Disinfection, sterilization, and antisepsis: An overview

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All invasive procedures involve contact by a medical device or surgical instrument with a patient's sterile tissue or mucous membranes. The level of disinfection or sterilization is dependent on the intended use of the object. Critical (items that contact sterile tissue, such as surgical instruments), semicritical (items that contact mucous membranes, such as endoscopes), and noncritical (devices that contact only intact skin, such as stethoscopes) items require sterilization, high-level disinfection, and low-level disinfection, respectively. Cleaning must always precede high-level disinfection and sterilization.

Antiseptics are essential to infection prevention as part of a hand hygiene program, as well as other uses, such as surgical hand antisepsis and preoperative skin preparation.

Each year in the United States, there are approximately 53,000,000 outpatient surgical procedures and 46,000,000 inpatient surgical procedures.[1] For example, there are at least 18 million gastrointestinal endoscopies per year.[2] Each of these procedures involves contact by a medical device or surgical instrument with a patient's sterile tissue or mucous membranes. A major risk of all such procedures is the introduction of infection. Failure to properly disinfect or sterilize medical devices and surgical instruments may lead to transmission via these devices (eg, endoscopes contaminated with carbapenem-resistant *Enterobacteriaceae*).[3]

Achieving disinfection and sterilization by disinfectants and sterilization practices is essential for ensuring that medical and surgical instruments do not transmit infectious pathogens to patients. Health care policies must identify whether cleaning, disinfection, or sterilization is indicated based primarily on the items' intended use. This article will capsulize and update other articles on this subject as well as provide updated information regarding newer sterilization, disinfection, and antisepsis technologies and practices.[4-7]

A RATIONAL APPROACH TO DISINFECTION AND STERILIZATION

Fifty years ago, Spaulding[8] devised a rational approach to disinfection and sterilization of patient care items and equipment. This classification scheme is so clear and logical that it has been retained, refined, and successfully used by infection control professionals and others when planning methods for disinfection and sterilization.[4-10] Spaulding believed that the nature of disinfection could be understood more readily if instruments and items for patient care were divided into 3 categories based on the degree of risk of infection involved in the use of the items. The 3 categories he described were critical (enters sterile tissue and must be sterile), semicritical (contacts mucous membranes or nonintact skin and requires high-level disinfection), and noncritical (comes in contact with intact skin and requires low-level disinfection). These categories and the methods to achieve sterilization, high-level disinfection, and low-level disinfection are summarized in Table 1. Although the scheme remains valid, there are some examples of disinfection studies with prions, viruses, mycobacteria, and protozoa that challenge the current definitions and expectations of high- and low-level disinfection.[11]

Critical items

Critical items are so-called because of the high risk of infection if such an item is contaminated with any microorganism, including bacterial spores. Thus, it is critical that objects that enter sterile tissue or the vascular system be sterile because any microbial contamination could result in disease transmission. This category includes surgical instruments, cardiac and urinary catheters, and implants. The items in this category should be purchased as sterile or sterilized by steam sterilization, if possible. If heat-sensitive, the object may be treated with ethylene oxide, hydrogen peroxide gas plasma, vaporized hydrogen peroxide, hydrogen peroxide vapor and ozone, or liquid chemical

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Table 1
Methods for disinfection and sterilization of patient care items and environmental surfaces*

