

## Recommended Practices for Preoperative Patient Skin Antisepsis

The following recommended practices for preoperative patient skin antisepsis were developed by the AORN Recommended Practices Committee and have been approved by the AORN Board of Directors. They were presented as proposed recommendations for comments by members and others. They are effective January 1, 2008.

These recommended practices are intended as achievable recommendations representing what is believed to be an optimal level of practice. Policies and procedures will reflect variations in practice settings and/or clinical situations that determine the degree to which the recommended practices can be implemented.

AORN recognizes the various settings in which perioperative nurses practice. These recommended practices are intended as guidelines adaptable to various practice settings. These practice settings include traditional operating rooms, ambulatory surgery centers, physician's offices, cardiac catheterization laboratories, endoscopy suites, radiology departments, and all other areas where surgery may be performed.

References to nursing interventions (I) used in the Perioperative Nursing Data Set, second edition, (PNDS) are noted in parentheses when a recommended practice corresponds to a PNDS intervention.<sup>1</sup> The reader is referred to the PNDS for further explanation of perioperative nursing diagnoses, interventions, and outcomes.

### Purpose

These recommended practices provide a guideline for achieving skin preparation of the surgical site. The goal of preoperative preparation of the patient's skin is to reduce the risk of postoperative surgical site infection by removing soil and transient microorganisms from the skin; reduce the resident microbial count to subpathogenic levels in a short period of time and with the least amount of tissue irritation; and inhibit rapid, rebound growth of microorganisms. The following recommended practices are considered established guidelines for perioperative practice.

### Recommendation I

**Patients undergoing open Class I surgical procedures below the chin should have two preoperative showers with chlorhexidine gluconate (CHG) before surgery, when appropriate.<sup>2</sup>**

The act of washing and rinsing removes microorganisms from the skin. Some organisms may be difficult or impossible to kill with the application of CHG alone.

*Staphylococcus aureus* is the most common organism causing surgical site infections.<sup>2,3</sup> In 2003, 64.4% of health care-associated *Staphylococcus aureus* infections were from methicillin-resistant *Staphylococcus aureus* (MRSA).<sup>4,5</sup> Many surgical site infections result from colonization of the surgical site with the patient's own flora; and colonization with *Staphylococcus aureus* is a known risk factor for surgical site infection.<sup>2,6,7</sup> Clinical trials support the use of preoperative antiseptic showers to reduce the number of microorganisms on the skin, including *Staphylococcus aureus*.<sup>8-11</sup> In 1999, the Centers for Disease Control and Prevention recommend requiring patients to "shower or bathe with an antiseptic agent at least the night before the operative day" (Category IB).<sup>2</sup>

- I.a. Unless contraindicated, patients should be instructed or assisted to perform two preoperative baths or showers with CHG before surgery to reduce the number of microorganisms on the skin and reduce the risk of subsequent contamination of the surgical wound. (PNDS: I48, I123, I104, I50, I36, I106)
  - I.a.1. Four percent CHG is more effective than povidone-iodine or soap, and more than one shower is necessary to achieve maximum antiseptic effectiveness.<sup>8,9</sup> One preoperative shower with 4% CHG was found to be twice as effective in reducing skin bacterial flora as showering with nonmedicated soap.<sup>3</sup> Two showers with 4% CHG were found to result in lower microbial counts than showers with bar soap, medicated soap, or povidone-iodine.<sup>8,9</sup> This greater reduction in microbial counts persisted for more than 11 hours.<sup>8</sup> One randomized clinical trial found two consecutive showers or baths with 4% CHG resulted in lower surgical site infection rates than bar soap (ie, 9% versus 12.8%).<sup>9</sup> Showering three times with 4% CHG was found to reduce skin flora 20-fold preoperatively and to lower bacterial counts of the incision taken at the end of the procedure.<sup>10</sup>

Researchers studied the effects of preoperative showering with 4% CHG and povidone-iodine on skin microbial counts of patients colonized with *Staphylococcus aureus*. Two consecutive showers with 4% CHG the evening before surgery reduced microbial counts in the subclavian and groin areas; however, povidone-iodine had little effect on colonization of the groin. Showering both the evening before and the morning of surgery with 4% CHG reduced the bacterial count further at both sites; povidone-iodine provided inconsistent results; and showering with lotion soap increased the colony counts in both the subclavian site and groin.<sup>11</sup>

A sequential process of two applications of CHG with a minimum of two minutes contact time for intraoperative skin preps is suggested by manufacturers' recommendations and supported by one efficacy study for surgical scrub agents.<sup>12-15</sup>

- I.a.2. The reduction of the patient's own flora is more important with regard to surgical wounds that are classified as clean or surgical wound Class I.<sup>2</sup> For wounds that are partially or heavily contaminated, other organisms are more likely to contribute to surgical site infection, and showering with CHG may not be as advantageous. Research has not addressed the value of decolonizing patients before surgery on the eyes, ears, face, or before laparoscopic procedures.
- I.a.3. Although there is sufficient evidence of the effectiveness of two CHG showers to reduce microbial counts, there is insufficient research to definitively link this decrease in microbial count to a reduction in surgical site infection rates.
- I.a.4. Following each preoperative shower, the skin should be
- thoroughly rinsed;
  - dried with a fresh, clean, dry towel; and
  - the patient should don clean clothing.
- Rinsing the skin removes residual CHG that may cause skin irritation.

After use, towels contain microorganisms that can grow in the presence of moisture. Using a fresh towel after each shower and donning clean clothing minimizes the risk of reintroducing microorganisms to clean skin.

