Decolonization of the Skin of the Patient and Surgeon

LENA M. NAPOLITANO

ABSTRACT

Objective: To review the evidence regarding antisepsis and decolonization of the skin of the patient and surgeon for the prevention of surgical site infection (SSI).

Data Sources: General bibliographic and specialist computer databases, along with manual searching of reference lists of primary and review articles, were used to search for relevant peer-reviewed citations.

Results: Antisepsis of the surgical site and of the hands of the surgeon is a mainstay in the prevention of SSI. Waterless and scrubless alcohol-based products are an alternative to traditional antiseptic scrubs. Chlorhexidine-based products for skin preparation at the surgical site have proved superior to other preparation products for bacterial decolonization. The efficacy of routine preoperative decolonization strategies, including the use of nasal mupirocin ointment and antiseptic body washes, has not been established definitively by randomized clinical trials.

Conclusions: Antisepsis of the skin of patient and surgeon are important in the prevention of SSI. Preoperative decolonization strategies for prevention of SSI, particularly those caused by antibiotic-resistant organisms, remain controversial.

INFECTIONS OF THE SURGICAL SITE may compromise the outcome of the operation and, under certain circumstances, endanger the life of the patient. Antisepsis of the surgical site and of the surgeon's hands is a mainstay of the prevention of surgical site infection (SSI) through conditions of asepsis, which is defined as performance of a process or procedure under conditions in which bacterial contamination has been minimized.

The most common mode of transmission of pathogens is via hands, and substantial evidence exists that hand hygiene reduces the incidence of infections [1]. The studies of Semmelweis and Holmes are the foundation of the identification of handwashing as one of the most important measures to be taken by healthcare practitioners to reduce cross-contamination. In 1847, Dr. Ignaz Semmelweis, a Viennese physician, discovered that fatal infections were spread among patients by physicians who failed to wash their hands between examinations [2]. Semmelweis instituted a disinfecting procedure whereby physicians were required to wash in a chloride of lime solution after autopsies and with soap and water between patient visits. Doctors also had to change into clean coats before examining patients. As a result, hospital mortality rates from infectious diseases declined.

Handwashing by clinical staff is the single most important measure for preventing transmission of nosocomial infection. Today, handwashing should be a simple, standard antiseptic technique. However, studies conducted at hospitals worldwide have documented that

Division of Acute Care Surgery, University of Michigan School of Medicine, Ann Arbor, Michigan.

compliance with handwashing is poor in the healthcare setting.

Since the late 1800s, when Lister promoted the application of carbolic acid to the hands of surgeons before procedures, preoperative cleansing of the hands and forearms with an antiseptic agent has been an accepted practice [3,4]. In the next section, we review the evidence regarding antisepsis and decolonization of both patient and surgeon in efforts to prevent SSI.

GUIDELINES FOR SURGEON HAND ANTISEPSIS

The Centers for Disease Control and Prevention (CDC) Guideline for Handwashing and Environmental Control was first published in 1985 and provided basic recommendations for hand hygiene [5]. The subsequent comprehensive CDC Guideline for Hand Hygiene in Health-Care Settings, published in 2002, provides evidence-based recommendations of the Healthcare Infection Control Practices Advisory Committee (HICPAC) and the HICPAC/Society of Healthcare Epidemiologists of America (SHEA)/Association of Professionals in Infection Control (APIC)/Infectious Diseases Society of America (IDSA) Hand Hygiene Task Force [1]. A section on "Surgical Hand Antisepsis" was included, and the final recommendations are listed in Table 1.

The Guideline for the Prevention of Surgical Site Infection [6], published in 1999, is an evidence-based comprehensive summary issued by the CDC and HICPAC. A summary and re-view of these evidence-based guidelines was also published, and summary recommendations for patient and surgeon antisepsis were provided (Table 2) [7]. In 2002, the CDC MMWR (Morbidity and Mortality Weekly Report) Guideline for Hand Hygiene in the Healthcare Setting 10-25-2002 recommended that "Surgical hand antisepsis using either an antimicrobial soap (2–5 min scrub) or an alcohol-based handrub with persistent activity is recommended before donning sterile gloves when performing surgical procedures (Category 1B recommendation)." The World Health Organization (WHO) Guidelines on Hand Hygiene in Health Care (Advanced Draft) [8] was published recently as part of the World Alliance for Patient Safety's Global Patient Safety Challenge 2005–2006 entitled "Clean Care is Safer Care" and "Clean Hands are Safer Hands." This worldwide guideline reiterates the CDC Hand Hygiene Guideline with regard to surgical hand antisepsis.

ISSUES IN SURGICAL HAND HYGIENE AND ANTISEPSIS

Perioperative surgical hand hygiene is a complex issue. The usual surgical antisepsis involves scrubbing the skin with antiseptic solutions. This procedure can damage the skin, with a paradoxical subsequent higher risk of infection for the patient. There now are several efficient and quick-acting antiseptic alcohol solutions that require no scrubbing. Because of their efficacy, persistent effect, and skin protection, many experts have advised that classi-

TABLE 1. SURGICAL HAND ANTISEPSIS: RECOMMENDATIONS OF THE
U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION

Remove rings, watches, and bracelets before beginning the surgical hand scrub (Category II).
Remove debris from underneath fingernails using a nail cleaner under running water (Category II).
Surgical hand antisepsis using either an antimicrobial soap or an alcohol-based hand rub with persistent activity is recommended before donning sterile gloves when performing surgical procedures (Category IB).
When performing surgical hand antisepsis using an antimicrobial soap, scrub hands and forearms for the length of time recommended by the manufacturer, usually 2–6 min. Long scrub times (e.g., 10 min) are not necessary (Category IB).
When using an alcohol-based surgical hand-scrub product with persistent activity, follow the manufacturer's instructions. Before applying the alcohol solution, wash hands and forearms with a non-antimicrobial soap and dry them completely. After application of the alcohol-based product as recommended, allow hands and forearms to dry thoroughly before donning sterile gloves (Category IB)

From reference 4.

