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SPECIAL REPORT

A Perspective on Surgical Site Infection Prevention

Patient Care Interventions to Help Reduce the Risk of Surgical Site Infections



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Health care—associated infections (HAIs) represent an obvious threat to patient safety, resulting in significant patient morbidity and contributing to increased use of hospital-based resources. National and state comparisons are now made using a standardized infection ratio (SIR). The SIR is a summary measure used to track HAI rates over time; it is adjusted for patients with varying risk in each health care facility. The SIR compares the actual number of HAIs that are reported with the baseline US experience, adjusting for several risk factors that have been documented to be associated with differences in the incidence of infection. The National Healthcare Safety Network (NHSN) is the nation's infection tracking network.¹ The NHSN aggregate data are used to determine the baseline US experience, and these baseline data are used to calculate the expected or predicted number of HAIs, adjusting for the identified risk factors.²

INCIDENCE OF SURGICAL SITE INFECTIONS NATIONWIDE

In March 2014, the Centers for Disease Control and Prevention (CDC) released the Healthcare-associated Infections (HAI) Progress Report.² This report includes national and state-by-state summations of selected HAIs, including surgical site infections (SSIs), and data from acute care hospitals that are part of the NHSN.² According to the progress report,

national composite data suggest that there was a 20% overall reduction in SSIs related to 10 selected surgical procedures from 2008 to 2012 (Table 1).² Although the national composite data appear encouraging, none of the states performed better than the national SIR in all four infection categories: central line—associated bloodstream infections, catheter-associated urinary tract infections, ventilator-associated pneumonia, and SSIs (including colon procedures and abdominal hysterectomies).³

The interpretation of the SIR for SSIs compared with the national baseline data suggests that a value

- greater than one indicates that there has been an increase in the number of SSIs,
- equal to one indicates that no progress has been made in reducing infections, and
- less than one indicates that progress has been made in reducing infections.

The SIR for SSIs also takes into consideration patient differences and procedure-related risk factors, including the following:

- duration of surgery,
- surgical wound class,
- use of laparoscopic equipment,
- reoperation status,
- patient age, and
- patient assessment at induction of anesthesia.

For example, in 2013 in Wisconsin, the SIR for colon surgeries was 0.97 (n = 84 hospitals) and the

TABLE 1. National Trends in Surgical Site Infections Related to 10 Common Surgical Procedures¹

Procedure type	Number of sites	Number of procedures	2012 standardized infection ratio	Percent change (decrease)
Hip arthroplasty	1,653	232,613	0.84	16%
Knee arthroplasty	1,663	341,048	0.77	23%
Colon procedures	3,318	288,362	0.80	20%
Rectal procedures	299	5,927	0.76	24%
Abdominal hysterectomy	3,172	299,412	0.89	11%
Vaginal hysterectomy	663	29,762	0.89	11%
Coronary artery bypass graft	718	106,494	0.71	29%
Other cardiac procedures	334	37,002	0.68	32%
Peripheral vascular procedures	135	4,399	0.74	26%
Abdominal aortic aneurysm repair	202	1,787	0.32	68%
Combined data	3,554	1,346,806	0.80	20%

1. Healthcare-associated Infections (HAI) Progress Report. Centers for Disease Control and Prevention. <http://www.cdc.gov/hai/progress-report/index.html>. Updated March 26, 2014. Accessed September 16, 2014.

SIR for abdominal hysterectomy was 0.90 ($n = 76$ hospitals). These values suggest that, compared with the previous reporting period (2012 to 2013), there was a 15% increase in the number of colon infections and a 6% reduction in the number of abdominal hysterectomy infections in the state of Wisconsin.⁴

The publication of CDC national composite data in 2014 provided acute care institutions with a vehicle for comparing their risk reduction efforts with peer organizations around the state and with the national composite value. The evolution of the Centers for Medicare & Medicaid Services' value-based purchasing initiative requires that health care providers be held accountable for the cost and quality of delivered care.⁵ Therefore, the NHSN, the SIR, and value-based purchasing are indelibly and intrinsically intertwined in the national effort to improve patient outcomes. Acute care facilities, and eventually ambulatory surgery centers, will have a financial incentive to improve the quality of care that patients receive by eliminating or reducing adverse events and, in the process, adopt evidence-based practices that reengineer the health care process to improve the patient care experience.

EVIDENCE-BASED STRATEGIES FOR REDUCING THE RISK OF SSIs

Between September 2013 and September 2014, several key reports were published that strengthen the argument for adopting selected evidence-based interventions to reduce the risk of SSIs.⁶⁻⁸ These intervention practices, in conjunction with selected core measures, can be integrated into a surgical care bundle to improve patient outcomes related to SSIs. These include surgical attire and hand hygiene, antimicrobial sutures, preadmission showers and cleansing, and weight-based dosing.

Surgical Attire and Hand Hygiene

Surgical attire is the foundation of cleanliness, although it is not the only part of this foundation. It is important that perioperative personnel, surgeons, anesthesia professionals, and visitors make sure they maintain good hygiene in general, wear appropriate surgical attire (eg, bouffant hair coverings; masks; eye protection; clean, freshly laundered surgical attire; cover jackets), and practice hand hygiene diligently.⁹⁻¹²

AORN publishes recommendations for clinical practice that provide strategies for minimizing risks

to patients. The AORN “Recommended practices for surgical attire,” for example, provides strategies for perioperative personnel to use surgical attire in such a way that the risk of SSIs is minimized.¹³ When the AORN “Recommended practices for surgical attire” was updated in November 2010, it set into motion a closer look at perioperative attire practices, such as allowing staff members’ hair or arms to be exposed, taking personal items or food into the OR, or wearing visibly soiled laboratory coats over surgical scrubs. To illustrate these inappropriate practices and demonstrate correct practices, AORN

published a “What’s Wrong With This Picture?”¹⁴ drawing in a 2012 article on the implementation of the recommended practices for surgical attire. The AORN recommended prac-

tices are intended to be achievable recommendations and represent what is believed to be an optimal level of practice.¹³ The Joint Commission and Centers for Medicare & Medicaid Services expect compliance with these national recommendations when surveying facilities.

