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 membrane 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 several other uses such as surgical hand antisepsis and pre-operative skin preparation.

All invasive procedures involve 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 pathogenic microbes leading to infection. Failure to properly disinfect or sterilize equipment may lead to transmission via contaminated medical and surgical devices (eg, *Mycobacterium tuberculosis*–contaminated bronchoscopes). This article will capsulize other articles on this subject and provide updated information of newer sterilization (eg, hydrogen peroxide vapor and ozone) and disinfection (eg, improved hydrogen peroxide) technologies.[1-4]

RATIONAL APPROACH TO DISINFECTION AND STERILIZATION

Almost 50 years ago, Spaulding[5] devised a rational approach to disinfection and sterilization of patient care items or 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 or sterilization.[1,6-8] 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.[10,12]

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.[13] 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.[14] 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 secondarily (ie, via a mucous membrane, such as a duodenoscope) enter normally sterile tissue of the vascular system or through which blood flows should be sterile.[14-16] Implementation of these recommendations requires sterilization technology that achieves a sterility assurance level of 10^{-6} (ie, a 12 $\log_{10}$ reduction of spores) of complex medical instruments, such as

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duodenoscopes. Ideally, this shift would eventually involve not only endoscopes that secondarily enter normally sterile tissue (eg, duodenoscopes, bronchoscopes) but also other semicritical devices (eg, gastrointestinal endoscopes).[14-16]

Critical items

Critical items are critical because of the high risk of infection if such an item is contaminated with any microorganism, including bacterial spores. Therefore, 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, implants, and ultrasound probes used in sterile body cavities. The items in this category should be purchased as sterile or be 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 sterilants if other methods are unsuitable. Tables 1–3 list sterilization processes and liquid chemical sterilants. 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 3-12 hours.[11] 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; therefore, it is impossible to maintain sterility after processing and during storage. Furthermore, devices may require rinsing after 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.

Semicritical items

Semicritical items are items that come in contact with mucous membranes or nonintact skin. Respiratory therapy and anesthesia equipment, gastrointestinal endoscopes, bronchoscopes, laryngoscopes, esophageal manometry probes, anorectal manometry catheters, endocavitary probes, prostate biopsy probes, cystoscopies, hysteroscopes, infrared coagulation devices, and diaphragm fitting rings are included in this category. These medical devices should be free of all microorganisms (ie, mycobacteria, fungi, viruses, bacteria); however, small numbers of bacterial spores may be present. 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

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	Steam (~40 min), dry heat (1-6 h depending on temperature)	Heat-tolerant critical (surgical instruments) and semicritical patient care items
		Low temperature	Ethylene oxide gas (~15 h), hydrogen peroxide gas plasma (28-52 min), hydrogen peroxide and ozone (46 min), hydrogen peroxide vapor (55 min), and ozone and hydrogen peroxide	Heat-sensitive critical and semicritical patient care items
		Liquid immersion	Chemical sterilants†: >2% glut (~10 h); 1.12% glut with 1.93% phenol (12 h); 7.35% HP with 0.23% PA (3 h); 8.3% HP with 7.0% PA (5 h); 7.5% HP (6 h); 1.0% HP with 0.08% PA (8 h); and ≥0.2% PA (12 min at 50°C-56°C)	Heat-sensitive critical and semicritical patient care items that can be immersed
HLD	Destroys all microorganisms except high numbers of bacterial spores	Heat-automated	Pasteurization (65-77°C, 30 min)	Heat-sensitive semicritical items (eg, respiratory therapy equipment)
		Liquid immersion	Chemical sterilants/HLDs‡: >2% glut (20-90 min at 20°C-25°C); >2% glut (5 min at 35°C-37.8°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); 400-450 ppm chlorine (10 min at 20°C); 2.0% HP (8 min at 20°C); and 3.4% glut with 26% isopropanol (10 min at 20°C)	Heat-sensitive semicritical items (eg, GI endoscopes, bronchoscopes, endocavitary probes)
Low-level disinfection	Destroys vegetative bacteria, 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 hydrogen peroxide, quaternary ammonium compounds—exposure times at least 1 min) or 70%-90% alcohol	Noncritical patient care item (blood pressure cuff) or surface (bedside table) with no visible blood