Process	Level of microbial inactivation	Method	Examples (with processing times)	Health care application (examples)
Sterilization†	Destroys all microorganisms, including bacterial spores	High temperature Low temperature Liquid immersion	Steam (~40 min), dry heat (1-6 h, depending on temperature) Ethylene oxide gas (~15 h), HP gas plasma (28-38 min, NX), HP and ozone (46-70 min, VP4), HP vapor (28-55 min, V-PRO maX) Chemical sterilants‡: >2% glut (~10 h at 20°C-25°C), 1.12% glut with 1.93% phenol (12 h at 25°C), 7.35% HP with 0.23% PA (3 h at 20°C), 7.5% HP (6 h at 20°C), 1.0% HP with 0.08% PA (8 h at 20°C), ~0.2% PA (12 min at 50°C-56°C)	Heat-tolerant critical (surgical instruments) and semicritical patient care items Heat-sensitive critical and semicritical patient care items Heat-sensitive critical and semicritical patient care items that can be immersed
High-level disinfection	Destroys all microorganisms except some bacterial spores	Heat-automated Liquid immersion	Pasteurization (65°C-77°C, 30 min) Chemical sterilants/HLDs‡: >2% glut (20-90 min at 20°C-25°C), >2% glut (5 min at 35°C), 0.55% OPA (12 min at 20°C), 1.12% glut with 1.93% phenol (20 min at 25°C), 7.35% HP with 0.23% PA (15 min at 20°C), 7.5% HP (30 min at 20°C), 1.0% HP with 0.08% PA (25 min at 20°C), 650-675 free chlorine (10 min at 25°C), 2.0% HP (8 min at 20°C), 3.4% glut with 20.1% isopropanol (5 min at 25°C)	Heat-sensitive semicritical items (eg, respiratory therapy equipment) Heat-sensitive semicritical items (eg, GI endoscopes, bronchoscopes, endocavitary probes)
Low-level disinfection	Destroys vegetative bacteria and some fungi and viruses, but not mycobacteria or spores	Liquid contact	EPA-registered hospital disinfectant with no tuberculocidal claim (eg, chlorine-based products, phenolics, improved HP, HP plus PA, quats, quats plus alcohol, or 70%-90% alcohol. Exposure time ≥1 min)	Noncritical patient care items (eg, blood pressure cuffs) or surfaces (eg, bedside tables) with no visible blood

AER, automated endoscope reprocessor; *EPA*, Environmental Protection Agency; *FDA*, Food and Drug Administration; *GI*, gastrointestinal; *glut*, glutaraldehyde; *HLD*, high-level disinfectant; *HP*, hydrogen peroxide; *NX*, next generation; *OPA*, ortho-phthalaldehyde; *PA*, peracetic acid; *quats*, quaternary ammonium compounds.
*Modified from Rutala and Weber[4-10,46-48] and Kohn et al.[49]
†Prions (eg, Creutzfeldt-Jakob disease) exhibit an unusual resistance to conventional chemical and physical decontamination methods and are not readily inactivated by conventional sterilization procedures.[50]
‡Consult the FDA-cleared package insert for information about the cleared contact time and temperature and see reference 5 for discussion regarding why >2% glut products are used at a reduced exposure time (2% glut at 20 min, 20°C). Increasing the temperature using an AER will reduce contact time (eg, OPA 12 min at 20°C but 5 min at 25°C in AER). Exposure temperatures for some HLDs listed above vary from 20°C to 25°C; check FDA-cleared temperature conditions.[24] Tubing must be completely filled for high-level disinfection and liquid chemical sterilization. Material compatibility should be investigated when appropriate (eg, HP and HP with PA may cause functional damage to endoscopes). Intermediate-level disinfectants destroy vegetative bacteria, mycobacteria, most viruses, and most fungi, but not spores, and may include chlorine-based products, phenolics, and improved HP. Intermediate-level disinfectants are not included in Table 1, as there is no device or surface for which intermediate-level disinfection is specifically recommended over low-level disinfection.

sterilants, if other methods are unsuitable. Tables 1-3 list sterilization processes, high-level disinfectants, and liquid chemical sterilants and the advantages and disadvantages of each. With the exception of 0.2% peracetic acid (12 minutes at 50°C-56°C), the indicated exposure times for liquid chemical sterilants range from 3 to 12 hours. Liquid chemical sterilants can be relied on to produce sterility only if cleaning, which eliminates organic and inorganic material, precedes treatment and if proper guidelines as to concentration, contact time, temperature, and pH are met. Another limitation to sterilization of devices with liquid chemical sterilants is that the devices cannot be wrapped during processing in a liquid chemical sterilant; thus, it is impossible to maintain sterility following processing and during storage. Furthermore, devices may require rinsing following exposure to the liquid chemical sterilant with water that, in general, is not sterile. Therefore, because of the inherent limitations of using liquid chemical sterilants in a nonautomated (or automated) reprocessor, their use should be restricted to reprocessing critical devices that are heat-sensitive and incompatible with other sterilization methods.

