American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update

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Guidelines for the prevention, detection, and management of surgical site infections (SSI) have been published previously.[1-3] This document is intended to update earlier guidelines based on the current literature and to provide a concise summary of relevant topics.

Surgical site infections are both common and morbid. Surgical site infections are now the most common and costly of all hospital-acquired infections, accounting for 20% of all hospital-acquired infections. Surgical site infections are associated with increased length of stay and a 2- to 11-fold increase in the risk of mortality. Although most patients recover from an SSI without long-term adverse sequelae, 77% of mortality in patients with an SSI can be attributed to the infection itself.[1,4]

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The incidence of SSI is 2% to 5% in patients undergoing inpatient surgery.[1] Estimated annual incidence varies widely, ranging from 160,000 to 300,000 in the US.[1,4] These estimates are likely understated, given the surveillance challenges after discharge.

The financial burden of SSI is considerable; it ranks as the most costly of the hospital-acquired infections.[1] The annual cost of SSI in the US is estimated at $3.5 to $10 billion.[1] Increased costs from SSIs are driven by increased length of stay, emergency department visits, and readmissions. On average, SSI extends hospital length of stay by 9.7 days, and increases the cost of hospitalization by more than $20,000 per admission. More than 90,000 readmissions annually are attributed to SSIs, costing an additional $700 million per year. Because up to 60% of SSIs were estimated to be preventable with the use of evidence-based measures,[1] SSI has become a pay-for-performance metric and a target of quality-improvement efforts.

The most widely used definition of SSI has been provided by CDC.[5] This definition is used for research, quality improvement, public reporting, and pay-for-performance comparisons. According to this definition, SSIs are classified by depth and tissue spaces involved. A superficial incisional SSI involves only the skin or subcutaneous tissue, a deep incisional SSI involves the fascia or muscular layers, and an organ space SSI involves any part of the body opened or manipulated during a procedure, excluding the previously mentioned layers.

Numerous risk factors have been identified for the development of an SSI after surgery. These risk factors can be broadly separated into intrinsic (patient) factors that are modifiable or nonmodifiable, as well as extrinsic (eg procedure, facility, preoperative, and operative) factors (Table 1). Potentially modifiable patient risk factors include glycemic control and diabetic status, dyspnea, alcohol and smoking status, preoperative albumin <3.5 mg/dL, total bilirubin >1.0 mg/dL, obesity, and immunosuppression. Nonmodifiable patient factors include increasing age, recent radiotherapy, and history

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Abbreviations and Acronyms

ACS = American College of Surgeons
DPC = delayed primary closure
OR = operating room
SCIP = Surgical Care Improvement Project
SSI = surgical site infection

of skin or soft tissue infection.[1,6] Procedure-related factors include emergency and more complex surgery and wound classification.[6] Facility risk factors include inadequate ventilation, increased operating room (OR) traffic, and appropriate sterilization of equipment.[1] Preoperative risk factors include presence of a pre-existing infection; inadequate skin preparation; hair removal; and antibiotic choice, administration, and duration.[1] Intraoperative risk factors include duration of surgery, blood transfusion, maintenance of asepsis, poor-quality surgical hand scrubbing and gloving, hypothermia, and poor glycemic control.[1,6,7]

The human and financial consequences of SSI are substantial. Surgical site infection is a complex problem influenced by numerous factors, only some of which are under the surgeon's control. Strategies to decrease SSI are multimodal and occur across a range of settings under the supervision of numerous providers. Ensuring high compliance with these risk-reduction strategies is crucial to the success of SSI reduction efforts.