TABLE 2.   SUMMARY OF EVIDENCE-BASED GUIDELINES FOR PREVENTION OF
SSI FROM CENTERS FOR DISEASE CONTROL AND PREVENTION

Preparation of the patient

Category 1A	Identify and treat all infections remote from the surgical site before elective operations; postpone operation until infection has resolved
	Do not remove hair unless it is at or near the incision site and will interfere with surgery. If hair is removed, this should be done immediately beforehand, preferably with electric clippers.
Category 1B	Control the blood glucose concentration in all diabetic patients and avoid hyperglycemia perioperatively
	Encourage abstinence from tobacco for a minimum of 30 days before surgery
	Do not withhold indicated blood donations as a means to prevent SSI
	Patients should shower or bathe with an antiseptic solution at least the night before surgery
	Wash and clean the incision site to remove gross skin contamination prior to the antiseptic skin preparation with an appropriate agent
Category 2	Prepare area by application of the antiseptic agent in concentric circles. The prepared area should be large enough to accommodate any necessary drains or stomas.
	Keep the preoperative hospital stay as short as possible consistent with adequate preparation for surgery

Hand/forearm antisepsis

Category 1B	Keep nails short; do not wear artificial nails
	Scrub the hands and forearms up to the elbows for at least 2 to 5 min with an appropriate antiseptic
	After the scrub, keep hands and arms up and away from the body so that water runs from the fingertips to the elbows. Dry with a sterile towel before donning sterile gown and gloves
Category 2	Clean under each fingernail before the first scrub of the day
Unresolved:	There is no recommendation regarding the wearing of nail polish

Infected/colonized surgical personnel

Category 1B	Educate and encourage personnel with signs and symptoms of a transmissible infectious disease to report it promptly to supervisors and occupational health officials
	Develop and maintain policies regarding patient-care responsibilities when personnel have potentially transmissible infections
	Obtain cultures from and exclude from duty personnel with draining skin lesions until infection is ruled out or the lesion has responded to anti-infective therapy
	Do not routinely exclude from patient care those personnel colonized with organisms such as *Staphylococcus aureus* or group A streptococci unless an epidemiologic link with dissemination has been established

Antimicrobial prophylaxis

Category 1A	Administer antibiotic prophylaxis only when indicated and only when efficacious against the pathogens most commonly causing SSI for the particular operation
	Administer initial dose intravenously, timed such that a bactericidal concentration of the drug is present in the serum and tissues when the incision is made.
	Maintain therapeutic concentrations of the agent in the serum and tissues for the duration of the operation. Therapeutic levels should be maintained at most only until a few hours after the incision is closed
	Before elective colon operations, prepare the colon mechanically with enemas or cathartic agents. Administer nonabsorbable oral antimicrobial agents in multiple doses on the day before surgery
	For high-risk cesarian section, administer the prophylactic antibiotic agent immediately after the umbilical cord is clamped
Category 1B	Do not use vancomycin routinely for surgical prophylaxis

Surgical attire and drapes

Category 1B	Wear surgical mask to cover the mouth and nose fully for the duration of the operation or while sterile instruments are exposed*
	Wear a cap or hood so as to cover all hair on head and face fully*
	Wear sterile gloves after a sterile gown is donned (all scrubbed surgical team members)*
	Do not wear shoe covers for the prevention of SSI*
	The surgical gowns and drapes used should be effective barriers when wet
	Change scrub suits that are visibly soiled or contaminated by blood or other potentially infectious materials

TABLE 2. SUMMARY OF EVIDENCE-BASED GUIDELINES FOR PREVENTION OF
SSI FROM CENTERS FOR DISEASE CONTROL AND PREVENTION (CONT'D)

Unresolved	No recommendations are made about restricting scrub suits to the operating suite or covering them when out of the suite
Asepsis and surgical technique	
Category 1A	Adhere to principles of asepsis when placing intravascular devices or when dispensing or administering intravenous drugs
Category 1B	Handle tissue gently, maintain hemostasis, minimize devitalized or charred tissue and foreign bodies, and eradicate dead space at the surgical site
	Use delayed primary skin closure or allow incisions to heal by secondary intention if the surgical site is contaminated or dirty
	Use closed suction drains when drainage is necessary, placing the drain through a separate incision distant from the operative incision. Remove drains as soon as possible
Category 2	Assemble sterile equipment and solutions immediately prior to use
Postoperative incision care	
Category 2	Keep a sterile dressing for 24 to 48 h postoperatively on an incision closed primarily. No recommendation is made regarding keeping a dressing on the wound beyond 48 h or for bathing and showering after the bandage is removed
	Wash hands before and after changing dressings and any contact with the surgical site. Use sterile technique to change dressings
	Educate the patient about SSI, relevant symptoms and signs, and the need to report them if noted
Unresolved	No recommendation is made with respect to keeping an incision covered for more than 48 h

*Regulated by the U.S. Occupational Health and Safety Administration.

Recommendations for intraoperative ventilation, cleaning and disinfection of environmental surfaces, sterilization of surgical instruments, epidemiologic investigations in the operating room, and surveillance may be found in the source document.

SSI = surgical site infection.

Modified from reference 1.

cal scrubbing with antiseptic solutions be replaced with gentle washing with a waterless alcohol solution [9].

The introduction of waterless, scrubless alcohol-based hand antiseptics into the operating room, where traditional scrubbing has been the standard, requires education for proper application and initiation of programs to monitor methodology and compliance. The integration of these rinseless products has been challenging. Contributing to the confusion is the U.S. Food and Drug Administration (FDA) statement that products considered to be surgical scrubs must show characteristics that include immediate microbial killing, broad-spectrum activity, and persistence of the effect for as long as six hours.

One of the largest surgical antisepsis studies compared hand rubbing with aqueous alcohol (75% aqueous alcoholic solution containing propanol-1, propanol-2, and mecetronium etilsulfate) with traditional scrubbing with an antiseptic preparation containing 4% povidone-

iodine or 4% chlorhexidine gluconate. A total of 4,387 consecutive patients who underwent clean and clean-contaminated surgery were studied in a randomized equivalence trial [10]. The 30-day SSI rates were 55 of 2,252 (2.44%) with the hand-rubbing protocol and 53 of 2,135 (2.48%) with the hand-scrubbing protocol, for a difference of 0.04% (95% confidence interval, -0.88%, 0.96%) (Table 3). Compliance with the recommended duration of hand antisepsis was better in the hand-rubbing than the hand-scrubbing protocol (44% vs. 28%, respectively; $p = 0.008$), as was tolerance, with less skin dryness and irritation after aqueous alcohol use. Hand rubbing with aqueous alcoholic solution, preceded by a 1-min nonantiseptic hand wash before each surgeon's first procedure of the day and before any procedure if the hands were soiled, was as effective as traditional hand scrubbing in preventing SSIs. The hand-rubbing protocol was tolerated better by the surgical teams and improved compliance with hygiene guidelines, leading to the conclusion that

