Chapter 19

Disinfection Policies in Hospitals and the Community

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The prevalance of hospital-acquired infections with multiresistant bacteria has increased in many countries around the world (Boyce, 1990). Nosocomial pathogens originating from colonized or infected patients can contaminate the environment and survive for extended periods. As a result, the hospital environment has become an important source (and or reservoir) of multiresistant bacteria capable of colonizing or infecting patients. Environmental surfaces have been associated with nosocomial outbreaks of multiresistant bacteria (Hayden, 2000; Talon, 1999) and community outbreaks of hepatitits A and acute gastroenteritis due to other viruses (Evans *et al*., 2002; Leoni *et al*., 1998; Love *et al*., 2002). Still these problems do not justify routine disinfection of surfaces and fomites, but targeted use of disinfectants is an important factor in preventing infections in the hospitals (and possibly in the community).

1. DEFINITIONS

Cleaning is the removal of all visible and invisible organic material (e.g., soil) from objects to prevent microorganisms from thriving, multiplying, and spreading. It is accomplished using water with detergents or enzymatic products. In sanitary facilities (e.g., washbasins, toilets), separate buckets and cloths have to be used and alkaline detergent is recommended for cleaning.

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Cleaning must precede disinfection and sterilization, since it reduces the number of microorganisms on contaminated equipment (Rutala, 1996; WIP, 2002 Module 6.1).

Disinfection describes the inactivation of pathogenic microorganisms (vegetative bacteria and/or fungi and/or viruses) on inanimate surfaces as well as intact skin and mucous membranes. It can be accomplished by the use of liquid chemicals or wet pasteurization in healthcare settings. Disinfection is aimed at minimizing the risk of transfer of microorganisms, but this process does not inactivate all microorganisms; bacterial endospores usually survive. Disinfection differs from sterilization by its lack of sporocidal activity, but a few disinfectants (frequently referred to as "chemical sterilants") will kill spores after prolonged exposure times (6–10 hr). At similar concentrations but with shorter exposure periods ($<$30 min), these disinfectants may kill all microorganisms with the exception of high numbers of bacterial spores and are called "high level disinfectants". Disinfectants that kill only most vegetative bacteria, some fungi, and some viruses ($\leq$10 minutes) are called "low level disinfectants" (Rutala, 1996).

Disinfection (as well as sterilization) can be effected by the prior cleaning of the object, organic load, the type and the level of microbial contamination, the concentration of and exposure time to the germicide, the nature of the object, and the temperature and the pH of the disinfection process.

Quaternary ammonium, iodine, alcohol, aldehyde, organic acid, peroxide, and halogenated compounds are the chemical disinfectants and have proven effective against a broad spectrum of microorganisms (Rutala, 1996; WIP, 2002 Module 6.1).

Based on the risk of infection, items are classified in three risk categories:

1. Critical items enter sterile tissue or the vascular system and if such an item is contaminated there is high risk of infection. Therefore these items must be sterile.
2. Semicritical items come in contact with mucous membranes or non-intact skin and these objects must be correctly cleaned and should undergo a disinfection process that eradicates all microorganisms and most bacterial spores.
3. Noncritical items come in contact with intact skin but not mucous membranes and these items need not be sterile. Environmental surfaces and fomites (e.g., bed rails, linens, bedside tables) in hospital are considered noncritical items (Rutala, 1996).

2. ENVIRONMENTAL CONTAMINATION

Outbreaks of hepatitis A or acute gastroenteritis can occur in hospitals, but are furthermore major public health problems, especially in schools, military

quarters, and nurseries. The aetiological agents of these diseases are excreted in high numbers in the faeces of infected individuals and are able to persist for extended periods of time in the environment (Evans *et al*., 2002; Kawai and Feinstone, 2000). In many outbreaks, surfaces may act as vehicles for the spread of the infection (Leoni *et al*., 1998; Lloyd-Evans *et al*., 1986; Weniger *et al*., 1983). During viral infections of the respiratory tract, patients shed large amounts of virus into their naso-tracheal secretions and these can contaminate the environment. Respiratory viruses, such as respiratory synscytial virus (RSV), rhinovirus, and parainfluenza virus have been shown to survive for extended periods in suspensions and on surfaces (Brady *et al*., 1990; Hall *et al*., 1980; Hendley *et al*., 1973; Sizun *et al*., 2000). Transmission of rhinovirus infection by contaminated surfaces was also shown in an experimental study (Gwaltney and Hendley, 1982). Contaminated environmental surfaces are considered to represent a significant vector for viral infections in the community and, also in paediatric units in the hospital. Next to direct droplet transmission, indirect transmission (environment → hands → self-inoculation of mucous membranes) is probably even more important in spreading viral respiratory diseases.