Sterilization technologies can be relied on to produce sterility only if cleaning—to eliminate organic and inorganic material as well as microbial load—precedes treatment.[12-14] Other issues sterile reprocessing and operating room professionals must deal with when reprocessing instruments include weight limits for instrument trays, wet packs, packaging, loaned instruments, cleaning monitoring, and water quality.[14,15]

In May 2015, the Food and Drug Administration (FDA) convened a panel to discuss recent reports and epidemiologic investigations of the transmission of infections associated with the use of duodenoscopes in endoscopic retrograde cholangiopancreatography procedures.[16] After presentations from industry, professional societies, and invited speakers, the panel made several recommendations, to include reclassifying duodenoscopes based on the Spaulding classification from semicritical to critical to support the shift from high-level disinfection to sterilization. This could be accomplished by shifting from high-level disinfection for duodenoscopes to sterilization and modifying the Spaulding definition of critical items from "objects which enter sterile tissue or the vascular system or through which blood flows should be sterile" to "objects which directly or indirectly (ie, via a mucous membrane such as duodenoscope) enter normally sterile tissue of the vascular system or through which blood flows should be sterile."[3,17-19] It is noteworthy that in the Spaulding scheme, which identifies how an object should be disinfected or sterilized, he stated that mucous membranes should be intact and that sterilization of semicritical items is desirable.[8] Implementation of this recommendation requires sterilization technology that achieves a sterility assurance level of 10^{-6} of complex medical instruments such as duodenoscopes. Ideally, this shift would eventually involve not only endoscopes that indirectly enter normally sterile tissue (eg, duodenoscopes, bronchoscopes) but also other semicritical devices (eg, gastrointestinal endoscopes).[17]

Semicritical items

Semicritical items are those that come in contact with intact mucous membranes or nonintact skin. Respiratory therapy and

Table 2
Summary of advantages and disadvantages of chemical agents used as chemical sterilants or HLDs*