Table 1. Surgical Site Infection Risk Factors

Risk Factor
Intrinsic (patient-related)
Non-modifiable
Increased age
Recent radiotherapy
History of skin or soft tissue infection
Modifiable
Diabetes
Obesity
Alcoholism
Current smoker
Preoperative albumin <3.5 mg/dL
Total bilirubin >1.0 mg/dL
Immunosuppression
Extrinsic (procedure-related)
Procedure
Emergency
Increasing complexity
Higher wound classification
Facility
Inadequate ventilation
Increased operating room traffic
Contaminated environmental surfaces
Non-sterile equipment
Preoperative
Pre-existing infection
Inadequate skin preparation
Inappropriate antibiotic choice, timing, and weight-based dosing
Hair removal method
Poor glycemic control
Intraoperative
Longer procedure duration
Blood transfusion
Breach in asepsis
Inappropriate antibiotic re-dosing
Inadequate gloving
Inappropriate surgical scrub
Poor glycemic control

METHODS

Earlier guidelines represent the cornerstone of this SSI guideline update. Within the framework of existing guidelines, specific topics were researched in PubMed, with a focus on more recent literature. Specifically, literature was sought out addressing knowledge gaps in previously published guidelines. This literature was summarized by one author and sent to an internal expert panel, as well as external context experts for review. Additional studies were added according to feedback from these experts. Guidelines were drafted according to the evidence provided by this literature. These were again reviewed by both an internal expert panel and by outside content experts to reach consensus agreement on the final guidelines presented here.

RESULTS

Tables 2–4 summarize all consensus statements and guidelines. Table 2 covers the prehospital setting, Table 3 covers the hospital setting, and Table 4 covers the post-discharge setting. Here, we provide a summary of the literature informing these guidelines.

Prehospital interventions

Preoperative patient optimization topics include bathing and showering techniques, smoking cessation, whether long-term glucose control affects SSI risk, MRSA screening and decolonization, and bowel preparation for elective colorectal surgery.

Preoperative bathing and showering

Chlorhexidine reduces the bacterial colonization of the skin,[8] however, a recent Cochrane database systematic

Table 2. Prehospital Interventions

Guideline	Intervention
1.1. Preoperative bathing	Routine preoperative bathing with chlorhexidine (when not part of a decolonization protocol or preoperative bundle) decreases skin surface pathogen concentrations, but has not been shown to reduce SSI.
1.2. Smoking cessation	Smoking cessation 4 to 6 weeks before surgery reduces SSI and is recommended for all current smokers, especially those undergoing procedures with implanted materials. There is no literature to support cessation of marijuana and electronic cigarette use to prevent SSI, but cessation is recommended before surgery based on expert consensus. American College of Surgeons patient education materials support the use of nicotine lozenges, nicotine gum, and medication to aid in smoking cessation.
1.3. Glucose control	Optimal blood glucose control should be encouraged for all diabetic patients; however, there is no evidence that improved Hgb A1C decreases SSI risk.
1.4. MRSA screening	Decision about whether or not to implement global *Staphylococcus aureus* screening and decolonization protocols should depend on baseline SSI and MRSA rates. Clinical practice guidelines from the American Society of Health-System Pharmacists recommend screening and nasal mupirocin decolonization for *S aureus*-colonized patients before total joint replacement and cardiac procedures. MRSA bundles (screening, decolonization, contact precautions, hand hygiene) are highly effective if adhered to, otherwise there is no benefit. No standard decolonization protocol supported by literature; consider nasal mupirocin alone vs nasal mupirocin plus chlorhexidine gluconate bathing. Decolonization protocols should be completed close to date of surgery to be effective. Vancomycin should not be administered as prophylaxis to MRSA-negative patients.
1.5. Bowel preparations	Combination mechanical and antibiotic (po) preparation is recommended for all elective colectomies.

SSI, surgical site infection.

meta-analysis review of chlorhexidine vs placebo studies failed to demonstrate a corresponding decrease in SSIs with chlorhexidine bathing (Guideline 1.1).[9] Studies in this review included a highly variable surgical patient population, and no single standardized bathing process was used across all studies.[10] Some research has shown that chlorhexidine needs to dry on the skin for maximal effect, which is a limiting factor in bathing.[11] In a recent study by Edmiston and colleagues,[10] a protocol of 2 to 3 sequential showers with 4% chlorhexidine gluconate with a 1-minute pause before rinsing resulted in maximal skin surface concentrations. Research is underway investigating the use of chlorhexidine-impregnated cloths to produce a more sustainable decrease in skin bacterial colonization to complement chlorhexidine bathing, but no high-quality studies have demonstrated a decreased SSI risk with these interventions.[11] It is important to differentiate the use of preoperative bathing practices as part of a formal decolonization protocol for MRSA or as part of a larger bundle, which have shown benefit in reducing SSI.[12-16]