One change in the AORN recommendations has been to advise against wearing skull caps in the surgical setting, because this type of head covering does not adequately cover the hair at the nape of the neck. This can result in exposure of hair, dandruff, sweat, and skin squames to the OR environment and the patient during surgery, which increases the risk of infection. Human skin is colonized with many bacteria; personnel can shed microorganisms into the air around them, which could fall into the surgical field. Case reports have shown cross infection from contaminated scalp squames and hair in the OR and the development of SSIs.^{13,15,16} Therefore, surgical headgear that covers hair at the nape of the neck and ears can reduce the number of bacteria introduced by

personnel into the air in the OR and prevent subsequent SSIs.^{13,17}

According to Loftus et al,¹⁸ potentially pathogenic organisms can be transmitted through anesthesia equipment during administration of anesthesia. The hands of anesthesia personnel were cultured and found to include both nonpathogenic and multidrug-resistant bacteria that were transmitted to the adjustable pressure-limiting valve and dial on the anesthesia machine. A second study evaluated the incidence of intraoperative bacterial transmission to the IV stopcock set from organisms

recovered from the hands of anesthesia professionals.¹⁹ Both of these studies demonstrate the importance of performing frequent hand hygiene in the OR to prevent direct transmission of potentially pathogenic

organisms to IV and anesthesia equipment.²⁰ Ideally, nonscrubbed OR personnel should have easy access to a container of alcohol-based hand rub.²¹

Antimicrobial Sutures

Reducing the risk of SSI requires a mechanistic understanding of the pathophysiology of the wound infection. All surgical wounds are contaminated to some degree at closure,²² and the factors that predispose a patient to risk of infection include the microbial burden within the wound and the intrinsic homeostasis within the wound bed. Therefore, a successful risk reduction intervention should focus on limiting or reducing the microbial burden within the wound at the time of closure.

Antimicrobial (ie, triclosan-coated) braided and monofilament sutures were introduced to the market more than 10 years ago with little, if any, evidence-based human studies to support clinical efficacy. The US Food and Drug Administration indication for use of this technology specifies that the presence of triclosan on the surface of the

Although not all of the studies showed a clinical benefit of using antimicrobial sutures, two independent meta-analyses documented that this technology represented clinical evidence that supports adopting the technology as a significant risk reduction intervention.

device reduced the risk of microbial attachment to the suture, decreasing the probability of the device becoming a possible nidus (ie, a central point of origin or focus where bacterial growth may occur in a living organism) for infection. A secondary consideration was the observation that as triclosan was eluted (ie, to extract an adsorbed material [the antibiotic] that has formed on the surface of a substance [the suture]) from the surface of the suture, a zone of inhibition was created around the suture, which may help reduce the wound burden at closure.

At the time this report was written, there were 30 studies in the surgical literature reflecting the broad spectrum of surgical services. Although not all of the studies showed a clinical benefit of using antimicrobial sutures, two independent meta-analyses^{23,24} published in 2013 documented that this technology represented clinical evidence with an appraisal score of I A, which supports adopting this technology as a significant risk reduction intervention. Although these two publications validate the benefits of antimicrobial sutures, the question remains largely unanswered regarding which surgical procedures would benefit most from this technology. Daoud et al²⁵ performed a meta-analysis that included 4,800 surgical patients. The study showed that use of triclosan-coated surgical sutures reduced the incidence of SSIs in clean, clean-contaminated, and contaminated surgical procedures, again validating clinical efficacy with an evidence appraisal score of I A. The analysis included patients undergoing upper and lower gastrointestinal, abdominal, breast, coronary bypass, hepatobiliary, and neurosurgical procedures.²⁵ In August 2014, an economic model published by a collaborative group at the University of Pittsburgh, Pennsylvania, and the Bloomberg School of Health at Johns Hopkins School of Medicine, Baltimore, Maryland, documented that “. . . switching to triclosan-coated sutures from the uncoated sutures can both prevent SSIs and save substantial costs for hospitals, third-party payers, and society, as long as efficacy in preventing SSIs is at least 10% and SSI risk is at least 10%.”^{26(p1013)}

These landmark publications represent an emerging trend that a well-conceived interventional technology addressing the mechanistic basis of HAI can lead to improved patient outcomes. At the same time, this technology can help conserve valuable institutional fiscal resources in an era of value-based purchasing.