Sterilization method	Advantages	Disadvantages
PA/HP	• No activation required	• Material compatibility concerns (lead, brass, copper, zinc), both cosmetic and functional • Limited clinical experience • Mucous membrane and respiratory health effects • Potential for eye and skin damage
Glut	• Numerous use studies published • Relatively inexpensive • Excellent material compatibility	• Respiratory irritation from glut vapor • Pungent and irritating odor • Relatively slow mycobactericidal activity (unless other disinfectants added, eg, phenolics, alcohol) • Coagulates blood and fixes tissue to surfaces • Allergic contact dermatitis • ACGIH recommends limiting employee exposure to ceiling concentration of 0.05 ppm
HP (standard)	• No activation required • May enhance removal of organic matter and organisms • No disposal issues • No odor or irritation issues • Does not coagulate blood or fix tissues to surfaces • Inactivates *Cryptosporidium* at 6%-7.5% • Use studies published	• Material compatibility concerns (brass, zinc, copper, and nickel/silver plating), both cosmetic and functional • Serious eye damage with contact
OPA	• Fast-acting HLD • No activation required • Odor not significant • Excellent materials compatibility claimed • Does not coagulate blood or fix tissues to surfaces (claimed) • Relatively rapid mycobactericidal activity	• Stains protein gray (eg, skin, mucous membranes, clothing, environmental surfaces) • More expensive than glut • Eye irritation with contact • Slow sporicidal activity • Anaphylactic reactions to OPA in bladder cancer patients with repeated exposure to OPA through cystoscopy
PA	• Standardized cycle (eg, liquid chemical sterilant processing system using PA, rinsed with extensively treated potable water) • Low-temperature (50°C-55°C) liquid immersion sterilization • Environmentally friendly by-products (acetic acid, O_2, H_2O) • Fully automated • Single-use system eliminates need for concentration testing • May enhance removal of organic material and endotoxin • No adverse health effects to operators under normal operating conditions • Compatible with many materials and instruments • Does not coagulate blood or fix tissues to surfaces • Sterilant flows through scope, facilitating salt, protein, and microbe removal • Rapidly sporicidal • Provides procedure standardization (constant dilution, perfusion of channel, temperature, exposure)	• Potential material incompatibility (eg, aluminum anodized coating becomes dull) • Used for immersible instruments only • Biological indicator may not be suitable for routine monitoring • One scope or a small number of instruments can be processed in a cycle • More expensive (endoscope repairs, operating costs, purchase costs) than high-level disinfection • Serious eye and skin damage (concentrated solution) with contact • Point-of-use system, no sterile storage • AER using 0.2% PA not FDA cleared as sterilization process but as HLD
Improved HP (2.0%), HLD	• No activation required • No odor • Nonstaining • No special venting requirements • Manual or automated applications • 12-month shelf life, 14-day reuse • 8 min at 20°C HLD claimed	• Material compatibility concerns because of limited clinical experience • Organic material resistance concerns because of limited data

NOTE. All products are effective in the presence of organic soil, are relatively easy to use, and have a broad spectrum of antimicrobial activity (bacteria, fungi, viruses, bacterial spores, and mycobacteria). The above characteristics are documented in the literature; contact the manufacturer of the instrument and HLD/chemical sterilant for additional information. All products listed above are FDA cleared as chemical sterilants, except OPA and 2% accelerated HP, which are FDA-cleared HLDs.
ACGIH, American Conference of Governmental Industrial Hygienists; *AER*, automated endoscope reprocessor; *FDA*, Food and Drug Administration; *glut*, glutaraldehyde; *HLD*, high-level disinfectant; *HP*, hydrogen peroxide; *OPA*, ortho-phthalaldehyde; *PA*, peracetic acid.
*Modified from Rutala and Weber.[4-10,46-48]

anesthesia equipment, some endoscopes, laryngoscope blades and handles,[20,21] esophageal manometry probes, endocavitary probes, nasopharyngoscopes, prostate biopsy probes,[22] infrared coagulation devices,[23] anorectal manometry catheters, cystoscopes, and diaphragm fitting rings are included in this category.[20] These medical devices should be free of all microorganisms, although small numbers of bacterial spores may be present. FDA's definition of high-level disinfection is a sterilant used for a shorter contact time to achieve at least a 6 $\log_{10}$ kill of an appropriate *Mycobacterium* species. Cleaning followed by high-level disinfection should eliminate all pathogens capable of causing infection.

Intact mucous membranes, such as those of the lungs or the gastrointestinal tract, generally are resistant to infection by common bacterial spores but susceptible to other organisms, such as bacteria, mycobacteria, and viruses. Semicritical items minimally require high-level disinfection using chemical disinfectants. Glutaraldehyde, hydrogen peroxide, ortho-phthalaldehyde, peracetic acid, hypochlorite (via superoxidized water), and peracetic acid with hydrogen peroxide are cleared by the FDA[24] and are dependable high-level disinfectants provided the factors influencing germicidal procedures are met (Tables 1 and 2). The exposure time for most high-level disinfectants varies from 8 to 45 minutes at 20°C-25°C. When a disinfectant is selected for use with certain patient care items, the chemical compatibility after extended use with the items to be disinfected must also be considered. The reprocessing of semicritical items such as endoscopes, laryngoscopes, and