TABLE 3.   SURGICAL SITE INFECTON (SSI) RATES AND DIFFERENCES BETWEEN HAND SCRUBBING AND HAND RUBBING

Altemeier class of contamination	No. SSI/no. operations (%)		Percent difference in SSI rate, scrubbing vs. rubbing (95% CI)	χ^2 test of equivalence (p value)
	Hand scrubbing	Hand rubbing		
Clean	29/1,485 (1.95)	32/1,520 (2.11)	−0.15 (−1.16, 0.85)	16.0 (<0.001)
Clean-contaminated	24/650 (3.69)	23/732 (3.14)	0.55 (−1.36, 2.46)	1.9 (0.09)
All	53/2,135 (2.48)	55/2,252 (2.44)	0.04 (−0.88, 0.96)	19.5 (<0.001)

CI = confidence interval.
From reference 10.

hand rubbing with a liquid aqueous alcoholic solution can be used safely for preoperative hand hygiene.

In another study [11], a comparison of five protocols for surgical handwashing confirmed that the alcohol-based antiseptics were associated with significantly lower numbers of colony-forming units in two of the three post-scrub samples (p = 0.003, p = 0.035). The five study protocols were: (1) An initial scrub of 5 min and consecutive scrubs of 3.5 min with 4% chlorhexidine gluconate; (2) an initial scrub of 3 min and consecutive scrubs of 2.5 min with 4% chlorhexidine gluconate; (3) an initial scrub of 3 min and consecutive scrubs of 2.5 min with 5% povidone-iodine and 1% triclosan; (4) an initial scrub of 2 min with 4% chlorhexidine gluconate followed by a 30 sec application of 70% isopropyl alcohol and 0.5% chlorhexidine gluconate, and a 30 sec application of 70% isopropyl alcohol and 0.5% chlorhexidine gluconate for consecutive scrubs; (5) an initial scrub of 2 min with 4% chlorhexidine gluconate followed by a 30 sec application of 70% ethanol and 0.5% chlorhexidine gluconate, and a 30 sec application of 70% ethanol and 0.5% chlorhexidine gluconate for consecutive scrubs. A scrub protocol using alcohol-based antiseptics was as effective as and no more damaging to skin than more time-consuming conventional methods using detergent-based antiseptics.

Similarly, Kac et al. [12] found that hand rubbing with an alcohol-based solution produced a significantly greater reduction in microbiological load than handwashing with unmedicated soap (p < 0.0001 for palms and p = 0.0003 for fingertips). After hand rubbing, no transient pathogens were recovered, whereas pathogens were recovered after handwashing in two cases. This study also confirmed that rubbing was more efficacious than washing for the decontamination of healthcare workers' hands after contact with patients and patient environments [12]. Handrubbing with an alcohol-based solution also is significantly more efficient in reducing hand contamination than washing with an antiseptic soap [13,14]. Furthermore, it has been recognized that an alcohol-based hand antiseptic used in conjunction with a scrub agent (i.e., after a brief surgical scrub) enhances the effectiveness of decontamination [15].

Additional studies have documented that hand antisepsis with an alcoholic gel regimen is well tolerated and does not cause skin irritation and dryness. In contrast, skin irritation and dryness increased significantly when washing with the unmedicated soap product. Newer alcoholic hand gels that are less irritating than soap may be more acceptable to staff and lead to better hand-hygiene practices [16,17].

Chlorhexidine gluconate and alcohol gel as disinfectants were compared in a randomized trial involving orthopedic surgeons [18]. The hand-washing protocol dictated that all surgeons wash for 5 min with chlorhexidine before their first case. Thereafter, the surgeon was randomized to wash for 3 min with either alcohol gel or chlorhexidine. At the end of each procedure, the gloves were removed, and an impression of the surgeon's fingertips was made on an agar plate. The numbers of bacterial colonies present after 24 h and 48 h of incubation were recorded for each agar plate by a microbiologist unaware of the washing protocol. Overall, 41 procedures and 82 episodes of hand washing were studied. Four hands (8%) were contaminated in the chlorhexidine group compared with 19 (34%) in the alcohol

group (p = 0.002; Fisher exact test). In addition, the average colony count was substantially higher in the alcohol group (20 colony forming units [CFU]) than in the chlorhexidine group (5 CFU). However, this is the only study to iden-

tify a higher risk of bacterial contamination of surgeons' hands washed with alcohol.

A comparison of the agents currently available for surgical hand antisepsis is presented in Table 4. A working knowledge of the charac-

TABLE 4. CHARACTERISTICS, EFFICACY, AND INDICATIONS FOR VARIOUS CLASSES OF TOPICAL SKIN ANTISEPTICS

	Characteristics	Efficacy	Indications
Alcohols	Excellent germicides Volatile, flammable Emollients needed to prevent drying Must dry to work No appreciable activity after evaporation	Excellent bactericides (gram-neg. and gram-pos.), including multi-resistant pathogens Excellent against *Mycobacterium tuberculosis* Good virucides (certain enveloped viruses such as herpes simplex, influenza, RSV; HBV less susceptible; HCV probably killed) Good fungicides Most rapid onset of action	Surgical hand scrubs and rubs; less for preparation Not recommended when soil and debris are present
Chlorhexidine gluconate (CHG)	Broad spectrum Binds to corneum stratum Substantial persistent activity Effectiveness increases with use Generally non-toxic but may be ototoxic and cause corneal damage Not for use past superficial layers of skin Less irritating than many agents; allergic reactions uncommon	Excellent antiseptic Immediate activity slower than with alcohols Excellent bactericide, although stronger against gram-pos. than gram-neg. Minimal activity against *M. tuberculosis* Effective against enveloped viruses (herpes simplex, HIV, CMV) 2% CHG somewhat less effective than 4%	Used predominantly for hand scrubs Used for hand antisepsis in high-risk areas such as ED and ICU Used for skin preparation Activity reduced by anionic surfactants in many hand lotions Influenza and RSV
Iodophors	Molecular iodine in carrier solution; amount of free iodine determines extent of antimicrobial activity Antimicrobial activity can be affected by pH, temp., exposure time, conc. of free iodine, presence of organic and inorganic compounds Cause less skin irritation and fewer allergic reactions than iodine but more contact dermatitis than other antiseptics commonly used for hand hygiene	Broad spectrum Bactericidal (gram-pos. and gram-neg.) Active against mycobacteria, viruses, and fungi Activity is substantially reduced in presence of organic matter Poor persistence	Surgical hand scrubs and skin preparation
Parachlorometaxylenol (PCMX)	Non-allergenic Concentrations differ Not as rapidly acting as CHG or iodophors	Bactericidal (good against gram-pos.; fair against gram-neg) Fair activity against *M. tuberculosis*, some fungi, certain viruses Less persistent than CHG Minimally affected by organic matter	Surgical scrubs Handwashing Neutralized by anionic surfactants