NOTE. Modified with permission from Rutala and Weber,[3] Rutala and Weber,[4] Rutala and Weber,[7] and Kohn et al.[9]
Abbreviations: *EPA*, Environmental Protection Agency; *GI*, gastrointestinal; *glut*, glutaraldehyde; *HLD*, high-level disinfection; *HP*, hydrogen peroxide; *OPA*, orthophthalaldehyde; *PA*, peracetic acid.
*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.[10]
†Consult the Food and Drug Administration–cleared package insert for information about the cleared contact time and temperature, and see Rutala and Weber[1] for discussion on why >2% glutaraldehyde products are used at a reduced exposure time (2% glutaraldehyde at 20 min, 20°C). Increasing the temperature using an automated endoscope reprocess will reduce the contact time (eg, OPA 12 min at 20°C, but 5 min at 25°C in automated endoscope reprocess). Exposure temperatures for some high-level disinfectants previously mentioned vary from 20°C-25°C; check Food and Drug Administration–cleared temperature conditions.[11] Tubing and lumens (normally requires active perfusion) 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 will 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 the table because there are no devices or surfaces for which intermediate-level disinfection is specifically recommended over low-level disinfection.

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

Sterilization method	Advantages	Disadvantages
Peracetic acid-hydrogen peroxide	• No activation required • Odor or irritation not significant	• Material compatibility concerns (lead, brass, copper, zinc) both cosmetic and functional • Limited clinical experience • Potential for eye and skin damage
Glutaraldehyde	• Numerous use studies published • Relatively inexpensive • Excellent material compatibility	• Respiratory irritation from glutaraldehyde vapor • Pungent and irritating odor • Relatively slow mycobactericidal activity (unless other disinfectants added, such as phenolic, alcohol) • Coagulates blood and fixes tissue to surfaces • Allergic contact dermatitis
Hydrogen peroxide	• 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 • Use studies published	• Material compatibility concerns (brass, zinc, copper, 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	• Stains protein gray (eg, skin, mucous membranes, clothing, environmental surfaces) • Limited clinical experience • More expensive than glutaraldehyde • Eye irritation with contact • Slow sporicidal activity • Anaphylactic reactions to OPA in bladder cancer patients with repeated exposure to OPA through cystoscopy
Peracetic Acid	• Standardized cycle (eg, liquid chemical sterilant processing system using peracetic acid, rinsed with extensively treated potable water) • Low temperature (50°C-55°C) liquid immersion sterilization • Environmental friendly by-products (acetic acid, O_2, H_20) • 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, temperatures, exposure)	• Potential material incompatibility (eg, aluminum anodized coating becomes dull) • Used for immersible instruments only • Biologic 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 • An AER using 0.2% peracetic acid, not FDA-cleared as sterilization process but HLD
Improved hydrogen peroxide (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 claim	• Material compatibility concerns because of limited clinical experience • Antimicrobial claims not independently verified • Organic material resistance concerns because of limited data

NOTE. Modified with permission from Rutala and Weber,[1] Rutala and Weber,[2] Rutala and Weber,[3] Rutala and Weber,[4] and Rutala and Weber.[7]
Abbreviations: *AER*, automated endoscope reprocessor; *FDA*, Food and Drug Administration; *HLD*, high-level disinfectants; *OPA*, ortho-phthalaldehyde.
*All products are effective in 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 aforementioned characteristics are documented in the literature; contact the manufacturer of the instrument and sterilant for additional information. All products listed are FDA-cleared as chemical sterilants except OPA, which is an FDA-cleared HLD.

items minimally require high-level disinfection using chemical disinfectants. Glutaraldehyde, hydrogen peroxide, ortho-phthalaldehyde, peracetic acid with hydrogen peroxide, and chlorine (via electrochemical activation) are cleared by the FDA[11] 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 8-45 minutes at 20°C-25°C. The reprocessing of semicritical items, such as endoscopes, laryngoscopes and nasopharyngoscopes, is discussed in detail in another article in this issue.[17]