Nosocomial infections result from a patient's endogenous flora, person-to-person transmission, or are linked to contaminated surfaces (Shaikh *et al*., 2002; Weber and Rutala, 1993). Extensive environmental contamination has been demonstrated in rooms housing patients with multiresistant bacteria (Byers *et al*., 1995; Dembry *et al*., 1995; Hargreaves *et al*., 2001; Rutala *et al*., 1983). Several investigators have demonstrated that the inanimate environment near an infected patient commonly becomes contaminated with pathogenic microorganisms (Bonten *et al*., 1996; Boyce *et al*., 1997; Karanfil *et al*., 1992; Weber and Rutala, 1997). Furthermore, these microorganisms can survive in the environment—including on working surfaces—for a long time (Ansari *et al*., 1988; Byers *et al*., 1998; Getchell-White *et al*., 1989; Mbithi *et al*., 1992; Neely and Maley, 2000; Weber and Rutala, 2001). Consequently, CDC guidelines include measures to prevent infection originating from environmental contamination (CDC, 2001, 2003c).

Despite the fact that noncritical items or contact with noncritical surfaces carries little risk of transmitting infectious agents to patients, these items may contribute to secondary transmission by contaminating hands of healthcare workers or medical equipment (Weber and Rutala, 1993). In a survey study, 63% of 369 infection control professionals strongly or somewhat agreed that the inanimate environment plays a critical role in transmission of organisms (Manangan *et al*., 2001).

Boyce *et al*. (1997) found environmental contamination of rooms in 73% of the rooms harboring patients with methicillin-resistant *Staphylococcus aureus* (MRSA) infections and 69% when patients were colonized with MRSA.

Objects that frequently were contaminated included the floor, bed linens, the patient's gown, tables, and blood pressure cuffs. Even in the absence of direct patient contact 42% of the healthcare workers (HCW) contaminated their gloves by touching contaminated surfaces, thereby proving that contaminated environmental surfaces may serve as a source for MRSA spread. Rightfully, infection control measurements for MRSA outbreaks include decontamination of the environment (Burd *et al*., 2003; Hails *et al*., 2003; O'Connell and Humphreys, 2000). While antibiotic-resistant pathogens, including MRSA, so far were a strictly nosocomial problem, it recently became an important and growing threat to the public health. Around the world, cases of serious infections due to community acquired MRSA have been described (Mongkolrattanothai *et al*., 2003).

Another bacterial genus that has emerged as important nosocomial pathogen with increasing resistance to antibiotics are enterococci. The National Nosocomial Infections Surveillance (NNIS) system has identified enterococci as the second most common nosocomial pathogen. The report also demonstrated an overall increase in the incidence of vancomycin-resistant enterococci (VRE) from 0.3% to 7.9% between 1989 and 1993 (CDC, 1993). In many reports, hospital outbreaks of VRE have been related to environmental contamination and most outbreaks have been controlled with appropriate infection control measures (Armstrong-Evans *et al*., 1999; Boyce, 1995; Boyce *et al*., 1995; Calfee *et al*., 2003; Karanfil *et al*., 1992; Mayer *et al*., 2003; Montelcalvo *et al*., 1999; Noskin *et al*., 1995; Porwancher *et al*., 1997; Sample *et al*., 2002; Smith *et al*., 1998; Timmers *et al*., 2002). On the other hand standard disinfection methods, as those used in the United States (using sprays to apply the disinfectant to the surface) may not be sufficient to properly free the environment and surfaces from VRE. In a study by Byers *et al*. (1998) only the use of the "bucket method" successfully achieved room decontamination.