TABLE 4. CHARACTERISTICS, EFFICACY, AND INDICATIONS FOR VARIOUS CLASSES OF TOPICAL SKIN ANTISEPTICS (CONT'D)

	Characteristics	Efficacy	Indications
Triclosan	Ideal concentration not known; 1%–2% Activity affected by pH, surfactants, emollients, ionic nature of formulation Formulations of <2% well tolerated and seldom cause allergic reactions	More effective against gram-pos. than gram-neg. Reasonably active against *M. tuberculosis* Limited activity against filamentous fungi Relatively broad-spectrum activity against viruses Intermediate speed of action Persistent on skin	In 1994, FDA Tentative Final Monograph stated "Triclosan less than 1 percent: insufficient data exists to classify this agent as safe and effective for use as an antiseptic handwash." Evaluation continues Handwash Consumer products Suture material

Abbreviations: RSV = respiratory syncytial virus; HBV = hepatitis B virus; HCV = hepatitis C virus; HIV = human immunodeficiency virus; CMV = cytomegalovirus; ED = emergency department; ICU = intensive care unit; FDA = U.S. Food and Drug Administration.

teristics, efficacy, and appropriate indications of these products is necessary for all practicing surgeons. The microbiologic activities and potential uses of these antiseptics are provided in detail in Table 5.

An alcohol-based product that could be used to decontaminate the hands with or without water (i.e., water optional) while providing immediacy of killing and persistence could reduce the confusion associated with the national handwashing guidelines [19]. Such a product has been developed. Triseptin (Healthpoint, Inc., Fort Worth, TX), which is alcohol-based (61%) and zinc pyrithione (ZPT)-preserved, is compliant with the FDA and CDC guidelines. The 61% alcohol-ZPT product easily produced >3.0 $\log_{10}$ reductions in the indicator strain (*Serratia marcescens*) with the first wash, exceeding the 2.0 $\log_{10}$ FDA requirement. This level of performance was maintained through the tenth wash, surpassing the 3.0 $\log_{10}$ FDA requirement for the handwash indication. For the assessment of persistence and residual effect in the waterless mode, the water-optional, 61% alcohol-ZPT product consistently produced $\log_{10}$ reductions of 3.5 or greater at every point over the entire study period. In the water-aided configuration, similar results were obtained, as $\log_{10}$ reductions of 2.5 were observed. The formulation was non-irritating, actually improving hand skin condition. The 61% alcohol-ZPT product therefore exceeded all FDA criteria for the health care personnel handwash indication and is a substantial advancement in the concept of skin antisepsis in

that it is a single product suitable for all hand-hygiene settings and demonstrates better antimicrobial persistence and residual effects. A previously reported study has documented it to be virucidal for several DNA and RNA viruses [20].

PREOPERATIVE BATHING OR SHOWERING WITH SKIN ANTISEPTICS TO PREVENT SSI

Preoperative bathing or showering with an antiseptic skin wash product is a well-accepted and commonly recommended procedure for reducing skin bacteria and microflora prior to surgery. The CDC Guideline for the Prevention of Surgical Site Infection now "strongly recommends" (Category IB) that healthcare facilities "require patients to shower or bathe with an antiseptic agent on at least the night before the operative day," as a preoperative antiseptic shower or bath decreased skin microbial colony counts ninefold in the studies they cite. Although the CDC cautions that the showers have not been shown definitively to reduce SSI rates, the practice is sound as it relates to skin microbiology, given the fact that the majority of SSIs are associated with skin flora.

A recent Cochrane systematic review examined six trials of preoperative bathing involving a total of 10,007 participants [21]. The antiseptic used in all trials was 4% chlorhexidine gluconate. Bathing with chlorhexidine com-

TABLE 5. MICROBIOLOGIC ACTIVITIES AND POTENTIAL USES OF ANTISEPTICS

Group	Spectrum of activity						Potential uses				Comments
	Gram+	Gram−	TB	Viruses	Fungi	Endospores	Speed of action	Effect of organic matter	Surgical scrub	Skin prep.	
Alcohols[a]	Exc	Exc	Exc	Exc	Exc	None	Fast	Mod	Yes	Yes	Not for use on mucous membranes; not good for physical cleaning of skin; does not persist
Chlorhexidine (2–4%)	Exc	Good	Fair	Exc	Fair	None	Int	Slight	Yes	Yes	Good persistence; toxic to eyes and ears
Iodine (3%)	Exc	Exc	Exc	Exc	Good	Fair	Int	Marked	No	Yes	Not for use on mucous membranes; can burn skin, so remove after several minutes
Povidone-iodine (7.5–10%)	Exc	Exc	Fair	Good	Good	None	Int	Mod	Yes	Yes	Can be used on mucous membranes
PCMX (0.5–4%)	Good	Exc	Fair	Good	Fair	Unknown	Slow	Minimal	No	Yes	Penetrates skin; should not be used on newborns
Triclosan (0.2–2%)	Exc	Good	Fair	Exc	None	Unknown	Int	Minimal	Yes	No	Acceptability on hands varies

[a]60–90% ethyl or isopropyl.

Abbreviations: TB = *Mycobacterium tuberculosis*; Exc = excellent; Mod = moderate; Int = intermediate; PCMX = para-chlorometaxylenol.

Adapted from reference 1 and Olmsted RN, ed. Infection control and applied epidemiology: principles and practices. St. Louis, MO: CV Mosby, 1996: table 19-2.

pared with a placebo did not result in a statistically significant reduction in SSIs (relative risk [RR] 0.91; 95% confidence interval [CI] 0.80, 1.04). When only high-quality trials were analyzed, the results were no different (RR 0.95; 95% CI 0.82, 1.0). Three trials of 1,443 participants compared bar soap with chlorhexidine; there was no difference in the risk of SSIs (RR 1.02; 95% CI 0.57, 1.84). Two trials involving 1,092 patients compared bathing with chlorhexidine and no washing; likewise, no difference was found (RR 0.70; 95% CI 0.19, 2.58). This Cochrane review provides evidence of no benefit for preoperative showering or bathing with chlorhexidine over other wash products. Efforts to reduce the incidence of nosocomial SSI should focus on interventions where effect has been demonstrated.