Because semicritical equipment has been associated with reprocessing errors that result in patient lookback and notifications, it is essential that control measures be instituted to prevent patient exposures.[18] Before new equipment (especially semicritical equipment because the margin of safety is less than that for sterilization)[15] is used for patient care on >1 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 that reprocess semicritical instruments (eg, instruments which contact a mucous membrane, such as vaginal probes, endoscopes, and prostate probes) are required to attend a 3-hour class on high-level disinfection of semicritical instruments. The class includes the rationale for and importance of high-level disinfection and discussion of high-level disinfectants and exposure times, reprocessing steps, monitoring minimum effective concentration, personal protective equipment, and the reprocessing environment (establish dirty-to-clean flow). Infection control rounds or audits should be conducted annually in all clinical areas that reprocess critical and semicritical devices to ensure adherence to the reprocessing standards and policies. Results of infection control rounds should be provided to the unit managers, and deficiencies in reprocessing should be corrected and the corrective measures documented to

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 for heat-sensitive instruments • Microsurgical instruments damaged by repeated exposure • May leave instruments wet, causing them to rust • Potential for burns
Hydrogen peroxide gas plasma	• Safe for the environment and health care worker • Leaves no toxic residuals • Cycle time is ≥28 min, and no aeration necessary • Used for heat- and moisture-sensitive items because process temperature <50°C • Simple to operate, install (208 V outlet), and monitor • Compatible with most medical devices • Only requires electrical outlet	• Cellulose (paper), linens, and liquids cannot be processed • Endoscope or medical device restrictions based on lumen internal diameter and length (see manufacturer's recommendations) • Requires synthetic packaging (polypropylene wraps, polyolefin pouches) and special container tray • Hydrogen peroxide may be toxic at levels >1 ppm TWA
100% ETO	• Penetrates packaging materials, device lumens • Single-dose cartridge and negative-pressure chamber minimizes 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 carcinogen, and flammable • ETO emission 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 and aeration time
Vaporized hydrogen peroxide	• Safe for the environment and health care worker • It leaves no toxic residue; no aeration necessary • Cycle time, 55 min • Used for heat- and moisture-sensitive items (metal and nonmetal devices)	• Medical devices restrictions based on lumen internal diameter and length; see manufacturer's recommendations (eg, stainless steel lumen 1 mm diameter, 125 mm length) • Not used for liquid, linens, powders, or any cellulose materials • Requires synthetic packaging (polypropylene) • Limited materials compatibility data • Limited clinical use and comparative microbicidal efficacy data
Hydrogen peroxide and ozone	• Safe for the environment and health care worker • Uses dual sterilants, hydrogen peroxide and ozone • No aeration needed because of no toxic by-products • Compatible with common medical devices • Cycle time, 46 min • FDA cleared for general instruments, single-channel flexible endoscopes, and rigid and semirigid channeled devices	• Endoscope or medical device restrictions based on lumen internal diameter and length (see manufacturer's recommendations) • Limited clinical use (no published data on material compatibility, penetrability, organic material resistance) and limited microbicidal efficacy data • Requires synthetic packaging (polypropylene wraps, polyolefin pouches) and special container tray

NOTE. Modified with permission from Rutala and Weber,[1] Rutala and Weber,[2] Rutala and Weber,[3] Rutala and Weber,[4] and Rutala and Weber.[7]
Abbreviations: *ETO*, ethylene oxide; *FDA*, Food and Drug Administration; *TWA*, time-weighted average.

infection control within 2 weeks (immediately correct patient safety issues such as exposure time to high-level disinfectant).

In September 2015, the Centers for Disease Control and Prevention issued a health advisory related to cleaning, disinfecting, and sterilizing reusable medical devices. Recent outbreaks of infection associated with medical instruments and infection control lapses because of noncompliance with recommended reprocessing procedures highlight a critical gap in patient safety. Health care facilities were urged to ensure training of all personnel who reprocess medical devices and regularly audit (monitor and document) adherence to cleaning, disinfection, and sterilization of medical devices. Health care facilities should provide feedback from audits to personnel and request corrective measures be untaken when lapses are identified.[19]

Noncritical items

Noncritical items are items 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, linens, bedside tables, patient furniture, and floors. In contrast with 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[20] when they are used as noncritical items and do not contact nonintact skin or mucous membranes. However, these items (eg, bedside tables, bed rails) could potentially contribute to secondary transmission by contaminating hands of health care personnel or by contact with medical equipment that will subsequently come in contact with patients.[21] 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.