Preadmission Showers and Cleansing

In 1999, the CDC Surgical Site Infection Prevention Guidelines designated the preadmission antiseptic shower as a category I B clinical practice, meaning that it was strongly recommended.²⁷ Unfortunately, the current proposed CDC recommendations appear to retreat from that position, in part influenced by selective publications purporting that no clinical evidence exists for the benefit of this intervention to reduce the risk of selective SSIs.²⁸ There are several deficiencies in the evidence presented in the Cochrane review²⁸:

- In the seven cited studies, there was no documentation of a uniform standard of practice; some patients showered multiple times, whereas others showered only once with an antiseptic soap.
- There is no evidence that an attempt was made to standardize a timed duration of the antiseptic shower or cleansing process in any of the reviewed studies.
- The surgical populations were highly heterogeneous, encompassing patients undergoing elective clean, clean-contaminated, and contaminated surgical procedures.
- There was no indication based on review of the seven studies as to whether an effort was made to assess patient compliance with the study protocols.
- Follow-up (30 days) did not occur in three of the seven studies; from a surveillance perspective, this makes it difficult, if not impossible, to accurately assess the benefit of any SSI interventional practice if the numerator (or denominator) component is lacking or inaccurate.
- Skin antisepsis (ie, preadmission bathing or perioperative skin prepping) is an adjunctive

component of an overall interventional process. The Cochrane analysis provides no data as to what other interventional practices may or may not have been in place at the time the surgical procedures were performed.

A potential problem with interpreting findings from studies conducted before 2009 is the lack of a standardized process. Two recent studies have documented that by using a standardized patient-centric regimen of two preadmission showers or skin cleansings with either 4% aqueous or 2% chlorhexidine gluconate (CHG)-impregnated polyester cloths, skin surface concentrations of CHG can be achieved that are 25 or more times greater than the minimum inhibitory concentration (MIC₉₀) required to inhibit or kill skin staphylococci, including methicillin-resistant *Staphylococcus aureus* (MRSA) (ie, the estimated concentration that would inhibit 90% [MIC₉₀] of bacterial isolates).^{29,30}

In a report that was published in August 2014, a team of investigators documented that use of electronic reminders was highly effective at enhancing patient compliance with a preadmission antiseptic (ie, CHG) showering regimen.³¹ In the study, electronic alerts were sent as voice mails, text messages, or e-mails; text messages were the most popular method and were selected by 80% of recruited volunteers. Volunteers were randomized to either take two showers (Group A) or three showers (Group B). The volunteers were further divided so that participants in Group A1 and Group B1 were prompted by an electronic alert reminder to shower, and participants in Group A2 and Group B2 did not receive an electronic prompt. Compliance was measured by analyzing skin surface concentrations of CHG at five separate anatomic sites.

Analysis showed that CHG skin surface concentrations were significantly higher ($P < .007$) in participants in Groups A1 and B1 compared with participants in Groups A2 and B2, suggesting the electronic alerts were successful in prompting the patients to shower. Furthermore, there was a 66% reduction in the composite mean concentration of CHG on the skin surface in those who were not alerted to shower compared with those who received electronic reminders.³¹ These results suggest that use of an electronic alert system is effective in improving compliance with the preadmission showering/cleansing regimen.

Future clinical investigations validating the role of the antiseptic shower to reduce the risk of SSIs should consider the findings of recent clinical studies, emphasizing both standardization and protocol compliance.

Table 2 lists 11 steps that should be considered in developing a thoughtful preadmission showering protocol.

Weight-Based Dosing

Since 2004, a number of research-based clinical studies have documented that the current therapeutic dosing used in perioperative antimicrobial prophylaxis is inadequate in terms of providing sufficient tissue penetration and establishing wound concentrations that are sufficient to inhibit gram-positive and gram-negative microbial populations associated with SSIs.³²⁻³⁵ However, clinical studies have not documented that the presence of subtherapeutic concentrations in the wound at the time of surgery increases the risk of SSIs, which creates a dilemma for clinicians. Despite this lack of documentation, it seems intuitive that if there is insufficient tissue penetration, the intraoperative

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TABLE 2. A Standardized Approach for Improving Patient Compliance With a Preadmission Showering Protocol

1. Provide the patient with chlorhexidine gluconate (CHG).
2. Provide the patient with oral and written instructions on how to perform the preadmission showering protocol.
3. Emphasize the overall benefits of the preadmission antiseptic shower.
4. Define a precise amount of CHG in milliliters to be used for each shower; performing a double application is warranted.
5. Ensure that the patient understands to allow a 60-second pause (ie, time out) before rinsing.
6. Instruct the patient not to apply lotions, creams, emollients, or perfumes after application of CHG because these products may mask or adversely (ie, pharmacologically) affect antimicrobial activity or increase skin sensitivity.
7. Instruct the patient to wear loose-fitting garments after application of CHG.
8. Instruct the patient to rinse immediately if significant burning or itching occurs and to report this occurrence to his or her health care provider.
9. Instruct the patient to prevent CHG from getting into the eyes or ears and to rinse immediately if the eyes or ears are exposed to CHG.
10. Provide the patient and his or her family members with a telephone contact if questions or concerns arise.
11. Use a variety of electronic alert systems (eg, text message, e-mail, voice mail) to remind the patient of the need to complete the preadmission showering protocol.

wound concentrations of antibiotic would provide little, if any, benefit against the gram-positive or gram-negative pathogens associated with SSIs.

The issue of weight-based dosing was addressed in 2013 with publication of the “Clinical practice guidelines for antimicrobial prophylaxis in surgery.”³⁶ At Froedtert Hospital, the clinical affiliate of the Medical College of Wisconsin, Milwaukee, clinicians have been using a weight-based dosing strategy since 2009, and the traditional 1-gram baseline dose is no longer part of the surgical prophylactic regimen. All surgical patients with a body mass index of 30 kg/m² or more (ie, weighing 100 kg or more) are given a 3-gram prophylactic dose of cefazolin at least 30 minutes before the incision is made. All patients with a body mass index of less than 30 kg/m² (ie, weighing less than 100 kg) are given a 2-gram prophylactic dose. As of 2014, however, not all hospitals in the United States have embraced the concept of weight-based dosing for antimicrobial prophylaxis in surgical patients; therefore, obese patients remain vulnerable to intraoperative wound contamination. Until a robust clinical trial is performed that investigates 2-gram versus 3-gram prophylaxis in surgical patients with a body mass index of 30 kg/m² or more, the use of antimicrobial prophylaxis in

patients who weigh 100 kg or more should be governed by available pharmacokinetic and pharmacodynamic studies conducted in similar patient populations.