- I.b. Chlorhexidine gluconate preparation products used for preoperative showers should be US Food and Drug Administration (FDA)-approved or cleared for use as a general cleansing agent. (PNDS: I22, I75)
- The FDA determines the appropriate uses for all approved or cleared products.<sup>16,17</sup>
- I.c. Patients undergoing surgery on the head should be instructed or assisted to perform two preoperative shampoos with 4% CHG before surgery to reduce the number of microorganisms and subsequent contamination of the surgical site. (PNDS: I48, I123, I104, I51, I36, I106, I50)
- Two shampoos with 4% CHG reduce the emergence of resident skin flora and contamination of the surgical wound.<sup>18</sup> Researchers found that patients receiving two 4% CHG-shampoos and an intraoperative skin prep with 4% CHG had fewer bacteria on the scalp, both preoperatively and postoperatively, and had significantly fewer positive postoperative scalp cultures than patients receiving either shampoos with povidone-iodine or no shampoos.<sup>18</sup>
- Conditioners and other hair care products should not be used after performing preoperative shampoos because a chemical reaction between CHG and the hair care product may impede the antiseptic effectiveness of the CHG.<sup>19</sup>
- I.c.1. Hair spray and other alcohol-based hair products should not be used during head and neck surgery.
- Alcohol-based hair products are flammable and should not be left on the hair during head and neck surgery because they pose a fire hazard.<sup>19,20</sup>
- I.d. Caution should be exercised to avoid CHG contact with the eyes, the inside of the ears, the meninges, or other mucous membranes. (PNDS: I75, I104, I36, I51)

Chlorhexidine gluconate is irritating to the eye and can cause corneal damage.<sup>19</sup> Exposure of CHG to the inner ear can result in permanent deafness.<sup>13,19,22</sup>

- I.d.1. If CHG solution gets into the eye, immediately rinse the area with copious amounts of running water for at least 15 minutes and seek medical attention.<sup>23</sup>
- I.d.2. Chlorhexidine gluconate should not be used on the head if the patient's tympanic membrane is not intact.
- I.e. Chlorhexidine gluconate should not be used on patients for whom it is contraindicated, including patients with a known hypersensitivity to CHG or any other ingredient in the product.<sup>19,22</sup>(PNDS: I123, I75)  
Isolated incidents of hypersensitivity to CHG have been reported. Relatively minor symptoms upon exposure have preceded more serious reactions in some patients.<sup>19</sup>

## Recommendation II

**Preoperative skin antiseptic agents that have been FDA-approved or -cleared and approved by the health care organization's infection control personnel should be used for all preoperative skin preparation. (PNDS: I122)**

The FDA determines the appropriate uses for products which the agency has approved or cleared.<sup>16</sup>

- II.a. Current research, recommendations from the Association for Professionals in Infection Control and Epidemiology, FDA information, manufacturers' literature, and material safety data sheets (MSDSs) should be consulted when selecting antiseptic agents for skin preparation within health care organizations. (PNDS: I122, I75)  
Decisions about which skin antiseptics should be used in the practice setting are complex. A variety of products may be necessary to meet the needs of various patient populations. Input from an infection control professional knowledgeable about antiseptics is helpful when reviewing the current research and documentation provided by manufacturers.

- II.b. The preoperative skin antiseptic agent should:
  - significantly reduce microorganisms on intact skin,
  - contain a nonirritating antimicrobial preparation,
  - be broad spectrum,
  - be fast acting, and
  - have a persistent effect.<sup>17</sup>

An antimicrobial ingredient is intended to kill microorganisms. A characteristic of certain antiseptic agents that sets them apart from plain soap is their ability to bind with the stratum corneum of the skin, resulting in persistent chemical activity. Alcohols provide the most rapid and greatest reduction in initial microbial counts on skin, but have no persistent activity.<sup>8</sup>

Persistent antimicrobial activity (ie, measured in hours) helps decrease rebound microbial growth after skin preparation. **Table 1** provides a summary of the characteristics of commonly used skin antiseptic agents.

- II.c. Products selected for preoperative skin preparation should meet FDA requirements, as outlined in the Tentative Final Monograph (TFM) for Health-Care Antiseptic Drug Products, or be the subject of a "New Drug Approval" or an "Abbreviated New Drug Approval" process.<sup>16,17,24</sup> (PNDS: I75, I122)

The FDA requires products for preoperative skin preparation to be

- fast acting (ie, a two-log bacterial reduction on the abdomen and three-log reduction on the groin within 10 minutes), and
- persistent (ie, no return to baseline flora count at six hours post application).<sup>16</sup>

- II.c.1. Persistence of the antimicrobial effect suppresses the regrowth of residual skin flora not removed by preoperative prepping, as well as suppressing transient microorganisms contacting the prepped site.
- II.c.2. Infection control professionals and committees should review the data provided by manufacturers to ensure that surgical antisepsis agents comply with current FDA testing and labeling criteria. The testing should be performed at an independent testing laboratory complying with current FDA requirements and subject to FDA inspection.

**Table 1**

<b>ACTIVITY AND CONSIDERATIONS FOR PREOPERATIVE SKIN PREPARATION ANTISEPTICS</b>						
<b>Antiseptic agent</b>	<b>Mechanism of action</b>	<b>Gram + bacteria</b>	<b>Gram – bacteria</b>	<b>Viruses</b>	<b>Rapidity of action</b>	<i>(continues on next page)</i>
Alcohol	Denatures proteins. <sup>1</sup>	Excellent <sup>1</sup>	Excellent <sup>1</sup>	Good <sup>1</sup>	Excellent <sup>1</sup>	
Chlorhexidine gluconate	Disrupts cell membrane. <sup>1</sup>	Excellent <sup>1</sup>	Good <sup>1</sup>	Good <sup>1</sup>	Moderate <sup>1</sup>	
Povidone-iodine	Oxidation/substitution with free iodine. <sup>1</sup>	Excellent <sup>1</sup>	Good <sup>1</sup>	Good <sup>1</sup>	Moderate <sup>1</sup>	
Chlorhexidine gluconate with alcohol	Disrupts cell membrane and denatures proteins. <sup>1,2</sup>	Excellent	Excellent	Good	Excellent	
Iodophor with alcohol	Oxidation/substitution by free iodine denatures proteins. <sup>1,3,4</sup>	Excellent <sup>1,3,4</sup>	Excellent	Good	Excellent	
Parachloroxylenol (PCMX)	Disrupts cell membrane. <sup>1</sup>	Good <sup>1</sup>	Fair <sup>1</sup>	Fair <sup>1</sup>	Moderate <sup>1</sup>	

**REFERENCES**

1. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. *Infect Control Hosp Epidemiol.* 1999;20:250-278.
2. Denton GW. Chlorhexidine. In: *Disinfection, Sterilization and Preservation*. 5th ed. Block SS, ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2001: 321-36
3. Bryant WP, Zimmerman D. Iodine-induced hyperthyroidism in a newborn. *Pediatrics.* 1995;95:434-436.

4. Smerdely P, Lim A, Boyages SC, et al. Topical iodine-containing antiseptics and neonatal hypothyroidism in very-low-birthweight infants. *Lancet.* 1989;2:661-664.