Table 3
Summary of advantages and disadvantages of commonly used sterilization technologies*

Sterilization method	Advantages	Disadvantages
Steam	• Nontoxic to patient, staff, environment • Cycle easy to control and monitor • Rapidly microbicidal • Least affected by organic/inorganic soils among sterilization processes listed • Rapid cycle time • Penetrates medical packing, device lumens	• Deleterious to heat-sensitive instruments • Microsurgical instruments damaged by repeated exposure • May leave instruments wet, causing them to rust • Potential for burns
HP gas plasma	• Safe for the environment and health care personnel • Leaves no toxic residuals • Cycle time 28-38 min and no aeration necessary • Used for heat- and moisture-sensitive items since process temperature <50°C • Simple to operate, install (208-V outlet), and monitor • Compatible with most medical devices • Requires only electrical outlet • Microbicidal efficacy data	• Cellulose (paper), linens, and liquids cannot be processed • Endoscope and other medical device restrictions based on lumen internal diameter and length (eg, single- and dual-channel device with stainless steel lumen that is ≥1.0 mm in internal diameter and ≤150 mm in length; see manufacturer's recommendations) • Requires synthetic packaging (polypropylene wraps, polyolefin pouches) and special container tray • HP may be toxic at levels greater than 1 ppm TWA • Organic matter reduces microbicidal activity
100% ETO	• Penetrates packaging materials, device lumens • Single-dose cartridge and negative-pressure chamber minimize the potential for gas leak and ETO exposure • Simple to operate and monitor • Compatible with most medical materials	• Requires aeration time to remove ETO residue • ETO is toxic, a probable carcinogen, and flammable • ETO emissions regulated by states, but catalytic cell removes 99.9% of ETO and converts it to CO_2 and H_2O • ETO cartridges should be stored in flammable liquid storage cabinet • Lengthy cycle/aeration time • Organic matter reduces microbicidal activity
Vaporized HP	• Safe for environment and health care personnel • Leaves no toxic residue, no aeration necessary • Cycle time 28-55 min • Used for heat- and moisture-sensitive items (metal and nonmetal devices)	• Medical device restrictions based on lumen internal diameter and length (eg, single-channel device with stainless steel lumen that is ≥0.7 mm in internal diameter and ≤500 mm in length; see manufacturer's recommendations) • Not used for liquid, linens, powders, or any cellulose materials • Requires synthetic packaging (polypropylene) • Limited materials compatibility data • Limited clinical use data • Limited comparative microbicidal efficacy data • Organic matter reduces microbicidal activity
HP and ozone	• Safe for environment and health care personnel • Uses dual sterilants, HP and ozone • No aeration needed because of no toxic by-products • Compatible with common medical devices • Cycle time 46-70 min • FDA cleared for general instruments and multichannel flexible endoscopes (see manufacturer's instructions)	• Endoscope and other medical device restrictions based on lumen internal diameter and length (eg, single- and dual-channel device with stainless steel lumen that is ≥0.7 mm in internal diameter and ≤500 mm in length; see manufacturer's recommendations) • Limited clinical use data • Limited materials compatibility data • Limited microbicidal efficacy data • Requires synthetic packaging (polypropylene wraps, polyolefin pouches) and special container tray • Organic matter reduces microbicidal activity

ETO, ethylene oxide; *FDA*, Food and Drug Administration; *HP*, hydrogen peroxide; *TWA*, time-weighted average.
*Modified from Rutala and Weber.[4-10,46-48]

nasopharyngoscopes is discussed in detail in another article in this journal.[25]