MRSA AND MSSA SURVEILLANCE FOR HIGH-RISK SURGICAL PATIENT POPULATIONS

Methicillin-resistant *S aureus* and methicillin-sensitive *S aureus* (MSSA) have acquired genes that encode antibiotic resistance or sensitivity, respectively, to penicillins, including methicillin and other β -lactamase antibiotics. The resistance of MRSA to many antibiotics is a significant cause of illness and sometimes death related to SSI.³⁶ Methicillin-resistant *S aureus* infection or colonization occurs most frequently among patients who

- are being treated in hospitals and health care facilities,
- have weakened immune systems, or
- undergo surgical procedures or invasive medical procedures.

Studies have established that patients who are nasal carriers of MRSA have a significant risk of developing SSIs with *S aureus*.^{37,38} Four studies identified *S aureus* nasal carriage as an important risk factor for the development of SSIs.^{37,39-41} Patients

who are colonized with MRSA are two to nine times more likely to develop an infection than noncarriers.^{37,39} In one study, *S aureus* SSI isolates matched those from the patients' nares 85% of the time.³⁹ Nasal carriage of *S aureus* was the only independent risk factor for the development of orthopedic implant SSI in another study,⁴⁰ and similar findings have been reported in cardiac surgery.⁴¹ Two recent reports have documented the risk of postoperative infection associated with MRSA and nasal colonization of MRSA in device-related surgical procedures.^{42,43}

In the perioperative setting, several strategies can be used to reduce the risk of MRSA infection, including active surveillance, decolonization with mupirocin, and CHG showers. These strategies also have been shown to reduce risk when they are used in a bundled approach. A recent report by Waits et al⁸ reviewed 4,085 colorectal surgical procedures, representing data from 24 hospitals participating in the Michigan Surgical Quality Collaborative. The authors documented that six separate perioperative care measures were effective when bundled together to reduce the colorectal SSI rate from 17.5% to 2.4% (80% reduction from baseline). Although these findings and selective care measures were in part specific to colorectal surgery, the study illustrates that implementation of a surgical care bundle that is evidence based and embraced by all stakeholders to achieve high compliance will improve the outcomes of surgical care.

A 2010 study by Kim et al³⁸ showed that even in a clinic environment in which there was a low rate of total joint infection (0.46), when a bundled program of active *S aureus* and MRSA surveillance was combined with mupirocin decolonization and CHG showers, the rate of total joint infection could be driven even lower (0.18, $P < .009$). Despite this, active surveillance is not always a common

practice. For example, Jarvis et al,⁴⁴ estimated that less than 30% of all orthopedic practices use active staphylococcal surveillance before elective total joint surgery; the numbers are even lower for cardiothoracic surgery, estimated at less than 25%. Although MRSA SSIs are more commonly associated with orthopedic and cardiothoracic surgical procedures,⁴⁴ a recent report suggested that *S aureus* and MRSA colonization was strongly predictive of postoperative infection in patients undergoing major gastrointestinal surgery as well.⁴⁵

Preoperative nasal screening and selective decolonization

treatment protocols for MRSA and MSSA carriers have been shown to achieve a significant reduction in the rate of SSIs. Most programs use rapid diagnostic polymerase chain reaction–based screening to facilitate identification of carriers and expedite the decolonization protocol before surgery.^{38-41,46-49}

Currently, the application of nasal mupirocin ointment is the most efficient method of eradicating *S aureus* colonization.³⁹ Although there is concern about the development of mupirocin resistance with indiscriminate use of the ointment, it is believed to be most effective when used with targeted patient populations, including patients undergoing dialysis or cardiac or orthopedic surgery who have been shown to be MRSA carriers.^{39-41,46-49}

The Institute for Healthcare Improvement has published the “How-to guide: prevent surgical site infection for hip and knee arthroplasty.”⁵⁰ In this guide, the Institute for Healthcare Improvement recommends three evidence-based interventions for preventing SSI after hip and knee arthroplasty. Caregivers should

- screen patients for *S aureus* and decolonize *S aureus* carriers with intranasal mupirocin for five days,

Implementation of a surgical care bundle that is evidence based and embraced by all stakeholders to achieve high compliance will improve the outcomes of surgical care.

- instruct patients to bathe or shower with CHG soap for at least three days before surgery, and
- use an alcohol-containing antiseptic agent for preoperative skin preparation.

Based in part on current understanding of the mechanistic etiology of SSIs, the following considerations are warranted for at-risk surgical populations:

- Caregivers should select an effective (ie, reduces risk, decreases costs) active surveillance strategy (ie, universal or targeted) that is based on the relative risk of MSSA or MRSA HAI in the surgical patient population.
- In the absence of universal or targeted surveillance, Anderson et al⁵¹ recommend routine administration of topical nasal mupirocin. They do not, however, recommend administration of systemic antimicrobial agents for eradication of MSSA or MRSA carriage in surgical patients.
- In the case of targeted surveillance, preoperative decolonization may be considered for patients colonized with MSSA or MRSA who are undergoing high-risk surgical procedures, such as
 - cardiothoracic procedures,
 - vascular procedures that include implantation of a prosthetic graft,
 - orthopedic total joint procedures, and
 - neurosurgical procedures with implantation of hardware.
- The optimal decolonization regimen is unclear, but a standardized regimen of mupirocin (ie, twice a day for five days) and cleansing of the body with 4% CHG (ie, once a day for two to five days) is reasonable.