5. EnviroSystems, Incorporated. Technical Overview, Biocides. <http://www.envirosi.com/TechInfo/technicaloverview.html>. Accessed November 6, 2007.

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**Table 1 (continued)**

<b>ACTIVITY AND CONSIDERATIONS FOR PREOPERATIVE SKIN PREPARATION ANTISEPTICS</b>						
<i>(continued from previous page)</i>	<b>Antiseptic agent</b>	<b>Persistent/residual activity</b>	<b>Use on eye or ear</b>	<b>Use on mucous membranes</b>	<b>Contraindications</b>	<b>Cautions</b>
	Alcohol	None <sup>1</sup>	No. Can cause corneal damage or nerve damage. <sup>1</sup>	No		Flammable. Does not penetrate organic material. Optimum concentration is 60% to 90%. <sup>1</sup>
	Chlorhexidine gluconate	Excellent <sup>1</sup>	No. Can cause corneal damage. Can cause deafness if in contact with inner ear. <sup>1</sup>	Use with caution. <sup>2</sup>	Known hypersensitivity to drug or any ingredient. <sup>2</sup> Lumbar puncture and use on meninges. <sup>2</sup>	Prolonged skin contact may cause irritation in sensitive individuals. Rare severe hypersensitivity reactions have been reported. <sup>2</sup> Use with caution on mucous membranes.
	Povidone-iodine	Minimal <sup>1</sup>	Yes. Moderate ocular irritant.	Yes	Sensitivity to povidone-iodine. (Shellfish allergies are not a contraindication). <sup>6</sup>	Prolonged skin contact may cause irritation. May cause iodism in susceptible individuals; avoid use in neonates. <sup>3,4</sup> Inactivated by blood. <sup>7,8</sup>
	Chlorhexidine gluconate with alcohol	Excellent	No. Can cause corneal damage. Can cause deafness if in contact with inner ear.	No	Known hypersensitivity to drug or any ingredient. Lumbar puncture and use on meninges.	Flammable.
	Iodophor with alcohol	Moderate	No. Can cause corneal damage or nerve damage.	No	Sensitivity to povidone-iodine. (Shellfish allergies are not a contraindication.)	Flammable.
	Parachloroxylenol (PCMX)	Moderate <sup>1</sup>	Yes <sup>5</sup>	Yes <sup>5</sup>	Known hypersensitivity to PCMX or any ingredient. <sup>5</sup>	Minimally effective in the presence of organic matter. The FDA has classified PCMX as a Category III (data are insufficient to classify it as safe and effective). The FDA continues to evaluate PCMX. <sup>5</sup>

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6. American Academy of Allergy Asthma and Immunology. Academy Position Statement: *The Risk of Severe Allergic Reactions from the Use of Potassium Iodide for Radiation Emergencies*. [http://www.aaaai.org/media/resources/academy\\_statements/position\\_statements/potassium\\_iodide.asp](http://www.aaaai.org/media/resources/academy_statements/position_statements/potassium_iodide.asp). Accessed August 28, 2007.

7. Zamora JL, Price MF, Chuang P, Gentry LO. Inhibition of povidone iodine's bactericidal activity by common organic substances: an experimental study. *Surgery*. 1985;98:25-9.

8. Gottardi W. Iodine and iodine compounds. In: *Disinfection, Sterilization and Preservation*. 5th ed. Block SS, ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2001:159-83.

The laboratory should employ either ASTM International (formerly known as the American Society for Testing and Materials) standard methods, or methods specifically approved by the FDA for use in conjunction with a particular New Drug Application subject product.

- II.c.3. Consult scientific data when selecting new products for use.<sup>25</sup>

### Recommendation III

#### The antiseptic agent used should be selected based on the patient assessment. (PNDS: I94)

The patient should be assessed for considerations affecting skin preparation.

- III.a. The patient should be assessed for allergy or sensitivity to skin preparation agents. (PNDS: I123)
- II.a.1. Povidone-iodine can cause contact dermatitis or irritant reactions and does not indicate an allergy to iodine. Anaphylaxis to povidone-iodine is extremely rare and has not been proven to be from the iodine.<sup>26</sup> There is no correlation between reactions to povidone-iodine and allergy to seafood or contrast media.<sup>27,28</sup>
- II.a.2. Chlorhexidine gluconate has triggered allergic reactions in sensitized individuals ranging from mild local symptoms to severe anaphylaxis. Mild symptoms may precede severe attacks.<sup>29</sup>
- III.b. The patient should be assessed for contraindications to specific skin preparation agents. (PNDS: I75, I122)
- Alcohol can cause tissue trauma (ie, necrosis, burns) in neonates with underdeveloped stratum corneum.<sup>30-32</sup>
  - Transcutaneous absorption of iodine in neonates can result in iodism.<sup>33-36</sup>
  - Safe use of CHG on neonates with underdeveloped stratum corneum has not been established.
  - Chlorhexidine gluconate is neurotoxic and can cause permanent injury if the inner ear is exposed to CHG through a nonintact

tympanic membrane. Chlorhexidine gluconate can cause corneal irritation if allowed to contact the eye.<sup>19</sup>

- Use of any agent is contraindicated if the patient has a known sensitivity.
- III.b.1. The manufacturer's written instructions should be reviewed for additional information about their product's use.
- III.c. The surgical site should be identified before skin preparation. (PNDS: I143, I124, I26)
- The surgical site should be confirmed before initiating the skin prep. This verification minimizes the risk of prepping the wrong area, which could contribute to wrong-site surgery.
- III.c.1. Verification should be done in advance of the "time out" period, which occurs immediately before the surgeon makes the incision.
- III.d. The marker used to make the surgical site mark should
- not facilitate microbial growth, and
  - provide a mark that remains visible after the surgical prep.<sup>25,37</sup> (PNDS: I138, I122, I98, I77, I75)
- Marking the skin with an alcohol-based surgical site marker before skin preparation does not increase the amount of microorganisms on the skin.<sup>38</sup> Water-based skin markers may wash off during skin preparation and have been found to transmit MRSA in laboratory tests.<sup>39</sup>
- III.d.1. Ballpoint pens should not be used for surgical skin marking because they may cause trauma to the skin during use.
- III.e. The patient's skin condition should be assessed for the presence of lesions or other tissue conditions at the surgical site before skin preparation begins. (PNDS: I94, I77, I15, I21)
- Unintentional removal of lesions (eg, nevi) traumatizes the skin at the surgical site and provides an opportunity for wound colonization by microorganisms.
- III.e.1. The presence of excessive hair that may interfere with the surgical procedure should be identified.