Since semicritical equipment has been associated with reprocessing errors that result in patient look-back and patient notifications, it is essential that control measures be instituted to prevent patient exposures.[26] Before new equipment (especially semicritical equipment, as the margin of safety is less than that for sterilization)[3] is used for patient care on more than one patient, reprocessing procedures for that equipment should be developed. Staff should receive training on the safe use and reprocessing of the equipment and be competency tested. At University of North Carolina Hospitals, to ensure patient-safe instruments, all staff who reprocess semicritical instruments (eg, instruments that contact a mucous membrane, including vaginal probes, endoscopes, prostate probes) are required to attend a 3-hour class on high-level disinfection of these instruments. The class includes the rationale for and importance of high-level disinfection and a discussion of high-level disinfectants and exposure times, reprocessing steps, monitoring minimum effective concentration, personal protective equipment, and the reprocessing environment (establishing "dirty-to-clean" flow). Infection control rounds or audits should be conducted at least annually in all clinical areas that reprocess critical and semicritical devices to ensure adherence to reprocessing standards and policies. Results of infection control rounds should be provided to unit managers, and deficiencies in reprocessing should be corrected (immediately, if patient safety issue, such as no brushing of channels) and corrective measures documented to infection control within 2 weeks.

Some items that may come in contact with nonintact skin for a brief period of time (eg, hydrotherapy tanks, ultrasound probes on intact skin [includes central line puncture site]) are usually considered noncritical surfaces and are disinfected with low- or intermediate-level disinfectants.[5,27,28] Since hydrotherapy tanks have been associated with spread of infection, some facilities have chosen to disinfect them with recommended levels of chlorine.[5,27]

Noncritical items

Noncritical items are those that come in contact with intact skin but not mucous membranes. Intact skin acts as an effective barrier to most microorganisms; therefore, the sterility of items coming in contact with intact skin is "not critical." Examples of noncritical items are bedpans, blood pressure cuffs, crutches, bed rails, bedside tables, patient furniture, toys,[29] portable equipment (eg, wheelchairs, infusion pumps, pulse oximeters, medication carts),[30,31] and floors.[32,33]

Table 4
Summary of advantages and disadvantages of disinfectants used as low-level disinfectants*