ANTIMICROBIAL IRRIGATION

The saying “the solution to pollution is dilution” is a viewpoint common to the OR setting and has been the driving force behind the widespread application of intraoperative irrigation across the spectrum of surgical services. The combination of saline irrigation and debridement plays a major role in the

management of infection prevention in traumatic open fractures in orthopedic surgery. Intraoperative peritoneal irrigation (ie, lavage) also has been a long-standing tradition in general surgery, especially if fecal contents have spilled in the abdomen after penetrating trauma or intraoperative injury. Some surgeons use an “antibiotic cocktail” of mixed antimicrobial agents, such as bacitracin and polymyxin, or a single antibiotic, such as cefazolin or vancomycin. There is very little evidence, however, that antimicrobial surgical irrigation preparations prevent SSIs. In addition, there are no official recommendations from any association or organization regarding the practice and very few well-designed clinical trials studying the practice.⁵²⁻⁵⁴

According to Barnes et al,⁵⁵ intraoperative irrigation with the addition of antimicrobials is an important strategy for reducing postoperative infection. The addition of antibiotics to irrigation fluid, however, does not realistically afford sufficient contact time to efficiently kill or inhibit bacterial growth in the surgical wound. Furthermore, according to some case reports, local antimicrobial irrigation may be associated with severe intraoperative anaphylaxis, which has been seen with bacitracin irrigation during certain surgical procedures (ie, cardiac, orthopedic, general neurosurgical).⁵² Surgical irrigation could be an important risk reduction strategy when used just before wound closure if an effective antiseptic agent is used rather than an antibiotic. With copious irrigation before closure, exogenous contaminants would be flushed out and a residual layer of antiseptic, such as CHG, would remain to kill any persistent microorganisms. This practice could potentially lead to a reduction in SSIs, both in superficial and deep tissue layers.^{52,55}

Three studies have suggested a benefit of using antiseptic solutions to irrigate surgical tissues.⁵⁶⁻⁵⁸ Povidone-iodine is an antiseptic commonly used because it is active against a broad spectrum of microorganisms that cause SSIs. The problem is it can adversely affect wound healing if a high concentration (5%) is used because it is inhibitory to

human fibroblasts.^{56,57} However, one study showed a reduction in infections after spine surgery with use of 0.35% povidone-iodine that was allowed to soak for three minutes and then irrigated with 2 L of normal saline before bone grafting and spinal instrumentation.⁵⁸ This practice would add additional procedure time and offset process improvement efforts to shorten surgical throughput times.

In 2009, the US Food and Drug Administration approved an irrigation system for wound debridement and cleaning using 0.05% CHG. Brief exposure (ie, one minute) to 0.05% CHG has been found to be nontoxic to granulation tissue and wound healing.⁵⁹ Two reports have suggested that intraoperative irrigation with 0.05% CHG is a safe and efficacious strategy for reducing contamination in the surgical wound before closure.^{57,59} A recent in vitro study assessed the efficacy of 0.05% CHG on certain surgical isolates.⁵² Exposure to a concentration of 0.05% CHG effectively produced a 5- to 6-log₁₀ (ie, 100,000 to one million fewer microbes) reduction, significantly reducing the microbial burden at one and five minutes to MRSA, *S aureus*, and *Staphylococcus epidermidis*. Unlike antimicrobial lavage, irrigating an implantable device with 0.05% CHG will exert an inhibitory or bactericidal effect within 20 to 30 seconds of application, even on a surface where biofilm is present.⁵² Barnes et al⁵⁵ suggested that if 0.05% CHG used for wound irrigation is to be an effective risk reduction strategy, a rigorous standardization process should be implemented as part of evidence-based practice. At the time this report was written, a multicenter, randomized, prospective clinical trial was being conducted that involved nine independent study sites to determine the efficacy of 0.05% CHG as an intraoperative irrigation strategy in elective and emergent abdominal Laparotomies.

One of the major concerns in surgery is the exposure of implant devices, mesh, grafts, allografts,

and other implanted materials to potential environmental contaminants. When implanting a device that becomes contaminated during insertion, the contaminating flora will down-regulate its metabolism, multiplying slowly on the surface of the device until reaching a critical density, at which time it will become evident that an infectious process is occurring (eg, fever, swelling, pain).⁶⁰

Irrigating the surgical wound and surface of an implantable device with 0.05% CHG before wound closure would be an effective and safe risk reduction strategy and a logical alternative to the questionable practice of antibiotic lavage.⁵²

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PERIOPERATIVE HAIR REMOVAL

Historically, preparation for surgery has involved routine removal of body hair at or around the surgical site. The traditional rationale for hair removal has been that the presence of hair may adversely affect or interfere with exposure of the surgical wound, suturing of the surgical incision, application of postoperative dressings, or performance of skin antisepsis at the incisional site.