Smoking cessation

Smoking has long been associated with an increased risk for SSI.[17-21] The etiology of this phenomenon is complex, but is partially related to vasoconstriction of vessels in the surgical bed that leads to tissue hypovolemia and hypoxia. In addition, poor tissue perfusion impedes transport of nutrients and alters the immune response. The magnitude of this impact as reported by Durand and colleagues[17] is particularly important in operations with implantation of mechanical devices and prosthetics. Regardless of the type of surgery, current smokers are at the highest risk for SSI, and former smokers are at higher risk than an individual who has never smoked.[18,19] As such, surgeons should counsel patients to completely refrain from smoking for a minimum of 4 to 6 weeks before elective surgery (Guideline 1.2). Smoking cessation in this time period

Table 3. Hospital Interventions

Guideline	Intervention
2.1. Glucose control	Hyperglycemia in the immediate preoperative period is associated with an increased risk of SSI. Target perioperative blood glucose should be between 110 to 150 mg/dL in all patients, regardless of diabetic status, except in cardiac surgery patients where the target perioperative blood glucose is $<$180 mg/dL. Target blood glucose rates $<$110 mg/dL have been tied to adverse outcomes and increased episodes of hypoglycemia and do not decrease SSI risk.
2.2. Hair removal	Hair removal should be avoided unless hair interferes with surgery. If hair removal is necessary, clippers should be used instead of a razor.
2.3. Skin preparation	Alcohol-containing preparation should be used unless contraindication exists (eg fire hazard, surfaces involving mucosa, cornea, or ear). No clear superior agent (chlorhexidine vs iodine) when combined with alcohol. If alcohol cannot be included in the preparation, chlorhexidine should be used instead of iodine unless contraindications exist.
2.4. Surgical hand scrub	Use of a waterless chlorhexidine scrub is as effective as traditional water scrub and requires less time, but there is no superior agent if used according to manufacturer instructions.
2.5. Surgical attire	There is limited evidence to support recommendations on surgical attire. Joint Commission and Association of Perioperative Registered Nurses policies support facility scrub laundering and the use of disposable bouffant hats. American College of Surgeons guidelines support the use of a skull cap if minimal hair is exposed, removing or covering all jewelry on the head and neck, and professional attire when outside the operating room (no scrubs or clean scrubs covered with a white coat).
2.6. Antibiotic prophylaxis	Administer prophylactic antibiotics only when indicated. Choice of prophylactic antibiotic should be dictated by the procedure and pathogens most likely to cause SSI. Prophylactic antibiotic should be administered within 1 hour before incision or within 2 hours for vancomycin or fluoroquinolones. Prophylactic antibiotic dosing should be weight-adjusted. Re-dose antibiotics to maintain adequate tissue levels based on agent half-life or for every 1,500 mL blood loss There is no evidence that prophylactic antibiotic administration after incision closure decreases SSI risk; prophylactic antibiotics should be discontinued at time of incision closure (exceptions include implant-based breast reconstruction, joint arthroplasty, and cardiac procedures where optimal duration of antibiotic therapy remains unknown).
2.7. Intraoperative normothermia	Maintain intraoperative normothermia to reduce SSI risk. Preoperative warming is recommended for all cases, and intraoperative warming methods should be employed for all but short, clean cases.
2.8. Wound protectors	Use of an impervious plastic wound protector can prevent SSI in open abdominal surgery. Evidence is strongest for elective colorectal and biliary tract procedures.
2.9. Antibiotic sutures	Triclosan antibacterial suture use is recommended for wound closure in clean and clean-contaminated abdominal cases when available.
2.10. Gloves	The use of double gloves is recommended. Changing gloves before closure in colorectal cases is recommended, however, rescrubbing before closure in colorectal cases is not recommended.
2.11. Instruments	The use of new instruments for closure in colorectal cases is recommended.
2.12. Wound closure	No high-quality evidence about delayed primary closure vs primary closure and SSI for contaminated and dirty incisions. Purse-string closure of stoma sites recommended over primary closure.