Disinfectant active	Advantages	Disadvantages
Alcohol	• Bactericidal, tuberculocidal, fungicidal, virucidal • Fast-acting • Noncorrosive • Nonstaining • Used to disinfect small surfaces (eg, rubber stoppers on medication vials) • No toxic residue	• Not sporicidal • Microbicidal activity affected by organic matter • Slow-acting against nonenveloped viruses (eg, norovirus) • No detergent or cleaning properties • Not EPA registered • Damages some instruments (eg, hardens rubber, deteriorates glue) • Flammable (large amounts require special storage) • Evaporates rapidly, making contact time compliance difficult • Not recommended for use on large surfaces • Outbreaks ascribed to contaminated alcohol[51]
Sodium hypochlorite (chlorine)	• Bactericidal, tuberculocidal, fungicidal, virucidal • Sporicidal (in high concentrations) • Fast-acting • Inexpensive (in dilutable form) • Not flammable • Unaffected by water hardness • Reduces biofilms on surfaces • Relatively stable (eg, 50% reduction in chlorine concentration in 30 d[52] • Used as the disinfectant in water treatment • EPA registered	• Reaction hazard with acids and ammonias • Leaves salt residue • Corrosive to metals (some ready-to-use products may be formulated with corrosion inhibitors) • Unstable active (some ready-to-use products may be formulated with stabilizers to achieve longer shelf life) • Microbicidal activity affected by organic matter • Discolors/stains fabrics • Potential hazard is production of trihalomethane • May cause skin and eye irritation • Odor (some ready-to-use products may be formulated with odor inhibitors) • Irritating at high concentrations
Improved (or accelerated) HP	• Bactericidal, tuberculocidal, fungicidal, virucidal • Fast efficacy • Easy compliance with wet treatment times • Safe for workers (lowest EPA toxicity category of IV) • Benign for the environment • Nonstaining • EPA registered • Not flammable	• More expensive than most other disinfecting actives • Not sporicidal at low concentrations • Some material compatibility issues
Iodophors	• Bactericidal, mycobactericidal, virucidal • Not flammable • Used for disinfecting blood culture bottles	• Not sporicidal • Shown to degrade silicone catheters • Require prolonged contact to kill fungi • Stain surfaces • Used mainly as antiseptics rather than disinfectants
Phenolics	• Bactericidal, tuberculocidal, fungicidal, virucidal • Inexpensive (in dilutable form) • Nonstaining • Not flammable • EPA registered	• Not sporicidal • Absorbed by porous materials and irritate tissue • Depigmentation of skin caused by certain phenolics • Hyperbilirubinemia in infants when phenolics not prepared as recommended
Quats (eg, didecyldimethylammonium bromide, dioctyldimethylammonium bromide)	• Bactericidal, fungicidal, virucidal against enveloped viruses (eg, HIV) • Good cleaning agents • EPA registered • Surface compatible • Nonstaining • Persistent antimicrobial activity when undisturbed • Inexpensive (in dilutable form)	• Not sporicidal • In general, not tuberculocidal or virucidal against nonenveloped viruses • High water hardness can make less microbicidal • A few reports documented asthma as a result of exposure to benzalkonium chloride • Microbicidal activity affected by organic matter • Absorption by cotton may diminish microbicidal activity • Multiple outbreaks ascribed to contaminated benzalkonium chloride[51]
Alcohol and quat	• Bactericidal, tuberculocidal, fungicidal, virucidal (enveloped and many nonenveloped viruses, eg, adenovirus, rotavirus, enterovirus, rhinovirus) • Fast-acting • Surface compatible • Nonstaining • Persistent antimicrobial activity when undisturbed • EPA registered	• Not sporicidal • Evaporate more rapidly than water-based disinfectants
PA/HP	• Bactericidal, fungicidal, virucidal, sporicidal (eg, *C difficile*) • Active in the presence of organic material • Environmentally friendly by-products (acetic acid, O_2, H_2O) • EPA registered • Surface compatible	• Lack of stability • Potential for material incompatibility (eg, brass, copper) • More expensive than most other disinfecting actives • Odor may be irritating • Can cause mucous membrane and respiratory health effects

NOTE. If low-level disinfectant is prepared on site (not ready to use), document correct concentration at a routine frequency, as the concentration delivered by automated disinfectant dispensers varies.
C difficile, *Clostridium difficile*; *EPA*, Environmental Protection Agency; *HP*, hydrogen peroxide; *PA*, peracetic acid; *quat*, quaternary ammonium compound.
*Modified from Rutala and Weber.[4-10,46-52]

Table 5
Antimicrobial spectrum and characteristics of hand hygiene antiseptic agents*

Group	Gram-positive bacteria	Gram-negative bacteria	Mycobacteria	Fungi	Viruses	Speed of action	Comments
Alcohols	+++	+++	+++	+++	+++	Fast	Optimum concentration 60%-95%, no persistent activity
Chlorhexidine (2%-4% aqueous)	+++	++	+	+	+++	Intermediate	Persistent activity, rare allergic reactions, not compatible with some anionic and nonionic detergents, ototoxicity
Iodine compounds	+++	+++	+++	++	+++	Intermediate	Cause skin burns, usually too irritating for hand hygiene
Iodophors	+++	+++	+	++	++	Intermediate	Less irritating than iodine
Phenol derivative (eg, PCMX)	+++	+	+	+	+	Intermediate	Not compatible with nonionic detergents, ecologic concerns
Triclosan	+++	++	+	-	+++	Intermediate	
Quats (eg, benzethonium chloride, cetrimide)	+	++	-	-	+	Slow	Not compatible with anionic detergents

NOTE. +++ = excellent, ++ = good, + = fair, - = no activity or not sufficient activity.
PCMX, para-chloro-meta-xylenol; *quats*, quaternary ammonium compounds.
*Modified from Boyce JM, Pittet D. Heathcare Infection Control Practices Advisory Committee.[45]