Perioperative hair removal by clipping rather than shaving is one of the sentinel core measures of the Surgical Care Improvement Project.⁶¹ AORN recommended practices⁶²—which are supported by the Society for Healthcare Epidemiology of America⁵¹ and the National Institute for Health and Care Excellence⁶³—include the practice of leaving hair at the surgical site unless the hair will interfere with the procedure. When the clinician determines that hair removal is required for an operative or other invasive procedure, AORN recommends the following process:

- “The patient’s hair should be removed in a location outside the operating or procedure room.”^{62(pe6)}
- “When necessary, hair at the surgical site should be removed by clipping or depilatory

methods in a manner that minimizes injury to the skin.”^{62(pe6)}

- “Single-use clipper heads should be used and disposed of after each patient use.”^{62(pe6)}

Both the CDC recommendations²⁷ and AORN recommended practices⁶² state that hair removal should be performed outside the OR. Although there has never been an evidence-based analysis of whether clipping in the OR represents a specific risk factor for SSI, this practice often represents a focus of intense discussion among members of the surgical team. This process is time consuming and often requires a lengthy cleanup that delays the start of the procedure.

An innovative solution to the issue of how much time hair clipping and cleanup can take was recently developed by two Wisconsin OR personnel (ie, RN circulator, scrub technician). The technology involves a portable, battery-operated, vacuum-assisted hair collection unit that attaches to the clipping edge of a traditional battery-operated surgical clipper. The clipped hair is captured in a disposable filter, preventing the adjacent dispersal of contaminated hair particles. In a preliminary analysis involving three study subjects, the vacuum-assisted hair clipper collection system was effective in capturing all clipped hair from both inguinal and leg test sites. A visual inspection of all skin test surfaces adjacent to the clipping site revealed no residual hair particles after removal with the surgical clippers fitted with the vacuum-assisted collection device. Preliminary unpublished studies with this battery-operated, vacuum-assisted clipper and hair collection device showed rapid removal of hair from all body test sites without creating an aerosol plume, eliminating postclipping cleanup of both the patient’s skin and adjacent surfaces. Further consideration is warranted in evaluating the potential benefits of this innovative technology in the perioperative environment.

PERIOPERATIVE IMPLICATIONS

The patient perioperative experience involves preoperative, intraoperative, and postoperative

measures to prevent SSIs. In the preoperative phase, important measures for nurses to implement include addressing patient risk factors. In particular, it is important that nurses perform preoperative screening for MRSA and *S aureus* in patients undergoing high-risk procedure, especially those involving implantable devices, and encourage preoperative body cleansing with CHG. During the intraoperative phase, nurses are instrumental in ensuring that thorough operative-site skin antisepsis is performed to reduce the microbial burden on skin. Nurses also are influential in ensuring that good surgical aseptic technique is followed throughout the procedure. Other innovative technologies that perioperative nurses should consider include antiseptic surgical irrigation and antimicrobial sutures. Postoperatively, nurses should ensure appropriate care of the incision to prevent exogenous contamination and, importantly, educate patients on how to prevent SSI in the home environment.

CONCLUSION

In 2014, SSIs are responsible for significant patient morbidity and excess use of institutional resources. Future efforts to reduce the risk of SSI and improve patient outcomes will require the focused commitment of all health care professionals, including surgeons, OR personnel, and infection preventionists. Although the Surgical Care Improvement Project is not the panacea for reducing all risk, it is an important component of an evidence-based multidisciplinary process that continues to evolve. [AORN](#)

References

1. National Healthcare Safety Network (NHSN). <http://www.cdc.gov/nhsn>. Accessed September 17, 2014.
2. Healthcare-associated Infections (HAI) Progress Report. Centers for Disease Control and Prevention. <http://www.cdc.gov/hai/progress-report>. Accessed September 16, 2014.
3. National and State Healthcare-Associated Infections Standardized Infection Ratio Report: Using Data Reported to the National Healthcare Safety Network. http://www.cdc.gov/HAI/pdfs/SIR/national-SIR-Report_03_29_2012.pdf. Accessed September 17, 2014.