Multi-resistant Gram-negative bacilli have emerged as nosocomial pathogens, especially in intensive care units and became endemic in many hospitals, causing local outbreaks. Since environmental contamination plays an important role in these outbreaks, they frequently have been controlled with simple infection control measures including environmental disinfection (Alfieri *et al*., 1999; Aygun *et al*., 2002; Berg *et al*., 2000; Dijk *et al*., 2002; Engelhart *et al*., 2002; Talon, 1999).

The risks of transmission of blood-borne viruses, like human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV) have been well documented (Bolyard *et al*., 1998; CDC, 2003a). Although percutaneous injuries are among the most efficient modes of HBV transmission, these exposures probably account for only a part of these infections among HCWs. In several investigations of nosocomial hepatitits B outbreaks, most infected HCWs could not recall an overt percutaneous injury, although in some studies, up to one third of infected HCWs recalled caring for a patient who was

HBsAg-positive. In addition, HBV demonstrated to survive in dried blood at room temperature on environmental surfaces for at least 1 week. The potential for HBV transmission through contact with environmental surfaces has furthermore been demonstrated in investigations of HBV outbreaks among patients and staff of haemodialysis units. Data on survival of HCV and HIV in the environment are limited (Bolyard *et al*., 1998; CDC, 2003b; Sattar *et al*., 2001). Transmission of these viruses from patient to staff or from patient to patient could theoretically be mediated by contaminated surfaces and instruments and avoiding contact with contaminated materials are valuable means of protection. The indirect spread of these viruses, although much less common, can occur when objects that are freshly contaminated with tainted blood enter the body or contact damaged skin (CDC, 1977; Lewis *et al*., 1992).

2.1. Cleaning or disinfection of environment

Cleaning is necessary to control environmental contamination and for minimizing the spread of microorganisms. Cleaning also serves aesthetic aspects and a clean environment promotes further hygienic action.

There are two cleaning methods: dry cleaning and wet cleaning. The choice between wet and dry cleaning depends on the nature of the dirt and the room. A dry system is preferred for the cleaning of floors and particular materials. The dry system uses little or no liquid. Floors remain dry during cleaning and can be used by HCWs and patients immediately after cleaning without the danger of slipping. While recent wet cleaning or fluid spillage promotes the growth of Gram-negative organisms, these pathogens are rare in dry cleaned environments (Ayliffe *et al*., 1990; Dharan *et al*., 1999). Ballemans *et al*. (2003) conducted an experimental prospective study over a 10-week period and compared a new dry cleaning method, using humidified high-performance cloths with the wet routine cleaning practice. They showed a statistically significant reduction of the total viable counts, for the new dry cleaning method compared with the wet mopping. Unfortunately the study did not look into the impact on infection rates and/or reduced cross-contamination. Despite these results, dry cleaning is not sufficient to remove "stuck-on dirt"; a wet system must be used. Wet cleaning has to be the choice in departments where frequent spilling occurs (e.g., intensive care units). In general, wet cleaning of large surface is always preceded by dry mopping (WIP, 2002 Module 6.4).

Patient areas should be cleaned periodically and after contamination. Tables 1–7 give the advised frequency of routine cleaning according to the national Dutch infection control guidelines (WIP) in the nursing department (Table 1), isolation rooms (Tables 2–4), outpatients' clinic (Table 5), operating department (Table 6), and in "other" rooms within healthcare institutions (Table 7) (WIP, 2002 Module 6.4).

Table 1. Frequency of routine cleaning in the nursing department (including contact isolation and droplet isolation)

	Floor	Furniture/objects
Patient room	Clean daily	Clean daily
Treatment room	Clean daily	Clean daily
Sanitary facilities	Sanitary clean twice a day, every day of the week	Sanitary clean twice a day, every day of the week
Utility room	Clean daily	Clean daily
Kitchen	Clean daily	Clean daily
Administrative area	Clean 5 days in a week	Dusting 3 days in a week
Storage room	Clean 2 days in a week	Dusting 1 day in a week
Cloakroom	Clean 2 days in a week	Dusting 1 day in a week
Hallways and stairs	Clean daily	

Table 2. Frequency of routine cleaning in isolation room: airborne isolation

	Floor	Furniture/objects
Room	Clean daily	Clean daily
Sanitary facilities	Sanitary clean twice a day, every day of the week	Clean daily
After end of isolation; room, sanitary facilities, and sluice	Clean	Clean