ANTISEPSIS OF THE SURGICAL SITE

Antiseptic preoperative skin site cleansing is used to prepare the operative site before making a surgical incision. The goal is a reduction in postoperative SSI. The usual method is scrubbing the skin with an antiseptic, traditionally povidone-iodine solution. Just as with surgeon hand hygiene, this procedure can damage the skin, possibly increasing the risk of infection. There are several efficient and quick-acting antiseptic alcohol solutions that require

no scrubbing. The traditional preoperative practice is increasingly being replaced by chlorhexidine, which, unlike povidone-iodine, remains active in the presence of blood and serum. One application of chlorhexidine exceeds the FDA criteria for antisepsis in preoperative patient skin preparation. ChloraPrep (2% chlorhexidine gluconate and 70% isopropyl alcohol; Medi-Flex, Inc., Leawood, KS) was superior to DuraPrep (0.7% iodine and 74% isopropyl alcohol; 3M Corp., St. Paul, MN) and Techni-Care (3.0% chloroxylenol; Care-Tech Laboratories, St. Louis, MO) in eliminating bacteria in a prospective study of 125 consecutive patients undergoing surgery of the foot and ankle [22]. These findings were confirmed in a randomized study [23].

It is crucially important to educate healthcare practitioners in the proper method of application of chlorhexidine solution, which should be scrubbed on for 30 sec in a back-and-forth motion, the friction of which is part of what makes the solution effective. The area does not need be doused or flooded with this agent, as some do with povidone-iodine solution. Scrubbing it on to cover the intended area is sufficient. The prepared area must then be allowed to dry completely, and the solution should not be blotted or wiped away. The preparation contains alcohol; therefore, adequate drying is also important for the prevention of fires caused by electrocautery. One previous difficulty with chlorhexidine skin preparations was the inability to discern that all areas of the skin had been covered, because the solution was colorless. A teal-colored tint has now been added for easier visibility.

If povidone-iodine skin preparation is to be used, there is still the question of whether scrub-and-paint vs. paint alone is superior. A randomized trial in 240 patients undergoing non-laparoscopic abdominal operations compared a vigorous 5-minute scrub with povidone-iodine soap followed by absorption with a sterile towel and painting with aqueous povidone-iodine (n = 115) with site preparation with povidone-iodine paint only (n = 119) [24]. The primary endpoint was the 30-day SSI rate, defined as the presence of clinical signs of infection necessitating therapeutic intervention. The patients in the two groups were well matched with respect to age, co-morbidity, wound classification, mean operative time, placement of drains, prophylactic antibiotic use, and surgical procedure (all p > 0.09). Surgical site infection occurred in 12 (10%) scrub-and-paint patients and 12 (10%) paint-only patients. According to the predefined parameters, these results were equivalent, suggesting that preoperative preparation of the abdomen with a povidone-iodine soap scrub and painting with aqueous povidone-iodine can be abandoned in favor of painting alone. However, this trial had a small sample size, and validation of the findings is warranted.

SKIN ANTISEPSIS IN CLEAN SURGERY

It is unclear whether preoperative skin antisepsis actually reduces SSI in clean surgery. A Cochrane review that examined this issue concluded that there is insufficient evidence that cleaning patients' skin with antiseptic before clean surgery reduces SSI [25]. Six eligible randomized controlled trials evaluated antiseptics applied immediately prior to incision in clean surgery. There was significant heterogeneity in the design of studies, however, and the results could not be pooled. In one of these studies, infection rates were significantly lower when skin was prepared using chlorhexidine rather than iodine. There was no evidence of a benefit in four trials that examined the use of iodophor-impregnated drapes.

A recent prospective cohort study compared SSI rates of 905 control patients who underwent skin preparation with normal saline compared with 905 patients for whom either chlorhexidine or povidone-iodine skin preparation was used. In both patient groups, a preoperative shower of the surgical site with soap and water was required. There were no SSIs in any group [26].

STAPHYLOCOCCUS AUREUS NASAL DECOLONIZATION FOR PREVENTION OF SSI

Staphylococcus aureus remains the most common cause of SSI. The ecologic niche of *S. aureus* is the anterior nares, and nasal colonization by the organism is common. Approximately one-third of humans have skin and mucosal colonization by *S. aureus*, although most

never become ill as a result. However, carriers are at higher risk for staphylococcal infections after invasive medical or surgical procedures than are non-carriers [27,28].

Decolonization, the use of antibiotics or antiseptics to reduce the magnitude of the reservoir in colonized patients, may be a useful undertaking. Several studies have reported lower rates of SSI among colonized patients who received 2% mupirocin ointment to the nares than among historical control subjects [29–31], although there is no benefit to the use of mupirocin for non-colonized patients.

A large randomized, double-blind, placebo-controlled trial (the Mupirocin and the Risk of *Staphylococcus aureus* — MARS — Study) examined whether preoperative nasal decolonization with mupirocin would decrease the rate of *S. aureus* SSI [32]. Overall, 2.3% of mupirocin recipients and 2.4% of the placebo recipients had *S. aureus* SSIs among the 3,864 patients in the intent-to-treat analysis, who underwent general, gynecologic, neurologic, or cardiothoracic surgery. Thus, prophylactic intranasal application of mupirocin did not significantly reduce the rate of *S. aureus* SSIs [32]. Interestingly, it did decrease significantly the rate of all nosocomial *S. aureus* infections among the patients who were carriers (4.0% vs. 7.7%; odds ratio [OR] 0.49; 95% CI, 0.25, 0.92; p = 0.002).

Another randomized study in 395 digestive surgery patients compared intranasal mupirocin 30 mg TID preoperatively for three days with no drug [33]. There were 21 gram-positive SSIs, 10 in the treated group and 11 in the control patients. Thus, intranasal mupirocin treatment had no significant impact on SSI after digestive surgery. However, this study did identify a significant reduction in the incidence of postoperative pneumonia, with none in the mupirocin-treated group and five in control patients (p = 0.028), with MRSA being the causative pathogen in four of the latter five patients.