(Continued)

Table 3. Continued

Guideline	Intervention
2.13. Topical antibiotics	Topical antibiotics can reduce SSI for specific cases, including spine surgery, total joint arthroplasty, and cataract surgery, but there is insufficient evidence to recommend routine use at this time.
2.14. Supplemental oxygen	The administration of supplemental oxygen (80%) is recommended in the immediate postoperative period after surgery performed under general anesthesia.
2.15. Wound care	There is no evidence in the literature that timing of dressing removal increases SSI risk. Early showering (12 hours postoperative) does not increase the risk of SSI. Use of wound vacuum therapy over stapled skin can reduce SSI in open colorectal (abdominal incision) and vascular (groin incision) cases. Mupirocin topic antibiotic application can decrease SSI compared with a standard dressing. Daily wound probing can decrease SSI in contaminated wounds.

SSI, surgical site infection.

decreases SSIs and a host of other surgical complications.[20] At this time, there is nothing in the literature about marijuana and SSI risk, but in the absence of data, marijuana cessation should be counseled before surgery in the same time frame. Similarly, the health effects of electronic cigarettes (e-cigarettes) remain undefined.[22] The most recent American College of Surgeons (ACS) Patient Education Committee Literature does not support e-cigarette use before surgery, and the American Heart Association does not recommend e-cigarettes be used as a smoking cessation aide.[22-24] The cessation of e-cigarette use should be counseled before surgery. Currently, there is no literature exploring the link between SSIs and use of alternative nicotine-containing substances (eg gum, patch, and lozenges). At this time, organizations including the ACS do support their use as smoking cessation aides before surgery.

Glucose control

Data linking long-term blood glucose control and SSI risk have been conflicting. The study by Dronge and colleagues[25] reported that an elevated Hgb A1c (marker of long-term glucose control) is associated with increased risk of postoperative infectious complications. However, all subsequent studies where multivariate analysis included both Hgb A1c and perioperative glucose levels failed to demonstrate a correlation with Hgb A1c and SSI.[26,27] These studies found that diabetes, use of diabetic medications, and perioperative hyperglycemia were risk factors for SSIs. In large databases, when multivariate analysis is performed using both Hgb A1c and perioperative glucose, glucose is significant and Hgb A1C is not.[28] Naturally, glucose control in patients with high Hgb A1C will be more difficult, and they are likely to have higher glucose values. Of note, perioperative hyperglycemia increases the risk of SSI in both diabetics and nondiabetics.[29-32] Based on this literature, short-term glucose control can be more impactful in decreasing SSIs than long-term control of Hbg A1c (Guideline 1.3).

Table 4. Post-Discharge Interventions

Guideline	Intervention
3.1	Wound care No formal wound care protocol has been described that decreases the risk of surgical site infection.
3.2	Surgical site infection surveillance No reliable post-discharge surgical site infection surveillance method has been identified.