Table 3. Frequency of routine cleaning in isolation room: strict isolation

	Floor	Furniture/objects
Room	Clean daily	Clean daily
Sanitary facilities	Sanitary clean twice a day, every day of the week	Clean daily
Sluice	Clean daily	Clean daily
After end of isolation; room, sanitary facilities, and sluice	Disinfection	Disinfection

Table 4. Frequency of routine cleaning in isolation room: protective isolation

	Floor	Furniture/objects
Room	Clean daily	Clean daily
Sanitary facilities	Sanitary clean twice a day, every day of the week	Sanitary clean twice a day, every day of the week

Table 5. Frequency of routine cleaning in the outpatients' clinic

	Floor	Furniture/objects
Treatment room[a]	Clean 5 days in a week	Clean 5 days in a week
Consulting room, hard floor covering[a]	Clean 5 days in a week	Clean (dusting) 5 days in a week
Consulting room, soft floor covering	Vacuum cleaning 2 days in a week	Clean (dusting) 2 days in a week
Examination room[a]	Clean 5 days in a week	Clean 5 days in a week

[a]If in use at the weekend, clean daily.

Table 6. Frequency of routine cleaning in the operating department

	Floor	Furniture/objects
Operating room	Clean daily	Clean daily
Scrub area	Clean daily	Clean daily
Room for immediate pre-operative care	Clean daily	Clean daily
Storage room	Clean daily	Clean (dusting) 1 day in a week
Waste storage room	Clean daily	Clean daily
Dirty linen storage room	Clean daily	Clean daily
Instrument washing room	Clean daily	Clean daily
Office area	Clean daily	Clean (dusting) 1 day in a week
Hallway	Clean daily	Clean (dusting) daily
Sluice	Clean daily	Clean (dusting) daily
Changing room	Clean daily	Clean (dusting) daily
Recovery room	Clean daily	Clean daily

[a]If not in use at the weekend, then clean 5 days in a week.

Table 7. Frequency of routine cleaning in various rooms

	Floor	Furniture/objects
Baby and children's room	Clean 5 days in a week	Clean 5 days in a week
Endoscopy room	Clean 5 days in a week	Clean 5 days in a week
Physiotherapy exercise room	Clean 5 days in a week	Clean 5 days in a week
Radiology, room for invasive examination	Clean 5 days in a week	Clean 5 days in a week
Radiology, room for other examination	Clean 5 days in a week	Clean (dusting) 2 days in a week
Rooms other than operating room in which invasive procedures are performed	Clean 5 days in a week	Clean 5 days in a week
Laboratory	Clean 5 days in a week	Clean 5 days in a week (only workbenches)
Central kitchen	Clean daily	Clean daily

[a]If in use at the weekend clean daily.

Routine cleaning of environmental surfaces with detergents and elimination of heavy dust is sufficient in most circumstances (WIP, 2002 Module 6.4). Detergents, disinfectants, and cleaning equipment itself may become a source of contamination. Werry *et al*. (1988) reported contamination of detergent solutions used for cleaning of surfaces. The contaminants, mainly Gram-negative non-fermentative bacilli, including *Acinetobacter* spp. and *Pseudomonas aeruginosa*. Since contamination may occur during the preparation of fresh solutions, cleaning solutions must be prepared daily or as needed, and frequently be replaced with fresh solution according to facility policies. The mop head should be changed at the beginning of each day and/or after cleaning up large spills of blood or other body substances. The use of disposable materials is preferred for all methods of cleaning. When using non-disposable materials, they have to be sent to the laundry service immediately after completing a cleaning job (WIP, 2002 Module 6.4).

Rutala *et al*. (2000) reviewed the epidemiological and microbiological data regarding the use of disinfectants on noncritical surfaces. They concluded to disinfect housekeeping and noncritical patient care equipment–surfaces given the minimal extra cost and added antimicrobial activity. Still, the routine use of disinfectants to clean hospital floors and other surfaces is controversial and the influence on nosocomial infections unclear. Danforth *et al*. (1987) compared the influence of disinfection vs cleaning using plain soap on nosocomial infection rates during a 6-month period. The combined nosocomial infection rate for the eight acute-care nursing wards did not differ between the disinfectant and detergent groups. No differences in floor contamination were observed. Comparing detergent- and disinfectant-use, Dharan *et al*. (1999) observed no change in the incidence of hospital-acquired infections during a 4-month trial period compared to the preceding 12 months.