The 5 most commonly touched noncritical items in the patient environment have been quantitatively shown to be bed rails, bed surfaces, supply carts, overbed tables, and intravenous pumps.[34] In contrast to critical and some semicritical items, most noncritical reusable items may be decontaminated where they are used and do not need to be transported to a central processing area. There is virtually no documented risk of transmitting infectious agents to patients via noncritical items[35] when they are used as noncritical items and do not contact nonintact skin, mucous membranes, or sterile tissue. However, these items (eg, bedside tables, bed rails) could potentially contribute to secondary transmission by contaminating hands of health care providers or by contacting medical equipment that will subsequently come in contact with patients.[36] Tables 1 and 4 list several low-level disinfectants that may be used for noncritical items. Table 4 lists the advantages and disadvantages of the low-level disinfectants that are used on noncritical patient care items (eg, blood pressure cuffs) and noncritical environmental surfaces. The exposure time for low-level disinfection of noncritical items is at least 1 minute.

Many Environmental Protection Agency–registered liquid disinfectants have a 10-minute label claim. However, multiple investigators have demonstrated the effectiveness of these disinfectants against vegetative bacteria (eg, *Listeria*, *Escherichia coli*, *Salmonella*, vancomycin-resistant enterococci, methicillin-resistant *Staphylococcus aureus*), yeasts (eg, *Candida*), mycobacteria (eg, *Mycobacterium tuberculosis*), and viruses (eg, poliovirus) at exposure times of 30-60 seconds.[5,37-42] Thus, it is acceptable from a microbial inactivation perspective to disinfect noncritical medical equipment (eg, blood pressure cuffs) and noncritical surfaces (eg, bedside tables) with an Environmental Protection Agency–registered disinfectant or disinfectant/detergent at the proper use dilution and a contact time of ≥1 minute.[5,43,44] Since the typical drying time for a liquid disinfectant or disinfectant towelette on a surface is 1-4 minutes[42] and microbial inactivation occurs in 30-60 seconds,[40,42] one application of the disinfectant with a contact time of ≥1 minute on all hand contact or touchable noncritical surfaces is recommended.

ANTISEPSIS

Antiseptics are used in health care to reduce the level of microorganisms on the skin to a level unlikely to allow transfer from providers to patients (eg, cross-transmission via hands) or be the nidus of infection (eg, skin preparation prior to insertion of an intravascular device). Table 5 summarizes the antimicrobial spectrum of the antiseptics most commonly used in health care.[45] Bacterial spores are not listed, as they are not susceptible to available antiseptics and can only be removed mechanically by hand hygiene with soap and water or scrubbing. The most commonly used antiseptics in health care are chlorhexidine (CHG) (alone or in combination with alcohol), alcohol (alone or in combination with CHG or iodophor), and iodophor (alone or in combination with alcohol). Antiseptics are used for microbial reduction on skin in the following ways: hand hygiene, preoperative showers, preoperative skin preparation, skin preparation prior to insertion of catheters, and routine daily bathing of patients. Regarding this issue, Boyce reviewed several important topics associated with the use of antiseptics to include: current issues in hand hygiene; daily CHG treatment in the intensive care unit; prevention of infection during intravascular access, and best products for skin antisepsis for preoperative bathing, surgical site preparation, and surgical hand scrubs. Antiseptics (10% povidone-iodine) have also been used to decontaminate bone, with minimum sacrifice of cell viability, after dropping a bone graft on the operating room floor.[53,54]

CONCLUSIONS

When properly used, disinfection and sterilization can ensure the safe use of invasive and noninvasive medical devices. Cleaning should always precede high-level disinfection and sterilization. Strict adherence to current disinfection and sterilization guidelines is essential to prevent patient infections and exposures to infectious agents.

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