursing. Provider #1447.

Upon completion of this program, the participant will be able to:

1. Identify several factors that can affect the persistence of microbes on surfaces
2. Identify various strategies for controlling the dissemination of microbes from surfaces
3. Explain the risks associated with the inappropriate use of prefilled flush syringes.
4. Discuss the differences in manufacturing and packaging processes for prefilled syringes.

Instructions

1. Read both articles.
2. Complete the post-test. (You may make copies of the answer form.)
3. Complete the participant evaluation.
4. Mail or fax the complete answer and evaluation forms to address on back page.
5. To earn 1.5 contact hours of continuing education, you must achieve a score of 70% or more. If you do not pass the test you may take it one more time.
6. Your results will be sent within four weeks after the form is received.
7. The fee has been waived through an educational grant from Covidien, Sharps Safety Division.
8. Answer forms must be postmarked by Feb. 13, 2010
9. Faculty Disclosure: No conflicts were disclosed.

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1. **Controlled studies have shown that it is possible for microorganisms to be transferred from an inanimate surface to a person or to her/his clothing.**
   a. true
   b. false
2. **Outbreak investigations have implicated fomites in the transmission of viruses, fungi, and bacteria.**
   a. true
   b. false
3. **Factors that affect the survival of microorganisms on dry surfaces can be divided into two main groups: those related to the microbe and those related to the environment.**
   a. true
   b. false
4. **Microbial factors that can influence the survival of a microorganism are:**
   a. the genus, species, and strain of that microbe
   b. the concentration of the microbe on the surface
   c. both a and b
   d. neither a nor b
5. **Environmental conditions that can influence microbial persistence on dry surfaces include:**
   a. light
   b. the medium in which the microbe is suspended
   c. the surface on which the microbe is deposited
   d. all of the above
6. **Many pathogenic microorganisms are capable of living on fabrics and surfaces long enough to be transferred by a HCW from one patient to another or from the healthcare environment to the HCW's home.**
   a. true
   b. false
7. **Some strategies for controlling microorganisms on surfaces in the healthcare environment include:**
   a. isolation precautions
   b. appropriate laundering
   c. communication and collaboration among departments
   d all of the above
8. **Alcohol-based products are always the best for hand hygiene.**
   a. true
   b. false
9. **HCWs can become contaminated if they do not remove PPE correctly.**
   a. true
   b. false
10. **All healthcare surfaces and fabrics should be disinfected in the same way.**
    a. true
    b. false
11. **Prior to administering medications through all intravenous catheters, the nurse must assess the catheter by:**
    a. flushing the catheter to check for resistance and aspiration of a brisk blood return
    b. flushing the catheter to assess for resistance but avoiding aspiration of blood into the catheter
    c. withdrawing and discarding any fluid previously held inside the catheter.
    d. aspirating for air and fluid and discarding that syringe.
12. **The volume of normal saline used to flush any intravenous catheter depends upon:**
    a. the insertion site of the catheter
    b. complaints of discomfort by the patient
    c. the medication being given
    d. the type of catheter and medication being given
13. **The use of prefilled saline syringes for diluting IV medications is**
    a. acceptable if addressed in hospital policy and procedure
    b. not acceptable under any circumstances
    c. acceptable for medications that are compatible with saline
    d. not acceptable for hospitalized patients
14. **The label on all medication syringes must include**
    a. Drug name, amount, strength, and expiration date or time
    b. Drug name and manufacturer
    c. Drug name and patient name
    d. Drug name and amount
15. **Terminal sterilization of prefilled syringes means that**
    a. the syringe and fluid are sterilized first and then assembled
    b. the syringe and fluid are assembled, packaged and then sterilized
    c. the syringe and fluid are assembled, sterilized and then packaged
    d. the syringe and fluid are sterilized separately then filled and packaged
16. **Prefilled syringes can be added to a sterile field:**
    a. if the label indicates a completely sterile package
    b. after removing the dust cover package
    c. immediately before it is needed in the procedure
    d. at any time during the procedure

Participant's Evaluation

What is the highest degree you have earned (circle one) ? 1. Diploma 2. Associate's 3. Bachelor's 4. Master's 5. Doctorate

Indicate to what degree this program met the objectives: Using 1 = Strongly disagree to 6 = strongly agree rating scale, please circle the number that best reflects the extent of your agreement to each statement.

	Strongly Disagree					Strongly Agree
1. Identify several factors that can affect the persistence of microbes on surfaces.	1	2	3	4	5	6
2. Identify various strategies for controlling the dissemination of microbes from surfaces.	1	2	3	4	5	6
3. Explain the risks associated with the inappropriate use of prefilled flush syringes.	1	2	3	4	5	6
4. Discuss the differences in manufacturing and packaging processes for prefilled syringes.	1	2	3	4	5	6

How long did it take you to complete this home-study program? _____

What other areas would you like to cover through home study?

_____

Name & Credentials _____

Position/Title _____

Address _____

City _____ **State** _____ **Zip** _____

Phone _____ **Fax** _____

Mark your answers with an X in the box next to the correct answer

	A	B	C	D
1	☐	☐	☐	☐
2	☐	☐	☐	☐
3	☐	☐	☐	☐
4	☐	☐	☐	☐
5	☐	☐	☐	☐
6	☐	☐	☐	☐
7	☐	☐	☐	☐
8	☐	☐	☐	☐
9	☐	☐	☐	☐
10	☐	☐	☐	☐
11	☐	☐	☐	☐
12	☐	☐	☐	☐
13	☐	☐	☐	☐
14	☐	☐	☐	☐
15	☐	☐	☐	☐
16	☐	☐	☐	☐

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