- III.f. The antiseptic product used for an individual patient should be selected based on
- patient allergies;
  - a patient’s report of significant skin irritation from specific antiseptic agents;
  - contraindications to specific antiseptic agents;
  - the surgical site to be prepped;
  - the presence of organic matter, including blood;
  - neonatal status;
  - large, open wounds;
  - a review of written manufacturer’s information; and
  - surgeon preference. (PNDS: I123, I94, I21, I75, I85)

Antiseptic agents used on the skin of patients with known hypersensitivity reactions (ie, allergies) may cause adverse outcomes (eg, blisters, rashes). Some antiseptic agents are affected by organic matter and/or saline and are rendered less effective (see **Table 1**). Some antiseptic agents may be absorbed by the skin or mucous membranes and become neurotoxic or ototoxic. Certain antiseptic agents are believed to be potentially harmful to neonates. Products made specifically for use on mucous membranes should be used following manufacturers’ recommendations.

## Recommendation IV

**Hair at the surgical site should be left in place (ie, not removed) whenever possible. (PNDS: I94)**

Research studies have found that preoperative shaving of the surgical site increases the risk of surgical site infection<sup>40-42</sup> and results in higher surgical site infection rates than using a depilatory cream or clipping.<sup>42</sup> Hair has successfully been left in place for neurosurgery without increasing the risk of surgical site infection.<sup>43,44</sup>

- IV.a. The patient should be instructed not to shave or use a depilatory on the surgical site before surgery. (PNDS: I136, I77, I106)

Removing hair at the surgical site abrades the skin surface and enhances microbial growth. Shaving has been found to increase the risk of surgical site infection.<sup>40-42</sup> Depilatory creams may cause skin reactions in some individuals, which could result in cancellation of surgery.<sup>42</sup>

- IV.b. Hair at the surgical site should not be removed with a razor. (PNDS: I77, I94)  
Shaving increases the risk of surgical site infection.<sup>39-41</sup>

- IV.b.1. Alternatives to hair removal for head and neck surgery include:
- braiding hair instead of shaving; and
  - using a nonflammable gel to keep the hair away from the incision.<sup>44</sup>

- IV.b.2. If the presence of hair will interfere with the surgical procedure and removal is in the best interest of the patient, the following precautions should be taken:

- Hair removal should be performed the day of surgery, in a location outside of the operating or procedure room.
- Only hair interfering with the surgical procedure should be removed.
- Hair should be clipped using a single-use electric or battery-operated clipper, or a clipper with a reusable head that can be disinfected between patients.

Clipping hair the morning of surgery has resulted in fewer surgical site infections than shaving or clipping the day before surgery.<sup>43</sup> Limiting the amount of clipping minimizes the risk of microscopic nicks. Clipping the hair outside of the operating room minimizes the dispersal of loose hair and the potential for contamination of the sterile field and surgical wound. During use, the clipper handle is contaminated with the patient’s skin flora. The clipper head may become contaminated with microscopic blood or body fluids; therefore, decontamination for bloodborne pathogens is necessary to prevent transmission.

- IV.b.3. Depilatories may be used for hair removal if skin testing has been performed without tissue irritation.

Depilatories may be used when hair is to be removed from the operative site. The use of depilatories, however, does increase the risk of hypersensitivity reactions. The written manufacturers’ instructions regarding skin testing and the use of chemical depilatories should be followed.

### Recommendation V

**The skin around the surgical site should be free of soil, debris, exudates, and transient microorganisms to minimize contamination of the surgical wound before application of the antiseptic skin preparation. (PNDS: I94)**

The efficacy of antiseptic agents is dependent on the cleanliness of the skin. Removal of superficial soil, debris, and transient microbes before applying antiseptic agents reduces the risk of wound contamination by decreasing the organic debris on the skin.

- ◆ No skin antiseptic alone is effective in killing spores (eg, clostridium).
  - ◆ Some anatomic areas contain more debris than others (eg, umbilicus, under fingernails, under foreskin). Cleaning these areas separately from the surgical prep prevents distribution of microorganisms from these areas to the surgical site.
  - ◆ Cleaning the foot before antiseptic skin preparation for surgery was found more effective in reducing bacterial counts between the toes than application of the antiseptic alone.<sup>46</sup>
- V.a. If preoperative showers have not been performed, perioperative personnel should wash the surgical site either in the preoperative area or immediately before applying the antiseptic agent in the practice setting. (PNDS: I94, I85)
- Preoperative washing removes gross contaminants and oils that may block penetration of the antiseptic agent and removes spores and other organisms that are not killed by the antiseptic agent.
- V.b. Cosmetics should be removed before the preoperative skin prep. (PNDS: I94, I85)
- Cosmetics may contribute to increased soil and contamination and impede the effectiveness of the antiseptic agent. The removal of facial cosmetics also may be indicated to prevent debris from irritating the eyes, to facilitate securing the endotracheal tube, or for other reasons identified by the surgical team.
- V.b.1. To remove facial cosmetics, the face should be gently cleansed with a non-irritating agent.
- Initial cleansing of the eyes, before application of the antiseptic agent, is not necessary because tears naturally rinse most contaminants from the eye.
- V.c. For abdominal surgery, the umbilicus should be cleaned before the antiseptic skin preparation. (PNDS: I94, I98)
- The organic and inorganic material in the umbilicus is a contaminant and cannot be adequately disinfected.
- V.c.1. To soften umbilical detritus, antiseptic solution may be instilled into the umbilicus before cleaning.
- V.c.2. Cotton applicators may be used to remove the detritus.
- V.d. Jewelry (eg, body piercing ornaments) at the surgical site should be removed before cleansing the skin. (PNDS: I94, I98, I102, I77, I72, I75, I57)
- Jewelry harbors microorganisms and traps these organisms in adjacent skin. Wearing of rings has been associated with up to a 10-fold increase in median skin microorganism count (ie, bioload).<sup>47</sup> Removal of jewelry before skin cleansing provides an opportunity to more effectively remove these microorganisms from the area that will be prepped.
- V.d.1. Jewelry should be removed to reduce the risk of injury related to
- positioning,<sup>48</sup> and
  - proximity to the incision site or active electrosurgical unit (ESU) electrode.<sup>49</sup>
- V.e. An intestinal or urinary stoma within the surgical field should be cleansed gently and separately from the rest of the prepped area. (PNDS: I94, I98, I85)
- Some antiseptics are ineffective in the presence of organic material.
  - Cleansing of the stoma removes mucin and organic material that impedes the effectiveness of the antiseptic agent.
- V.f. Surgical fields that include the penis require the foreskin (ie, prepuce), if present, to be retracted before the glans is gently cleansed. (PNDS: I94, I98, I85, I75, I150, I152)

Organic material (ie, smegma) and microorganisms accumulate under the foreskin.