4. HAI prevention. Healthcare-associated infections (HAI). Wisconsin Department of Health Services. <http://www.dhs.wisconsin.gov/communicable/HAI/Index.htm>. Published August 21, 2014. Accessed October 6, 2014.
5. Centers for Medicare & Medicaid Services (CMS), HHS. Medicare program; hospital inpatient prospective payment systems for acute care hospitals and the long-term care hospital prospective payment system and fiscal year 2015 rates; quality reporting requirements for specific providers; reasonable compensation equivalents for physician services in excluded hospitals and certain teaching hospitals; provider administrative appeals and judicial review; enforcement provisions for organ transplant centers; and electronic health record (EHR) incentive program. Final rule. *Fed Regist*. 2014;79(163):49853-50536.
6. Rasouli MR, Jaber MM, Hozack WJ, Parvizi J, Rothman RH. Surgical Care Improvement Project (SCIP): has its mission succeeded? *J Arthroplasty*. 2013;28(7):1072-1075.
7. Young H, Knepper B, Vigil C, Miller A, Carey JC, Price CS. Sustained reduction in surgical site infection after abdominal hysterectomy. *Surg Infect*. 2013;14(5):460-463.
8. Waits SA, Fritze D, Banerjee M, et al. Developing an argument for bundle interventions to reduce surgical site infection in colorectal surgery. *Surgery*. 2014;155(4):602-606.
9. Belkin NL. Use of scrubs and related apparel in health care facilities. *Am J Infect Control*. 1997;25(5):401-404.
10. Callaghan I. Bacterial contamination of nurses' uniforms: a study. *Nurs Stand*. 1998;13(1):37-42.
11. Neely AN, Maley MP. Survival of enterococci and staphylococci on hospital fabrics and plastic. *J Clin Microbiol*. 2002;38(2):724-726.
12. Friberg B, Friberg S, Ostensson R, Burman LG. Surgical area contamination—comparable bacterial counts using disposable head and mask and helmet aspirator system, but dramatic increase upon omission of head-gear: an experimental study in horizontal laminar air-flow. *J Hosp Infect*. 2001;47(2):110-115.
13. Recommended practices for surgical attire. In: *Perioperative Standards and Recommended Practices*. Denver, CO: AORN, Inc; 2011:57-72.
14. Braswell M, Spruce L. Implementing AORN recommended practices for surgical attire. *AORN J*. 2012;95(1):122-137.
15. Dineen P, Drusin L. Epidemics of postoperative wound infections associated with hair carriers. *Lancet*. 1973;2(7839):1157-1159.
16. Mastro TD, Farley TA, Elliott JA, et al. An outbreak of surgical-wound infections due to group A streptococcus carried on the scalp. *N Engl J Med*. 1990;323(14):968-972.
17. Boyce JM. Evidence in support of covering the hair of or personnel [Guest Editorial]. *AORN J*. 2014;99(1):4-8.
18. Loftus RW, Muffly MK, Brown JR, et al. Hand contamination of anesthesia providers is an important risk factor for intraoperative bacterial transmission. *Anesth Analg*. 2011;112(1):98-105.
19. Loftus RW, Koff MD, Burchman CC, et al. Transmission of pathogenic bacterial organisms in the anesthesia work area. *Anesthesiology*. 2008;109(3):399-407.
20. Munoz-Price LS, Arheart KL, Mills JP, et al. Associations between bacterial contamination of health care workers' hands and contamination of white coats and scrubs. *Am J Infect Control*. 2012;40(9):e245-e248.
21. Recommended practices for hand hygiene in the perioperative setting. In: *Perioperative Standards and Recommended Practices*. Denver, CO: AORN, Inc; 2011:73-86.
22. Belda FJ, Aguilera L, García de la Asunción J, et al. Supplemental perioperative oxygen and the risk of surgical wound infection: a randomized controlled trial. *JAMA*. 2005;294(16):2035-2042.
23. Wang ZX, Jiang CP, Cao Y, et al. Systematic review and meta-analysis of triclosan-coated sutures for the prevention of surgical-site infection. *Br J Surg*. 2013;100(4):465-473.
24. Edmiston CE, Daoud FC, Leaper D. Is there an evidence-based argument for embracing an antimicrobial (triclosan)-coated suture technology to reduce the risk of surgical site infections?: a meta-analysis. *Surgery*. 2013;154(1):89-100.
25. Daoud F, Edmiston CE, Leaper D. Meta-analysis of prevention of surgical site infections following incision closure with triclosan-coated sutures: robustness of new evidence. *Surg Infect*. 2014;15(3):165-181.
26. Singh A, Bartysch SM, Muder RR, Lee BY. An economic model: value of antimicrobial-coated sutures to society, hospitals, and third-party payers in preventing abdominal surgical site infections. *Infect Control Hosp Epidemiol*. 2014;35(8):1013-1020.
27. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol*. 1999;20(4):250-278.
28. Webster J, Osborne S. Preoperative bathing or showering with skin antiseptics to prevent surgical site infection. *Cochrane Database Syst Rev*. 2012;9:CD004985.
29. Edmiston CE, Krepel CJ, Seabrook GT, et al. Preoperative shower revisited: can high topical antiseptic levels be achieved on the skin surface before surgical admission? *J Am Coll Surg*. 2008;207(2):233-239.
30. Edmiston CE, Okoli O, Graham MB, Sinski S, Seabrook GR. Evidence for using chlorhexidine gluconate preoperative cleansing to reduce the risk of surgical site infection. *AORN J*. 2010;92(5):509-518.
31. Edmiston CE, Krepel CJ, Edmiston SE, et al. Empowering the surgical patient: a randomized, prospective analysis of an innovative strategy for improving patient compliance with preadmission showering protocol. *J Am Coll Surg*. 2014;219(2):256-264.
32. Edmiston CE, Krepel C, Kelly H, et al. Perioperative antibiotic prophylaxis in the gastric bypass patient: do we achieve therapeutic levels? *Surgery*. 2004;136(4):738-747.
33. Pevzner L, Swank M, Krepel C, Wing DA, Chan K, Edmiston CE. Effects of maternal obesity on tissue concentrations of prophylactic cefazolin during cesarean delivery. *Obstet Gynecol*. 2011;117(4):877-882.