DECOLONIZATION OF COLONIZED PATIENTS

A number of surgical patients are colonized with antibiotic-resistant pathogens, particularly methicillin-resistant *S. aureus* (MRSA), in the preoperative period and therefore are at higher risk for SSI with these pathogens. Consensus regarding the optimal preoperative preparation of MRSA-colonized patients, and whether preoperative decolonization should be attempted, has not been achieved. Furthermore, the optimal antimicrobial or antiseptic agents to use for prophylaxis in these colonized patients have not been determined.

A number of studies have documented a reduction in SSI with decolonization, but most were not randomized and controlled [30,34,35]. Topical perioperative prophylaxis for prevention of MRSA SSIs was examined using a controlled before–after approach on patients undergoing insertion of metal orthopedic prostheses or fixation. Patients received perioperative prophylaxis with nasal mupirocin ointment for five days and a shower or bath with 2% triclosan before surgery. Patients were followed for 12 months postoperatively. After introduction of the decolonization regimen, there was a marked decrease in the incidence of MRSA SSIs, from 23 per 1000 operations in the six months before the regimen to 3.3 (p < 0.001) and 4 (p < 0.001) in subsequent consecutive six-month periods. Point prevalence nasal carriage of MRSA decreased from 38% before the decolonization regimen was initiated to 23% immediately after, and 20%, 7%, 10%, and 8% (p < 0.001) at six-monthly intervals post-intervention [36]. Low-level mupirocin resistance was identified in 2.3% of *S. aureus* isolates from patients before the decolonization regimen was initiated and in 3.9%, 6.1%, 10%, and 0% in subsequent six-month periods. Furthermore, no *S. aureus* strains with high-level mupirocin resistance were isolated. The study investigators concluded that this regimen could reduce the incidence of MRSA SSI after orthopedic surgery, probably by reducing endemic nasal MRSA carriage, without selecting for mupirocin resistance. On the other hand, a randomized, placebo-controlled, double-blind trial to evaluate the efficacy of mupirocin for eradicating carriage of MRSA suggested that nasal mupirocin was only marginally effective in the eradication of multi-site MRSA carriage in a setting where MRSA was endemic [37]. The SHEA Guideline for Preventing Nosocomial Transmission of Multidrug-Resistant Strains of *Staphylococcus aureus* and *Enterococcus* (May 2003) can be found in Table 6 [38–47]. Similarly, the Guidelines for the Con-

TABLE 6. SHEA Guideline for Preventing
Nosocomial Transmission of Multidrug-Resistant
Strains of Gram-Positive Cocci

Consider MRSA decolonization therapy for both
patients and healthcare workers as an adjunctive
measure for controlling spread of MRSA in selected
populations when appropriate (Category IB)

Any program of decolonization therapy should
incorporate routine susceptibility testing, as selection
of inactive agents is less likely to achieve eradication
(Category II)

Widespread use, prolonged use, or both of
decolonization therapy should be avoided, because
this has been associated with the evolution and
spread of antibiotic-resistant strains, undermining the
effectiveness of the control effort (Category IB)

SHEA = Society of Healthcare Epidemiologists of
America; MRSA = methicillin-resistant *Staphylococcus
aureus.*

trol and Prevention of MRSA in Healthcare Fa-
cilities, published by the Joint Working Party of
the British Society of Antimicrobial Chemother-
apy, the Hospital Infection Society, and the In-
fection Control Nurses Association [48] recently
published recommendations regarding decolo-
nization (Table 7).

A Cochrane review examined all randomized,
controlled trials of MRSA-colonized patients who
were decolonized with topical or systemic an-
timicrobials or given a placebo or no treatment,
as well as trials that compared combinations of
single topical or systemic agents with no treat-
ment, placebo, or topical or systemic agents [49].
Six trials (384 participants) met the inclusion cri-
teria. No difference in MRSA eradication was
detected in four studies: One that compared
mupirocin with placebo, two that compared one
systemic agent with no treatment (fusidic acid in
one and rifampin or minocycline in the other),
and one that compared mupirocin with topical
fusidic acid and oral trimethoprim–sulfame-thox-
azole. One study compared minocycline with ri-
fampin, with rifampin being more effective in the
eradication of MRSA from all sites at day 30 (RR
0.16; 95% CI 0.02, 1.00), but there was no differ-
ence at 90 days. Two studies (one testing novo-
biocin and rifampin, the other cipro-floxacin and
rifampin, versus trimethoprim–sulfamethoxa-
zole and rifampin) demonstrated no difference in
eradication of MRSA at all sites (n = 94). Adverse
events occurred in as many as 20% of participants
receiving systemic agents; however, event re-
porting was sporadic, and denominators were

small. All trials detected development of resis-
tance to antimicrobial agents used. The conclu-
sion is that there is insufficient evidence to sup-
port use of topical or systemic antimicrobials for
eradicating nasal or extra-nasal MRSA, and there
is no demonstrated superiority of either topical
or systemic therapy, or of combinations of these
agents, yet potentially serious adverse events and
antimicrobial resistance can result.

Another guideline, the North Carolina Guide-
lines for Control of Antibiotic-Resistant Organ-
isms [50], states: "Routine decolonization for
MRSA is not recommended. The need for de-
colonization should be based on the patient's
medical condition and expected outcome. Topi-

TABLE 7. Joint British Guidelines for Control and
Prevention of MRSA in Healthcare Facilities

Nasal decolonization

Patients receiving prophylaxis for an operative
procedure and in an outbreak situation under the
advice of the infection control team should undergo
nasal decolonization. This should be undertaken by
applying mupirocin 2% in a paraffin base (ointment)
to the inner surface of each nostril (anterior nares)
three times daily for five days. The patient should be
able to taste mupirocin at the back of the throat after
application (Category 1B).

Mupirocin should not be used for prolonged periods or
used repeatedly (i.e., for more than two courses for
five days), as resistance may be encouraged
(Category 1A). The presence of a foreign body such
as a nasogastric tube may reduce the efficacy of
treatment with nasal mupirocin (Category 2).

Nasal decolonization using topical nasal mupirocin
should be used with other forms of intervention such
as skin decolonization with 4% chlorhexidine
gluconate aqueous solution (Category 2).

Skin decolonization

Skin decolonization using 4% chlorhexidine
bodywash/shampoo, 7.5% povidone-iodine or 2%
triclosan is useful in eradicating or suppressing skin
colonization for short times, particularly pre-
operatively to reduce the risk of SSIs (Category 1A).