- V.f.1. After cleaning, the foreskin should be pulled back over the glans to prevent circulatory compromise.
- V.g. For surgery on the hand or wrist, the patient's nails should be short and natural without artificial nail surfaces (eg, extensions, overlays, acrylic, silk wraps, enhancements) in the prepped area. (PNDS: 194, 198, 185, 1138)
 

The subungual region harbors the majority of microorganisms found on the hand. The variety and amount of potentially pathogenic bacteria cultured from fingertips of persons wearing artificial nails is greater than from those with natural nails, both before and after handwashing.<sup>50-52</sup>

There is insufficient evidence to determine whether fresh or chipped nail polish in the surgical field increases the risk of surgical site infection.<sup>53</sup> There is, however, a theoretical risk of chipped nail polish fragments entering the wound.
- V.h. Cleansing traumatic orthopedic injuries with exposed bone may be facilitated by pulse lavage, high-pressure parallel water-jet, or brush-suction irrigation. (PNDS: 194, 198, 185, 1138, 1152, 1122, 177, 1128, 138)

In a randomized clinical trial, low-pressure pulse lavage decreased wound contamination by 86.9% and high-pressure parallel water-jet decreased contamination by 90.8%.<sup>54</sup> In a laboratory study, high-pressure lavage removed less inorganic contaminants and caused more tissue damage than a brush-suction method.<sup>55</sup>

When irrigating traumatic wounds:

- sterile 0.9% saline solution should be used for the irrigation;
- caution should be exercised to avoid aerosolization of wound contaminants onto the sterile field during irrigation; and
- the use of a pulse lavage protective shield may be beneficial.

## Recommendation VI

**Protective measures should be implemented to prevent skin and tissue injury due to prolonged contact with skin prep agents. (PNDS: 194, 198, 185, 1138, 175, 170)**

Chemical burns and skin irritations are more likely when antiseptic solutions are not allowed to dry and remain in contact with the skin for prolonged periods of time.<sup>22,31,56</sup>

The iodine in povidone-iodine prep solutions remains free until it has dried and can chemically irritate the skin. When the skin is occluded, the solution is unable to dry, the chemical contact is sustained, and the skin is macerated. The use of forced-air warming under the surgical drapes adds heat to antiseptic solutions, which may increase the likelihood of a chemical or thermal injury. In a series of povidone-iodine burns, authors reported burns resulting from

- ◆ soaked linen,
- ◆ soaked adhesive tape,
- ◆ drips on padding under tourniquet cuffs,
- ◆ solution running off surgical sites and onto the patients' backs, and
- ◆ a povidone-iodine-soaked gauze being used to cover an epidural site during surgery.<sup>56</sup>

- VI.a. Sheets, padding, positioning equipment, and adhesive tape should be protected from the dripping or pooling of prep agents beneath and around the patient. (PNDS: 194, 175, 1138)
 

If antiseptic solutions drip onto fabrics and positioning equipment, the surgical drapes may prevent the solution from evaporating, thus prolonging skin contact with the wet solution.

- VI.a.1. Special attention should be paid when the patient is in lithotomy position because antiseptic solution running down the gluteal cleft may not be apparent.
- VI.a.2. For vaginal procedures, using a fluid-resistant towel or drape with an adhesive strip below the patient's buttocks may be beneficial.

- VI.b. Electrodes, including the ESU dispersive electrode, should be protected from dripping or pooling of antiseptic agents. (PNDS: 1122, 175, 172)

Antiseptic solutions contacting these electrical devices may cause chemical or thermal burns. The adhesive material holds the solution next to the skin, and the solution is unable to dry. Solution between the skin and the electrode increases impedance and increases the risk of a pad-site injury or equipment malfunction.

- VI.b.1. If antiseptic solution contacts the ESU dispersive electrode,
- the dispersive electrode should be removed,
  - the antiseptic solution cleaned from the patient's skin, and
  - a new dispersive electrode applied.
- VI.c. If a tourniquet is used, the cuff, padding, and skin under the cuff should be protected from contact with prep solutions. (PNDS: I75, I77, I122)
- Antiseptic solutions contacting tourniquet cuffs are compressed against and occlude the skin, increasing the likelihood of a chemical burn.
- VI.c.1. Use of an impervious tourniquet cuff protector or towelette drape with an adhesive strip may prevent prep solution contact with the skin under the tourniquet.
- VI.c.2. If contact occurs, the cuff and/or padding should be replaced before draping.

### Recommendation VII

**The antiseptic agent should be applied to the skin over the surgical site and surrounding area in a manner to minimize contamination, preserve skin integrity, and prevent tissue damage. (PNDS: I10, I77, I75, I94, I98, I122, I152, I150)**

- VII.a. Nonscrubbed personnel should apply the skin antiseptic. (PNDS: I10, I94, I98)
- The risk of contamination to sterile gown and gloves is high, in most circumstances, when scrubbed personnel perform the prep.
- VII.b. Hand hygiene should be performed before initiating the surgical prep.<sup>52,58</sup> (PNDS: I98, I138, I122) Hand hygiene prevents contamination of the prepped area in the event of a glove failure.
- VII.c. Antiseptic agents used for skin preparation should be applied using sterile supplies. (PNDS: I70, I94)
- There is insufficient evidence to determine if using only clean supplies is a safe practice. In one study, using a combination povidone-iodine scrub and paint, researchers found

that using clean prep kits with reusable sponge sticks for the paint, assembled in a central sterilizing area, did not result in higher microbial counts on the skin than when similar trays were sterilized first.<sup>59</sup>