When surfaces, furniture, or objects are found to be contaminated with blood or other body fluids, disinfectants must be used. Further indications for disinfection are: rooms of patients infected or colonized with multiresistant microorganisms, for example, MRSA, VRE, multiresistant Gram-negative bacteria (Hayden, 2000; Muto *et al*., 2003) and during viral epidemics, for example, HAV, coronavirus, rotavirus, etc. (Griffith *et al*., 2000; Leoni *et al*., 1998; Lloyd-Evans *et al*., 1986; Rutala and Weber, 1997). In general, when controlling epidemics, disinfection should be part of the solution to control the spread.

For noncritical instruments and devices as well as for general environmental surfaces high level disinfectants/liquid chemical sterilants should not be used (Rutala, 1996). As mentioned above, pre-disinfection cleaning is necessary, to reduce the biological burden and to remove organic matter (e.g., blood) that can partly inactivate disinfectants. Only a few industrial products offer cleaning and disinfection in one. Furthermore, disinfectants must be applied in

the right concentration and the prescribed contact time must be used (WIP, 2002 Module 6.4).

A chlorine-based disinfectant is typically used for disinfection of floors and other large surfaces. It is bactericidal, virucidal, tuberculocidal, and fungicidal. When chlorine reacts with proteinaceous material, such as blood, some of the chlorine combines with proteins and forms N-chloro compounds. The surface should be cleaned before the disinfectant is applied. Otherwise, a high concentration of available chlorine is required to inactivate virus in the presence of undiluted blood. Surfaces contaminated by blood or other body fluids which cannot be physically cleaned before disinfection, should be disinfected with 0.5% (5,000 ppm, i.e., 1:10 dilution) available chlorine or iodine. On the other hand, if the surface is hard and smooth and has been cleaned appropriately, 0.05% (500 ppm, i.e., 1:100) solutions are sufficient. Higher concentrations (1,000 ppm) are required to kill *Mycobacterium tuberculosis*. Once surfaces and objects have been cleaned, they must be in contact with the chlorine ("wet") for at least 5 min. This is the minimum time required to let the disinfectant take effect. After disinfection surfaces should be allowed to air dry (Rutala, 1996). *Clostridium difficile* has been associated with outbreaks of diarrhea and colitis in hospitalized adults, especially those receiving antimicrobial therapy. Although there is evidence of person-to-person transmission in the hospital as well as transmission via contaminated environmental surfaces and transiently colonized hands, control of *C. difficile* is usually achieved by proficient cleaning of environmental surfaces (McFarland *et al*., 1989). In order to reduce surface contamination and to control outbreaks, the use of sodium hypochlorite solutions (500 and 1,600 ppm) were shown to be more effective than chlorine. Thus, in outbreak situations, sodium hypochlorite should be the disinfectant of choice in reducing the levels of environmental contamination with *C. difficile* (Rutala and Weber, 1997).

Viruses can be transmitted from environmental surfaces either directly to mucous membranes or from surface-to-finger-to-mucous membranes. There may be discontinuous phases of infections between hospitals and the community involving environmental surfaces (Griffith *et al*., 2000; Rheinbaben *et al*., 2000; Rutala and Weber, 2000). Apart from good hand hygiene, Ward *et al*. (1991) showed, in an experimental study, that the use of disinfectants is an efficient method of inhibiting the transmission of rotavirus to human subjects. Sattar *et al*. (1993) determined that chlorine, phenolic, and phenol/ethanol products prevented rotavirus transmission from stainless steel disks to fingerpads. Infection occurred in 63% to 100% of volunteers who licked rotavirus-contaminated fingers/surfaces, but no volunteers became infected after licking contaminated surfaces that had been disinfected with the phenolic/ethanol spray. Hypochlorite was shown to be effective in controling outbreaks with coronavirus (1,000 ppm, 1 min), human parainfluenza virus (1,000 ppm, 1 min),

coxsackie B virus and adenovirus type 5 (5,000 ppm, 1 min), rotavirus (800 ppm, 10 min), hepatitis A virus (5,000 ppm, 1 min), and rhinovirus type 14 (800 ppm, 10 min) (Abad *et al*., 1997; Muto *et al*., 2003).