MRSA

The prevalence of MRSA has increased dramatically in recent decades. Current literature shows that almost 7% of patients screen positive for MRSA.[33] Although the incidence of MRSA infection after a major surgical procedure is estimated at only 1% overall, MRSA colonization is associated with worse outcomes and a higher risk for both MRSA SSI and SSI overall.[33-35] Given the increased risk of MRSA SSI in patients who screen positive for MRSA, substantial literature has explored both the use of MRSA decolonization protocols preoperatively and use of vancomycin intraoperatively for antibiotic prophylaxis. The use of MRSA bundles, including screening, decolonization, contact precautions in the hospital, and vancomycin-containing antibiotic prophylaxis, are associated with decreased rates of SSI if compliance is high with all parts of the protocol (Guideline 1.4).[13-16] Indeed, one large cohort study showed considerable benefit in decolonization of both methicillin-sensitive *Staphylococcus aureus* and MRSA when all parts of the protocol were followed, but tailored the IV prophylaxis based on the presence or absence of MRSA.[15] There is evidence that decolonization protocols must take place close to the time of surgery to be effective.[36] Typical preoperative decolonization protocols include the use of 2% nasal mupirocin Bid for 5 days and bathing with chlorhexidine gluconate at days 1, 3, and 5 preoperatively, although no one protocol is standard and supported by the literature.[13,37] The use of nasal mupirocin alone reduces *S aureus* SSI risk,[38] but MRSA can develop resistance with widespread (nontargeted) use.[39] Hospitals should evaluate their SSI and MRSA rates to determine whether implementation of a screening program is appropriate. The American Society of Health-System Pharmacists recommends screening and nasal mupirocin decolonization for *S aureus* for all patients before total joint replacement and cardiac procedures. For antibiotic prophylaxis, use of vancomycin alone in MRSA-negative patients was associated with a higher risk of methicillin-sensitive *S aureus* SSI.[40] In patients who screen negative for MRSA, risk factors for conversion to MRSA-positive status and development of SSI include advanced age, overall SSI risk, and treatment with vancomycin antibiotic prophylaxis during surgery.[41] For these reasons, routine administration of vancomycin antibiotic prophylaxis in MRSA-negative patients is not recommended.

Bowel preparations

The use of preoperative bowel preparation for elective colorectal surgery has been studied extensively. Common practices have evolved over time and, in recent years, the literature has come full circle to support the combination of mechanical and oral antibiotic preparation, similar to that originally proposed by Nichols and Condon, as described by Fry.[42] Mechanical bowel preparation alone does not decrease SSIs.[43,44] Similarly, oral antibiotics or IV antibiotics alone provide suboptimal benefit.[44-46] Multiple studies demonstrate a benefit to using a combination of mechanical and po antibiotic bowel preparations, including lower rates of SSI, anastomotic leak, *Clostridium difficile* infection, and postoperative ileus.[44-50] Use of a combined preparation also reduces length of stay and is associated with lower readmission rates.[50] It is recommended that antibiotics be delivered both orally, as part of a preoperative bowel preparation the day before surgery, and intravenously, in the immediate preoperative period, in accordance with prophylaxis guidelines to minimize SSI risk (Guideline 1.5).[49]

Bundling prehospital and hospital interventions

Bundling preoperative planning and hospital intervention processes has been shown to decrease SSIs in some studies, but results with bundles are mixed and depend on high patient and provider compliance rates. Cima and colleagues[12] successfully reduced SSI rates from 4.9% to 1.6% after implementation of a colorectal bundle. Multiple other single-institution studies have showed similarly promising results.[51,52] In contrast, a recent randomized trial showed an increase in SSI rates after initiation of a bundle for colorectal surgery, although of note, this bundle omitted a mechanical bowel preparation.[53] Successful implementation of a bundle requires buy-in from relevant stakeholders (eg patients, surgeons, and anesthesia) and verification of compliance.[51]

Hospital interventions

Hospital interventions covered include perioperative blood glucose control, hair-removal technique, skin preparation, surgical hand scrub, surgical attire, antibiotic prophylaxis, intraoperative normothermia, use of wound protectors, antibiotic-coated suture, glove and instrument use, wound closure techniques, topical antibiotics, supplemental oxygen delivery, and wound care practices in the hospital.