Patients should bathe daily for five days with the
chosen antiseptic detergent. The skin should be
moistened and the antiseptic detergent should be
applied thoroughly to all areas before rinsing in the
bath or shower. Special attention should be paid to
known carriage sites such as the axilla, groin and
perineal area. The antiseptic should also be used for
all other washing procedures and for bed bathing.
Hair should be washed with antiseptic detergent
(Category 1A).

After satisfactory completion of a course of treatment,
clean clothing, bedding and towels should be
provided after each bath and hairwash (Category 2).

MRSA = methicillin-resistant *Staphylococcus aureus.*

cal or systemic antibiotics, including trimetho-prim–sulfamethoxazole, rifampin, ciprofloxacin, erythromycin, doxycycline, bacitracin, and mupirocin have been used with variable results to eradicate colonization by MRSA. Vancomycin is not indicated for decolonization therapy, as it is ineffective for this purpose. There is no clini-cally proven decolonization regimen for van-comycin-resistant enterococci (VRE)."

REFERENCES

1. Boyce JM, Pittet D; Healthcare Infection Control Prac-tices Advisory Committee, HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Guideline for Hand Hygiene in Healthcare Settings. MMWR 2002;51(RR-16):1–48.

2. Wyklicky H, Skopec M. Ignaz Philipp Semmelweis, the prophet of bacteriology. Infect Control 1983;4:367–370.

3. Classic articles in colonic and rectal surgery. On the an-tiseptic principle in the practice of surgery by Joseph Lister 1867. Dis Colon Rectum 1982;25:173–178.

4. Gröschel DHM, Pruett TL. Surgical antisepsis. *In*: Block SS, ed. Disinfection, sterilization and preserva-tion. 4th ed. Philadelphia. Lea and Febiger, 1991.

5. Garner JS, Favero MS. CDC Guideline for hand-washing and hospital environmental control, 1985. In-fect Control 1986;7:231–243.

6. Mangram AJ, Horan TC, Pearson ML, et al. Guideline for prevention of surgical site infection, 1999. Hospi-tal Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol 1999;20:250–278.

7. Lee JT. A new surgical site infection (SSI) prevention guideline. Surgical Infections 2000;1:127–131.

8. Available at http://www.who.int/patientsafety/events/05/HH_en.pdf.

9. Herruzo-Cabrera R, Vizcaino-Alcaide MJ, Fernandez-Acenero MJ. Usefulness of an alcohol solution of N-duopropenide for the surgical antisepsis of the hands compared with handwashing with iodine-povidone and chlorhexidine: Clinical essay. J Surg Res 2000; 94:6–12.

10. Parienti JJ, Thibon P, Heller R, Antisepsie Chirurgi-cale des Mains Study Group. Hand-rubbing with an aqueous alcoholic solution vs. traditional surgical hand-scrubbing and 30-day surgical site infection rates: A randomized equivalence study. JAMA 2002;288:722–727.

11. Pereira LJ, Lee GM, Wade KJ. An evaluation of five protocols for surgical handwashing in relation to skin condition and microbial counts. J Hosp Infect 1997;36:49–65.

12. Kac G, Podglajen I, Gueneret M, et al. Microbiological evaluation of two hand hygiene procedures achieved by healthcare workers during routine patient care: A randomized study. J Hosp Infect 2005;60:32–39.

13. Girou E, Loyeau S, Legrand P, et al. Efficacy of hand-drubbing with alcohol based solution versus standard handwashing with antiseptic soap: Randomised clin-ical trial. BMJ 2002;325:362–364.

14. Mulberry G, Snyder AT, Heilman J, et al. Evaluation of a waterless, scrubless chlorhexidine gluconate/ethanol surgical scrub for antimicrobial efficacy. Am J Infect Control 2001;29:377–382.

15. Nishimura C. Comparison of the antimicrobial effi-cacy of povidone-iodine, povidone-iodine-ethanol and chlorhexidine gluconate–ethanol surgical scrubs. Dermatology 2006;212(Suppl 1):21–25.

16. Boyce JM, Kelliher S, Vallande N. Skin irritation and dryness associated with two hand-hygiene regimens: Soap-and-water hand washing versus hand antisep-sis with an alcoholic hand gel. Infect Control Hosp Epidemiol 2000;21:442–448.

17. Larson EL, Aiello AE, Heilman JM, et al. Comparison of different regimens for surgical hand preparation. AORN J 2001;73:412–414, 417–418, 420.

18. Hajipour L, Longstaff L, Cleeve V, et al. Hand wash-ing rituals in trauma theatre: Clean or dirty? Ann R Coll Surg Engl 2006;88:13–15.

19. Guthery E, Seal LA, Anderson EL. Zinc pyrithione in alcohol-based products for skin antisepsis: Persis-tence of antimicrobial effects. Am J Infect Control 2005;33:15–22.

20. Seal LA, Rizer RL, Maas-Irslinger R. A unique water optional healthcare personnel handwash provides an-timicrobial persistence and residual effects while de-creasing the need for additional products. Am J In-fect Control 2005;33:207–216.

21. Webster J, Osborne S. Preoperative bathing or show-ering with skin antiseptics to prevent surgical site in-fection. Cochrane Database Syst Rev 2006;CD004985.

22. Ostrander RV, Botte MJ, Brage ME. Efficacy of surgi-cal preparation solutions in foot and ankle surgery. J Bone Joint Surg [Am] 2005;87:980–985.

23. Bibbo C, Patel DV, Gehrmann RM, Lin SS. Chlorhex-idine provides superior skin decontamination in foot and ankle surgery: A prospective randomized study. Clin Orthop Relat Res 2005;438:204–208.

24. Ellenhorn JD, Smith DD, Schwarz RE, et al. Paint-only is equivalent to scrub-and-paint in preoperative preparation of abdominal surgery sites. J Am Coll Surg 2005;201:737–741.

25. Edwards PS, Lipp A, Holmes A. Preoperative skin an-tiseptics for preventing surgical wound infections af-ter clean surgery. Cochrane Database Syst Rev 2004; CD003949.

26. Kalantar-Hormozi AJ, Davami B. No need for preop-erative antiseptics in elective outpatient plastic surgi-cal operations: A prospective study. Plast Reconstr Surg 2005;116:529–531.