Also phenolics and quaternary ammonium can be used to disinfect environmental surfaces. Sodium hypochlorite has the additional advantage of being considerably less expensive than commercially available phenolic and quaternary disinfectants. Also, cleaning with sodium hypochlorite solutions may exacerbate respiratory disorders in some patients. When sodium hypochlorite is inappropriate, a phenolic or quaternary ammonium compound may be the preferred alternative. The phenolic detergents are tuberculocidal, fungicidal, virucidal, and bactericidal at their recommended use-dilution. The quaternary ammonium compounds sold as hospital disinfectants are generally fungicidal, bactericidal, and virucidal against lipophilic viruses (HBV, HCV, HIV, HSV-1); they are not sporocidal and generally not tuberculocidal or virucidal against hydrophilic viruses (Rutala, 1996).

For disinfection of smaller surfaces and materials, 70% alcohol can be used. Engelenburg *et al*. (2002) showed that a high concentration alcohol mixture (80% ethanol and 5% isopropanol) has a high virucidal potential in particular for the blood-borne lipid-enveloped viruses HIV, HBV, and HCV. But they are flammable, evaporate quickly, and are not appropriate for large surfaces cleaning (Rutala, 1996).

Also, for fomites (beds, bed linens, tray tables, etc.) in the patient room, cleaning and, if necessary (i.e., blood and/or other body fluids are detected or contamination with multiresistant bacteria), disinfection should be done regularly. The fomites are cleaned after the patient is discharged or in the event of visible soiling. If the fomites are used by the same patient for a long period of time, they must be cleaned at least once every 4 weeks. Shortstay beds and the other fomites for outpatients' treatment are cleaned after each use (WIP, 2002 Module 33.1).

2.2. Susceptibility to disinfectants

The multiple antibiotic-resistant Gram-negative bacilli, MRSA, and VRE have become established as a major problem in many hospitals around the world (Alfieri *et al*., 1999; Aygun *et al*., 2002; Berg *et al*., 2000; Boyce, 1990; Burd *et al*., 2003; Dijk *et al*., 2002; Engelhart *et al*., 2002; Getchell-White *et al*., 1989; Mongkolrattanothai *et al*., 2003; Timmers *et al*., 2002). Repeated exposure of hospital pathogens to antibiotics can lead to resistance, and also a similarly intensive exposure to antiseptics and disinfectants might result in a possible resistance to these agents.

Russell *et al*. (1998) have developed stable chlorhexidine resistance in some strains of *Pseudomonas stutzeri* by exposure to increasing concentrations of the

bisbiguanide. The chlorhexidine-resistant strains showed a variable increase in resistance to quaternary ammonium compounds and to trichlosan. Additionally, these chlorhexidine-resistant strains demonstrated a variable increase in resistance to polymyxin B, gentamicin, nalidixic acid, erythromycin, and ampicillin. They concluded that concomitant antibiotic and antiseptic resistance in Gram-negative bacteria may occur. Thomas *et al*. (2000) reported a stable increase in chlorhexidine MICs for *P. aeruginosa* after exposure to subinhibitory concentrations simulating residual levels of this antiseptic in the environment. Increases in resistance may result from exposure of microorganisms to sublethal doses of disinfectants. The high organic load or bioburden protects the bacteria and requires higher concentrations of the disinfectant to reach the disinfecting efficacy on the predominant microflora (Gebel *et al*., 2002).

However, Martro *et al*. (in press) assessed the bactericidal activity of several antiseptics and disinfectants on *Acinetobacter baumannii* strains obtained from clinical and environmental specimens in an intensive care unit during an outbreak. And observed neither evidence of development of resistance to biocides over time, nor a correlation between resistance to antibiotics and a decreased susceptibility to antiseptics or disinfectants.

The studies about activity of disinfectants against VRE, found no difference in the *in vitro* susceptibility of VRE and vancomycin-susceptible enterococci to standard hospital disinfectants (Block *et al*., 2000; Saurina *et al*., 1997). Also, Rutala *et al*. (1997) conducted a study to evaluate the susceptibility of antibiotic-susceptible and antibiotic-resistant hospital bacteria and did not find a correlation between antibiotic resistance and resistance to disinfectants. So, routine disinfection methods do not need to be altered for resistant bacteria.

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