- VII.c.1. Sterile gloves should be worn unless the antiseptic prep applicator is of sufficient length to prevent the antiseptic and patient's skin from contact with the nonsterile glove.
- VII.c.2. Any supplies touching the prepped area after the prep has been completed should be sterile to prevent introduction of microorganisms.
- VII.d. When not part of the surgical procedure, a highly contaminated site (eg, anus, colostomy) should be isolated from the area to be prepped. (PNDS: I21, I94, I98)
- Isolating the contaminated area confines and contains microorganisms away from the surgical site.
- VII.d.1. An adhesive, fluid-resistant or plastic drape may be beneficial in sealing the contaminated area.<sup>60,61</sup>
- VII.e. Application of the skin antiseptic should progress from the incision site to the periphery of the surgical site. (PNDS: I94, I98)
- In most surgical procedures, the incision site is in close proximity to anatomic areas with high microbial counts (eg, laparotomy incision/umbilicus/groin; neck/mouth/nares; ankle/toes; shoulder/axilla; hand/fingernails). Progressing from the incision site to the periphery prevents reintroducing microorganisms from these areas into the incision site.
- VII.e.1. The prep sponge or applicator should be used for a single application and discarded.
- VII.e.2. Subsequent applications should be applied with a fresh sponge or applicator to prevent contamination of the incision site.
- VII.e.3. When using a commercially available applicator, refer to the manufacturer's instructions to ensure uniform distribution of the antiseptic.

- VII.f. Special consideration on skin prep implementation is necessary when the incision site is more highly contaminated than the surrounding skin. (PNDS: I21, I94, I98, I150)
- VII.f.1. If a highly contaminated area is part of the procedure, the area with a lower bacterial count is prepped first, followed by the area of higher contamination, as opposed to working from the incision site toward the periphery.
- VII.f.2. When prepping the anus or vagina or a stoma, sinus, ulcer, or open wound, the sponge should be applied once to that area and then discarded.
- VII.f.3. An antiseptic-soaked sponge may be applied to the contaminated area during prepping of the surrounding skin.
- VII.f.4. Vaginal preps for procedures that include the abdomen should be performed in a manner to prevent splashing of antiseptic agent expelled from the vagina onto the prepped abdomen.
- VII.f.5. Urinary catheter insertion should be performed using sterile supplies and aseptic technique. Using sterile supplies for the urinary catheter insertion prevents the risk of cross-contamination of the genitourinary tract.
- VII.g. Special precautions and consideration for skin prep implementation is necessary for burns, open wounds, and fragile skin. (PNDS: I21, I94, I98, I36, I75, I77, I152, I131, I138, I122, I128, I51)
- VII.g.1. When prepping fragile tissues, gentle friction should be used to prevent tissue damage.
- VII.h. The prepared area of skin should extend to an area large enough to accommodate potential shifting of the drape fenestration, extension of the incision, the potential for additional incisions, and all potential drain sites. (PNDS: I21, I94, I98, I138)
- An unprepared area may be exposed when enlarging the drape fenestration or if shifting of the drapes occurs, resulting in contamination of the surgical site.
- VII.h.1. Consideration of the potential need to convert a minimally invasive procedure to an open procedure will determine the extent of the area to be included in the prep.
- VII.i. The antiseptic agent should remain in place for the full time suggested by the manufacturer's written recommendations. (PNDS: I94, I122)
- Testing of antiseptic agents has demonstrated effectiveness under specific conditions and contact times. Complying with recommended exposure times facilitates the occurrence of the best antiseptic conditions. For example, povidone-iodine reaches maximum effectiveness only after it has dried.
- VII.i.1. To prevent surgical fires, flammable prep agents must have thoroughly dried and vapors dissipated before applying drapes.<sup>62-64</sup>
- VII.j. Adhesive incision drapes may be used to minimize the gaping and shifting of surgical drapes and to contain residual microorganisms on the skin. (PNDS: I70, I98)
- Adhesive incision drapes may be advantageous in sealing the surgical field; however, the utility of the iodine-impregnation of these drapes has not been demonstrated.<sup>65</sup> One randomized clinical trial investigating the utility of these drapes after povidone-iodine prep reported no reduction in surgical site infection risk when using iodine-impregnated incision drapes.<sup>66</sup>

### Recommendation VIII

**If a flammable prep agent is used, additional precautions should be taken to minimize the risk of a surgical fire and patient burn injury. (PNDS: I76, I75, I122)**

Using flammable skin prep agents in the operating room or procedural area poses a serious risk of fire because of the common use of ignition and heat sources (eg, electrosurgery, lasers, drills, fiberoptic cables). Special precautions have been developed by the National Fire Protection Association (NFPA), and have been incorporated in the National Patient Safety Goals by the Joint Commission.<sup>63,67</sup>

VIII.a. Perioperative personnel should be familiar with the flammability characteristics of all prep agents stored or used in the patient care area. (PNDS: I122)

Fires have resulted when personnel did not know or remember that a prep agent was flammable and used a heat source during the procedure.<sup>68</sup>

VIII.b. When flammable prep agents are used, they should be packaged in small quantities appropriate for a single application or be prepackaged in a unit dose.<sup>63,67</sup> (PNDS: I122)

Packaging in small quantities may minimize the risk of soaking materials adjacent to the prepped area and limits the amount left over for disposal.

VIII.c. The prep agent should not contact fabric or be allowed to pool on or under body parts (eg, umbilicus, groin). (PNDS: I75, I76, I122)

Solution in contact with fabric may not dry adequately. Pooled prep agents require longer periods of time for evaporation.

VIII.d. If pooling occurs, the excess solution should be wicked away. Any solution-soaked materials should be removed from the procedure room before draping or using electrosurgery, laser, or other heat source.<sup>63,64,67</sup> (PNDS: I75, I76, I122)

Wicking solution away from pooled areas allows the remaining solution to dry adequately. Solution-soaked materials are easily ignitable, and removal from the operating room minimizes the risk of fire.

VIII.e. The prep agent should be allowed to dry and vapors to dissipate before application of an incise drape or surgical drape, or use of electrosurgery, laser, or other heat source.<sup>62,64</sup> (PNDS: I75, I76, I122)

The prep agent remains flammable until completely dry. Vapors occurring during evaporation are also flammable. Trapping of solution or vapors under drapes increases the risk of fire or burn injury.

VIII.f. The use of a flammable prep agent should be discussed during the “time out” period used to verify the surgical procedure and site. (PNDS: I75, I76, I122)

Active communication about the use of flammable prep agents alerts all personnel to the inherent risks and verifies that appropriate precautions have been taken. At times, the person operating the heat (ie, ignition) source may be unaware that a flammable prep agent was used. Active communication prevents this misunderstanding.