27. Perl TM, Golub JE. New approaches to reduce *Staphy-lococcus aureus* nosocomial infection rates: Treating *S. aureus* nasal carriage. Ann Pharmacother 1998;32:S7–S16.

28. Wenzel RP, Perl TM. The significance of nasal car-riage of *Staphylococcus aureus* and the incidence of

postoperative wound infection. J Hosp Infect 1995; 31:13–24.

29. Kluytmans JAJW, Mouton JW, VandenBergh MFQ, et al. Reduction of surgical-site infections in cardiothoracic surgery by elimination of nasal carriage of *Staphylococcus aureus*. Infect Control Hosp Epidemiol 1996;17:780–785.

30. Cimochowski GE, Harostock MD, Brown R, et al. Intranasal mupirocin reduces sternal wound infection after open heart surgery in diabetics and nondiabetics. Ann Thorac Surg 2001;71:1572–1579.

31. Gernaat-van der Sluis AJ, Hoogenboom-Verdegaal AM, Edixhoven PJ, Spies-van Rooijen NH. Prophylactic mupirocin could reduce orthopedic wound infections: 1,044 patients treated with mupirocin compared with 1,260 historical controls. Acta Orthop Scand 1998;69:412–414.

32. Perl TM, Cullen JJ, Wenzel RP, et al.; the Mupirocin and the Risk of *Staphylococcus aureus* Study Team. Intranasal mupirocin to prevent postoperative *Staphylococcus aureus* infections. N Engl J Med 2002;346:1871–1877.

33. Suzuki Y, Kamigaki T, Fujino Y, et al. Randomized clinical trial of preoperative intranasal mupirocin to reduce surgical site infection after digestive surgery. Br J Surg 2003;90:1072–1075.

34. Kluytmans JA, Mouton JW, Banden Bergh MF, et al. Reduction of surgical site infections in cardiothoracic surgery by elimination of nasal carriage of *Staphylococcus aureus*. Infect Control Hosp Epidemiol 1996;17: 780–785.

35. Yano M, Kodi Y, Inoue M, et al. Preoperative intranasal mupirocin ointment significantly reduces postoperative infection with *Staphylococcus aureus* in patients undergoing upper gastrointestinal surgery. Surg Today 2000;30:16–21.

36. Wilcox MH, Hall J, Pike H, et al. Use of perioperative mupirocin to prevent methicillin-resistant *Staphylococcus aureus* (MRSA) orthopaedic surgical site infections. J Hospital Infection 2003;54:196–201.

37. Harbarth S, Dharan S, Liassine N, et al. Randomized, placebo-controlled, double-blind trial to evaluate the efficacy of mupirocin for eradicating carriage of methicillin-resistant *Staphylococcus aureus*. Antimicrob Agents Chemother 1999;43:1412–1416.

38. Muto CA, Jernigan JA, Ostrowsky BE, et al. SHEA Guideline for preventing nosocomial transmission of multidrug-resistant strains of *Staphylococcus aureus* and *Enterococcus*. Infect Control Hosp Epidemiol 2003;24:362–386.

39. Boyce JM, Opal SM, Potter-Bynoe G, Mederios AA. Spread of methicillin-resistant *Staphylococcus aureus* in a hospital and after exposure to a health-care worker with chronic sinusitis. Clin Infect Dis 1993;17:496–504.

40. Kluytmans J, van Leeuwen W, Goessens W, et al. Food-initiated outbreak of methicillin-resistant *Staphylococcus aureus* analyzed by pheno and genotyping. J Clin Microbiol 1995;33:1121–1128.

41. Lessing MP, Jordens JZ, Bowlwer IC. When should health care workers be screened for methicillin resistant *Staphylococcus aureus*? J Hosp Infect 1997;35:320–321.

42. Struelens MJ, Ronveaux O, Jans B, Mertens R, Groupement pour le Dépistage, Étude et la Prévention des Infections Hospitalières. Methicillin-resistant *Staphylococcus aureus* epidemiology and control in Belgian hospitals, 1991 to 1995. Infect Control Hosp Epidemiol 1996;17:503–508.

43. Karchmer TB, Jernigan JA, Durbin BM, Simonton BM, Farr BM. Eradication of methicillin-resistant *S. aureus* (MRSA) colonization with different regimens [abstract 65:42]. Presented at the Ninth Annual Meeting of the Society for Healthcare Epidemiology of America; April 18–20, 1999; San Francisco, CA.

44. Kotilainen P, Routamaa M, Peltonen R, et al. Eradication of methicillin-resistant *Staphylococcus aureus* from a health center ward and associated nursing home. Arch Intern Med 2001;161:859–863.

45. Walker ES, Vasquez JE, Dula R, et al. Mupirocin-resistant, methicillin-resistant *Staphylococcus aureus*: Does mupirocin remain effective? Infect Control Hosp Epidemiol 2003;24:342–346.

46. Vasquez JE, Walker ES, Franzus BW, et al. The epidemiology of mupirocin resistance among methicillin-resistant *Staphylococcus aureus* at a Veterans Affairs hospital. Infect Control Hosp Epidemiol 2000;21:459–464.

47. Miller MA, Dascal A, Portnory J, Mendelson J. Development of mupirocin resistance among methicillin-resistant *Staphylococcus aureus* after widespread use of nasal mupirocin ointment. Infect Control Hosp Epidemiol 1996;17:811–813.

48. Coia JE, Duckworth GJ, Edwards DI, et al.; Joint Working Party of the British Society of Antimicrobial Chemotherapy, the Hospital Infection Society, and the Infection Control Nurses Association. Guidelines for the control and prevention of methicillin-resistant *Staphylococcus aureus* (MRSA) in healthcare facilities. J Hospital Infection 2006;63:1–44.

49. Loeb M, Main C, Walker-Dilks C, Eady A. Antimicrobial drugs for treating methicillin-resistant *Staphylococcus aureus* colonization. Cochrane Database Syst Rev 2003;CD003340.

50. Hoffmann KK, Kittrell IP. North Carolina guidelines for control of antibiotic-resistant organisms, specifically methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE). 1997. Available at http://www.unc.edu/depts/spice/guide2.html

Address reprint requests to:
Dr. Lena M. Napolitano
Department of Surgery
University of Michigan Health System
Room 1C421, University Hospital, Box 0033
1500 E. Medical Center Drive
Ann Arbor, MI 48109-0033

E-mail: lenan@umich.edu