34. Waisbren E, Rosen H, Bader AM, et al. Percent body fat and prediction of surgical site infection. *J Am Coll Surg*. 2010;210(4):381-389.
35. Borracci T, Adembri C, Accetta G, et al. Use of the parenteral antibiotic ertapenem as short term prophylaxis in bariatric surgery: a pharmacokinetic-pharmacodynamic study in class III obese female patients. *Minerva Anestesiol*. 2014;80(9):1005-1011.
36. Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. *Am J Health-Syst Pharm*. 2013;70(3):195-283.
37. Kluytmans J, van Belkum A, Verbrugh H. Nasal carriage of *Staphylococcus aureus*: epidemiology, underlying mechanisms, and associated risks. *Clin Microbiol Rev*. 1997;10(3):505-520.
38. Kim DH, Spencer M, Davidson SM, et al. Institutional prescreening for detection and eradication of methicillin-resistant *Staphylococcus aureus* in patients undergoing elective orthopaedic surgery. *J Bone Joint Surg Am*. 2010;92(9):1820-1826.
39. Perl TM, Cullen JJ, Wenzel RP, et al. Intranasal mupirocin to prevent postoperative *Staphylococcus aureus* infections. *N Engl J Med*. 2002;346(24):1871-1877.
40. Kalmeijer MD, van Nieuwland-Bollen E, Bogaers-Hofman D, de Baere GA. Nasal carriage of *Staphylococcus aureus* is a major risk factor for surgical-site infections in orthopedic surgery. *Infect Control Hosp Epidemiol*. 2000;21(5):319-323.
41. Muñoz P, Hortal J, Giannella M, et al. Nasal carriage of *S aureus* increases the risk of surgical site infection after major heart surgery. *J Hosp Infect*. 2008;68(1):25-31.
42. Levy PY, Ollivier M, Drancourt M, Raoult D, Argenson JN. Relation between nasal carriage of *Staphylococcus aureus* and surgical site infection in orthopedic surgery: the role of nasal contamination. A systematic literature review and meta-analysis. *Orthop Traumatol Surg Res*. 2013;99(6):645-651.
43. Chen AF, Heyl AE, Xu PZ, Rao N, Klatt BA. Preoperative decolonization effective at reducing staphylococcal colonization in total joint arthroplasty patients. *J Arthroplasty*. 2013;28(8 Suppl):S18-S20.
44. Jarvis WR, Jarvis AA, Chinn RY. National prevalence of methicillin-resistant *Staphylococcus aureus* in inpatients at United States health care facilities, 2010. *Am J Infect Control*. 2012;40(3):194-200.
45. Ramirez MC, Marchessault M, Govednik-Horny C, Jupiter D, Papaconstantinou HT. The impact of MRSA colonization on surgical site infection following major gastrointestinal surgery. *J Gastrointest Surg*. 2013;17(1):144-152.
46. Kluytmans JA, Mouton JW, VandenBergh 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(12):780-785.
47. VandenBergh MF, Kluytmans JA, van Hout BA, et al. Cost-effectiveness of perioperative mupirocin nasal ointment in cardiothoracic surgery. *Infect Control Hosp Epidemiol*. 1996;17(12):786-792.
48. 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(4):412-414.
49. Kalmeijer MD, Coertjens H, van Nieuwland-Bollen PM, et al. Surgical site infections in orthopedic surgery: the effect of mupirocin nasal ointment in a double-blind, randomized, placebo-controlled study. *Clin Infect Dis*. 2002;35(4):353-358.
50. How-to guide: prevent surgical site infection for hip and knee arthroplasty. Institute for Healthcare Improvement. <http://www.ihl.org/resources/Pages/Tools/HowtoGuidePreventSSIforHipKneeArthroplasty.aspx>. Accessed September 19, 2014.
51. Anderson DJ, Kaye KS, Classen D, et al. Strategies to prevent surgical site infections in acute care hospitals. *Infect Control Hosp Epidemiol*. 2008;29(Suppl 1):51-61.
52. Edmiston CE, Bruden B, Rucinski MC, Henen C, Graham MB, Lewis BL. Reducing the risk of surgical site infections: does chlorhexidine gluconate provide a risk reduction benefit? *Am J Infect Control*. 2013;41(Suppl):549-555.
53. Crowley DJ, Kanakaris NK, Giammoudis PV. Irrigation of the wounds in open fractures. *J Bone Joint Surg*. 2007;89B:580-585.
54. Koyonos L, Zmistowski B, Della Valle CJ, Parvizi J. Infection control rate of irrigation and debridement for periprosthetic joint infection. *Clin Orthop Relat Res*. 2011;469(11):3043-3048.
55. Barnes S, Spencer M, Graham D, Johnson HB. Surgical wound irrigation: a call for evidence-based standardization of practice. *Am J Infect Control*. 2014;42(5):525-529.
56. Vilijanto J. Disinfection of surgical wounds without inhibition of normal wound healing. *Arch Surg*. 1980;115(3):253-256.
57. Lineaweaver W, McMorris S, Soucy D, Howard R. Cellular and bacterial toxicity of topical antimicrobials. *Plast Reconstr Surg*. 1985;75(3):394-396.
58. Cheng MT, Chang MC, Wang ST, Yu WK, Liu CL, Chen TH. Efficacy of dilute betadine solution irrigation in the prevention of postoperative infection of spinal surgery. *Spine*. 2005;30(15):1689-1693.
59. Best AJ, Nixon MF, Taylor GJ. Brief exposure of 0.05% chlorhexidine does not impair non-osteoarthritic human cartilage metabolism. *J Hosp Infect*. 2007;67(1):67-71.
60. Hasanadka R, Seabrook GR, Edmiston CE. Vascular graft infections. In: Rello J, Vanes J, Kollef M, eds. *Critical Care Infectious Diseases*. 2nd ed. Boston, MA: Kluwer Academic Publishers; 2007:531-542.
61. Surgical Care Improvement Project. Surgery patients with appropriate hair removal. The Joint Commission. http://www.jointcommission.org/assets/1/6/HIQR_SpecsManual_v4_2b_PDF4.zip. Accessed September 19, 2014.
62. Recommended practices for preoperative patient skin antisepsis. In: *Perioperative Standards and Recommended Practices*. Denver, CO: AORN, Inc; 2014:e57-e80.
63. Surgical site infection. National Institute for Health and Care Excellence. <https://www.nice.org.uk/Guidance/QS49>. Accessed July 14, 2014.

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