VIII.f.1. Active communication between the surgical team members should include that

- a flammable prep agent was used;
- the application site was dry before draping;
- pooling of the prep solution did not occur or has been corrected; and
- any materials soaked with the prep agent have been removed from the procedure room.<sup>63,67</sup>

VIII.g. Disposal of unused flammable prep agents must be handled in a manner to decrease the risk of fire and in accordance with federal, state, and local regulations. (PNDS: I138, I122)

Disposal of residual flammable prep agents is regulated by the Environmental Protection Agency.<sup>69</sup> Fires can occur when these agents are discarded in nonhazardous trash. Incineration or autoclaving of biohazardous waste can rapidly ignite flammable prep agents.

VIII.g.1. Residual flammable prep agents may be safely discarded in a chemical hazardous waste receptacle outside of the operating or procedure room or immersed in water in a soiled utility room to render the agents nonhazardous.

VIII.h. Flammable skin preparation agents should not be heated. (PNDS: I122)

Heating flammable preparation agents poses a serious risk of fire. When the temperature of these agents increases, they become more unstable and may ignite easily.

### Recommendation IX

**Manufacturers’ written recommendations and MSDSs for handling, storing, and heating of all skin preparation agents should be readily available, reviewed, and followed. (PNDS: I122)**

Testing antimicrobial agents is a complex process and not practical in the patient care setting. Data from current research, manufacturers' literature, and the FDA provides direction for storage, safe use, and product efficacy.

- IX.a. Skin antiseptic agents should be stored in their original containers; these containers should not be refilled. (PNDS: I138, I122)

Prolonged use of a multi-use container, transferring solutions to secondary containers, and refilling containers of povidone-iodine has resulted in contamination of the antiseptic with *Pseudomonas aeruginosa*.<sup>70-74</sup> These microorganisms can survive more than one year in povidone-iodine;<sup>71</sup> and contaminated povidone-iodine has resulted in transmission of the contaminating organism and subsequent infections.<sup>71,72,74-76</sup> Use of single-dose containers eliminates this risk.

- IX.b. If the skin preparation solution is poured into a secondary container, it should be labeled and the label verified before use of the prep agent. (PNDS: I138)

A label placed on the secondary container communicates to anyone using the agent the contents of the container. A patient death resulted when a skin preparation agent was erroneously mistaken for another drug and injected.<sup>77</sup> Health care accreditation agencies require labeling to identify the skin preparation name and strength.<sup>78-80</sup>

- IX.c. Heating of nonflammable skin preparation solutions should only be performed in accordance with the manufacturer's written instructions. (PNDS: I122)

Heating these solutions may cause thermal or chemical burns. Heating may alter the chemical composition of the prepping agent and may alter the effectiveness of the antiseptic. Heating povidone-iodine alters the equilibrium of the iodine content.<sup>81</sup> Manufacturers may have a time limit that an antiseptic agent may be warmed slightly, after which it should be discarded.

- IX.d. Skin preparation agents should never be warmed in a microwave oven or autoclave. (PNDS: I122)

The temperature of the skin preparation agent is uncontrolled when heated in a microwave or autoclave, and temperature extremes may result in a patient injury.

- IX.e. Material safety data sheets for all antiseptic agents and other chemicals used must be available in the practice area.<sup>82</sup> (PNDS: I122, I138)

Material safety data sheets provide information about the flammability of skin antiseptic agents and the maximum safe storage temperature. The Occupational Safety and Health Administration (OSHA) requires that MSDSs be available for all chemicals used in the practice setting. These documents outline the hazards related to the chemicals and appropriate action to be taken in the event of an exposure (eg, splash to the eyes).<sup>82</sup>

- IX.f. Storage of flammable preparation agents must be in compliance with local, state, and federal regulations. (PNDS: I138, I122)

Alcohol-based antiseptics are flammable and should be stored away from high temperatures, sparking devices, or flames.<sup>62-64,67</sup>

- IX.f.1. Alcohols are extremely volatile, and their containers should be sealed to prevent spilling, leaking, and evaporation.

- IX.f.2. Flammable antiseptic agents should not be stored in egress hallways.

- IX.f.3. Large quantities of flammable preparation agents should not be stored in an operating room or procedure area.

The NFPA recommends solutions are to be stored in a flammable solutions cabinet designed to minimize the risk of ignition when the amount of alcohol stored in one location is 10 gallons or more.<sup>83</sup>

- IX.f.4. Perioperative personnel should refer to their facility's policies and procedures and individual state regulations for additional information.

### Recommendation X

**At the end of the surgical procedure, the skin preparation agent should be thoroughly removed from the skin unless otherwise indicated by the manufacturer's written instructions. (PNDS: I75, I122, I51, I36)**

Active and inactive ingredients in the solution may cause skin irritation and contact dermatitis in sensitive individuals.<sup>19,22,56</sup>

- X.a. Residual antiseptic agent should be removed before application of an occlusive dressing or tape.

Removing the solution as soon as possible after completion of the procedure minimizes the risk of ongoing irritation. Trapping antiseptic solutions under occlusive dressings has resulted in chemical burns.

- X.a.1. All visible antiseptic agent should be removed from the skin.

Residual antiseptics can cause irritation.<sup>22,56</sup> Some manufacturers recommend that specific preparation agents be left on the skin and allowed to wear off naturally.

- X.a.2. As soon as feasible, the patient should be rolled to the side and posterior skin surfaces examined to identify any residual antiseptic that should be removed.

A thorough evaluation of the patient's skin may need to be postponed until after the patient is transferred to the postoperative area.

### Recommendation XI

#### **Competency**

**Personnel should receive initial education, training, and competency validation on skin preparation agent selection, application procedures, and patient assessments.**

Initial competency validation, in addition to the annual review and evaluation of individual competency skills, should be performed to maintain proficiency in application of knowledge and use of critical thinking concerning performance of skin preparation.

- XI.a. Personnel who could be potentially exposed to antiseptic preparation agents must be made aware of the exposure risk associated with these chemicals.<sup>82</sup>

Workers have the right to know about workplace hazards and OSHA requires employers to provide this information. Information about chemical hazards should be offered during initial orientation.<sup>82</sup>

- XI.b. Personnel should receive education and training on selection of skin preparation agents.

Personnel should be knowledgeable about skin preparation agents, indications, contraindications, and special precautions to be used when handling flammable antiseptic agents.

- XI.c. Personnel providing preoperative patient instructions should receive education on the evidence base for preoperative patient showers.