ANTISEPSIS

Antiseptics are used in health care to reduce the level of microorganisms on the skin to a level unlikely to allow transfer 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.[23,24] Bacterial spores are not listed because they are not susceptible to available antiseptics and can only be removed mechanically by scrubbing. The most commonly used antiseptics in health care are chlorhexidine (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 the microbial reduction on skin in the following ways: hand hygiene, preoperative showers, preoperative skin preparation, skin preparation prior to insertion of catheters, or routine daily bathing of patients.

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, such as rubber stoppers on medication vials • No toxic residue	• Not sporicidal • Affected by organic matter • Slow-acting against nonenveloped viruses (eg, norovirus) • No detergent or cleaning properties • Not EPA registered • Damage some instruments (eg, harden rubber, deteriorate 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
Sodium hypochlorite	• Bactericidal, tuberculocidal, fungicidal, virucidal • Sporicidal • 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) • 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) • Affected by organic matter • Discolors and stains fabrics • Potential hazard is production of trihalomethane • Odor (some ready-to-use products may be formulated with odor inhibitors) may be irritating at high concentrations
Improved hydrogen peroxide	• Bactericidal, tuberculocidal, fungicidal, virucidal • Fast efficacy • Easy compliance with wet contact times • Safe for workers (lowest EPA toxicity category, IV) • Benign for the environment • Surface compatible • Nonstaining • EPA registered • Not flammable	• More expensive than most other disinfecting actives • Not sporicidal at low concentrations
Iodophors	• Bactericidal, mycobactericidal, virucidal • Not flammable • Used for disinfecting blood culture bottles	• Not sporicidal • Shown to degrade silicone catheters • Requires prolonged contact to kill fungi • Stains surfaces • Used mainly as an antiseptic rather than disinfectant
Phenolics	• Bactericidal, tuberculocidal, fungicidal, virucidal • Inexpensive (in dilutable form) • Nonstaining • Not flammable • EPA registered	• Not sporicidal • Absorbed by porous materials and irritates tissue • Depigmentation of skin caused by certain phenolics • Hyperbilirubinemia in infants when phenolic not prepared as recommended
Quaternary ammonium compounds (eg, didecyl dimethyl ammonium bromide, dioctyl dimethyl ammonium bromide)	• Bactericidal, fungicidal, virucidal against enveloped viruses (eg, HIV) • Good cleaning agents • EPA registered • Surface compatible • Persistent antimicrobial activity when undisturbed • Inexpensive (in dilutable form)	• Not sporicidal • In general, not tuberculocidal and virucidal against nonenveloped viruses • High water hardness and cotton-gauze can make less microbicidal • A few reports documented asthma as a result of exposure to benzalkonium chloride • Affected by organic matter • Multiple outbreaks ascribed to contaminated benzalkonium chloride
Peracetic acid and hydrogen peroxide	• Bactericidal, fungicidal, virucidal and sporicidal (eg, *Clostridium difficile*) • Active in the presence of organic material • Environmental friendly by-products (acetic acid, O_2, H_2O) • EPA registered • Surface compatible	• Lack of stability • Potential to material incompatibility (eg, brass, copper) • More expensive than most other disinfecting actives

NOTE. Modified with permission from Rutala and Weber.[22]
Abbreviation: *EPA*, Environmental Protection Agency.

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 some anionic and nonionic detergents; ototoxicity; combined with alcohol
Iodine compounds	+++	+++	+++	++	+++	Intermediate	Causes 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	
Quaternary ammonium compounds (eg, benzethonium chloride, cetrimide)	+	++	–	–	+	Slow	Not compatible with anionic detergents

NOTE. Modified with permission from Boyce JM, Pittet D, Heathcare Infection Control Practices Advisory Committee.[23]
Abbreviations: *PCMX*, para-chloro-meta-xylenol; +, fair; ++, good; +++, excellent; –, no activity or not sufficient activity.

CONCLUSION

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 exposure to infectious agents.

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