Patient compliance is enhanced by appropriate education about the importance of preoperative showers, strategies for facilitating the shower, and preventing recontamination of the skin.

- XI.d. Personnel removing hair should receive instruction on the risks associated with shaving, shaving alternatives, and proper hair-removal techniques.

Understanding risks and alternatives to hair removal reinforces discernment to avoid hair removal. Appropriate hair-removal techniques minimize the risk of skin injury and surgical site infection.

- XI.e. Personnel should receive education and guidance on skin preparation for the types of procedures performed and precautions to be taken.

Skin preparation techniques vary by surgical procedure and patient condition. Educating personnel about these variations and providing didactic instruction enhances required skills.

- XI.f. Administrative personnel should validate the competence of personnel participating in skin preparation activities. (PNDS: I1)

Validation of competence provides an indication that personnel are able to appropriately perform skin preparation.

### Recommendation XII

#### **Documentation**

**Patient skin preparation should be documented in the medical record. (PNDS: I27;I30;I116)**

Documentation provides communication among all care providers involved in planning and implementing the patient's care. Documentation of

surgical skin preparation may assist in the investigation of infections or adverse reactions and identify opportunities for performance improvement. Accountability is established by recording names of personnel who perform procedures. Predetermined documentation fields or indicators also may prompt compliance with policies and procedures.

- XII.a. Documentation should include, but not be limited to,
- preoperative instructions;
  - patient report of compliance with preoperative showering instructions;
  - removal and disposition of any jewelry;
  - condition of the skin at the surgical site (eg, presence of rashes, skin eruptions, abrasions, redness, irritation, burns);
  - hair removal, if performed, including method, time of removal, and area;
  - antiseptic agent used;
  - area prepped;
  - name(s) of person(s) performing skin preparation;
  - precautions taken when flammable agents are used (eg, agent allowed to completely dry);
  - removal of prepping agent; and
  - postoperative skin condition, including any skin irritation or hypersensitivity (allergic) response to preparation solutions.

### Recommendation XIII

#### ***Policies and Procedures***

**Policies and procedures on the skin preparation of patients should be written, reviewed annually, and readily available within the practice setting.**

Policies and procedures assist in the development of patient safety, and quality assessment and improvement activities. Policies and procedures establish authority, responsibility, and accountability and serve as operational guidelines. Policies and procedures establish guidelines for performance improvement activities to be used when monitoring and evaluating skin preparation in the operating room.

- XIII.a. Policies about preoperative skin preparation should be developed in collaboration with surgeons and an infection control professional.

- XIII.a.1. Policies should include, but not be limited to,

- patient education or assistance in performing two CHG-showers;
- appropriate restrictions on and alternatives to hair removal;
- removal of jewelry at the surgical site;
- assessments to be performed before skin preparation;
- approved skin antiseptic agents;
- if flammable skin preparation agents are permitted or not;
- precautions to be taken if flammable skin preparation agents are used;
- removal of preparation agents and evaluation of the skin condition at the end of the procedure;
- documentation;
- storage of flammable skin preparation agents;
- maintenance of MSDS sheets; and
- reporting adverse events.

- XIII.b. An introduction and review of policies and procedures should be included in the initial orientation and ongoing education of health care personnel.

Review of policies and procedures assist health care professionals in the development of knowledge, skills, and attitudes that affect patient outcomes.

### Recommendation XIV

#### ***Quality***

**A quality management program should be in place to evaluate skin preparation procedures and identify and respond to opportunities for improvement.**

A fundamental precept of AORN is that it is the responsibility of professional perioperative registered nurses to ensure safe, high-quality nursing care to patients undergoing operative and invasive procedures.

- XIV.a. A quality management program should be in place to evaluate skin preparation procedures and to identify and respond to opportunities for improvement.

“Surgery patients with appropriate hair removal” is a Surgical Care Improvement Project and National Hospital Quality Measures evidence-based practice indicator used by the Centers for Medicare and Medicaid

Services and the Joint Commission.<sup>84-86</sup> The abstraction criterion indicating compliance is: "Surgical patients with surgical site hair removal by clippers or depilatory or no surgical site hair removal."<sup>84</sup> Public reporting of the percent of compliance with this indicator is required for Medicare or Medicaid reimbursement.<sup>86,87</sup>

- XIV.b. Adverse reactions to skin antiseptic agents should be reported in the health care organization's adverse event reporting system and reviewed for potential opportunities for improvement. (PNDS: I92)
- XIV.b.1. Surgical fires resulting from skin preparation agents should be reported and investigated as serious adverse events through a root cause analysis and corrective action taken to prevent recurrence.
- XIV.b.2. Near misses should be investigated and corrective action taken to prevent serious adverse events.

### Glossary

**Antisepsis:** The prevention of sepsis by preventing or inhibiting the growth of resident and transient microbes.

**Antiseptic:** A product with antimicrobial activity that formerly may have been referred to as an *antimicrobial agent*.

**Antiseptic agent:** Antimicrobial substance applied to the skin to reduce the log number of microbial flora. Examples include alcohols, chlorhexidine gluconate, chlorine, hexachlorophene, iodine, parachloroxylenol, quaternary ammonium compounds, and triclosan.

**Denature:** To alter the chemical structure of a protein so that biological activity is diminished or eliminated. Made unnatural or changed from the normal in any of a substance's characteristics.

**Detritus:** Accumulated debris resulting from the wearing away or deterioration of tissue or other deposited material. Any broken-down material.

**Flammable:** Capable of being easily ignited and burning rapidly.

**Gluteal cleft:** Cleft of the buttocks.

**Iodism:** Poisoning by iodine, manifested by severe rhinitis, frontal headache, emaciation, weakness, and skin eruptions. Caused by the administration of iodine or one of the iodides.

**Log reduction:** The logarithmic death progression of microorganisms after exposure to a sterilant or antiseptic agent. The reduction difference between average surviving microbes for control and test carriers used as an efficacy parameter.

**Neurotoxic:** Poisonous or destructive to nerves, nerve tissue, or nervous system.

**Ototoxic:** Having a toxic or injurious effect on the ear, especially the nerve supply, affecting hearing and balance.

**Oxidation:** The combination of a substance with oxygen, altering cell biologic activity.

**Subungual:** Under the nail (eg, fingernail).

**Toxicity:** The degree to which a substance can harm humans or animals.

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AORN Perioperative Standards and  
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