Glucose control

Management of perioperative hyperglycemia with insulin to obtain glycemic control is important to minimize the risks of SSIs (Guideline 2.1). Kwon and colleagues[30] showed a dose-response relationship between degree of glycemic control and SSI, with patients who maintained a serum glucose <130 mg/dL having the lowest SSI rate. This effect is not limited to a specific field of surgery or to diabetics alone. The study by Ata and colleagues[54] showed a correlation with blood glucose <140 mg/dL and lower SSIs in all general surgery patients, although not in vascular procedures. However, Kotagal and colleagues[31] did demonstrate this benefit in vascular and other surgery (ie abdominal and spine), although their patient cohort included nondiabetics, and the target glucose level was lower at <125 mg/dL. This study also showed a greater risk from hyperglycemia in nondiabetics than in diabetics. In another study, Vriesendorp and colleagues[55] showed a very significant risk for hyperglycemia in infrainguinal vascular operations. For cardiac surgery, the accepted glucose threshold is higher at <180 mg/dL.[56,57] Multiple prospective randomized trials of higher vs lower glucose target levels have shown a considerably lower SSI rate for the tighter controls, but with targets generally in the 100 to 150 mg/dL range.[57-63] There is evidence in the literature, however, that target rates <110 mg/dL are tied to adverse outcomes and increased episodes of hypoglycemia without decreasing SSI risk.[1] In summary, the consensus is that better short-term perioperative glucose control in the 110 to 150 mg/dL range is important for all patients to lower SSI risk.

Hair removal

Factors related to patient preparation in the operating room have been examined, including hair removal. According to CDC, hair in the surgical site should only be removed if it will interfere with surgery (Guideline 2.2). Shaving causes microscopic cuts and abrasions, resulting in disruption of the skin's barrier defense against microorganisms.[21] As such, razors are no longer recommended, except in the scrotal area or scalp after traumatic injury.[1,3] According to studies by Mangram and colleagues[3] and Anderson and colleagues,[1] clippers should be used instead of razors to remove hair.

Skin preparation

Although there is general agreement that a preparation solution of some kind is needed to scrub the surgical site, the active ingredient in the scrub solution is debated. Many randomized trials have compared chlorhexidine-based with iodine-based antiseptics for preoperative skin preparation, however, most have been underpowered to detect differences in SSI rates.[21,64] Overall, there is evidence that alcohol-based preparations are more effective in reducing SSI than aqueous preparations, and should be used unless contraindications exist (Guideline 2.3).[64,65] The rationale for alcohol-based solutions is rapid bactericidal effect, but this benefit is limited by its lack of persistent antimicrobial effect. The addition of iodine-based and chlorhexidine-based solutions prolongs bactericidal activity in alcohol-based preparations. Although many small randomized controlled trials have demonstrated superior decontamination of skin flora with chlorhexidine-isopropyl alcohol compared with iodine-containing solution plus alcohol (in clean cases), no study has convincingly demonstrated the superiority of alcohol-containing chlorhexidine to iodine and alcohol skin preparations with regard to SSIs.[64,66] When alcohol preparations are not available, chlorhexidine might be superior to iodine.[1]

Surgical hand scrub

Studies have shown that waterless chlorhexidine scrub is as effective as traditional water-based scrubs and requires less time.[67] A recent systematic review concluded that there is overall low quality of evidence to support any one intervention over another.[68] There is some evidence that alcohol scrubs reduce colony-forming units compared with aqueous scrubs, and that chlorhexidine gluconate scrubs reduce colony-forming units compared with povidone iodine scrubs, however, there is no evidence that lower colony-forming units after surgical hand scrub are associated with lower SSI risk.[68] The use of either a traditional scrub or a waterless chlorhexidine scrub is acceptable in accordance with each product's instructions (Guideline 2.4).

Surgical attire

The topic of surgical attire has been debated in recent years. Formerly acceptable practices, including home laundering of scrubs and use of cloth scrub hats, are no longer supported by Joint Commission and Association of Perioperative Registered Nurses policies. Unfortunately, there is a paucity of data to guide evidence-based practices in this realm. Many current guidelines reflect historical practices with intuitive infection-control benefits that are now firmly ingrained in surgical culture and patient-safety expectations. From a feasibility standpoint, it would be nearly impossible to test the effects of these practices on SSI. A task force convened by the ACS Board of Regents released new guidelines on surgical attire earlier this year.[69] These guidelines reflect the ACS commitment to professionalism and are guided by common sense and evidence, whenever available.

Current Association of Perioperative Registered Nurses guidelines call for wearing clean, facility-laundered scrubs that should be changed daily or when visibly soiled,[70,71] however, the 1999 CDC guidelines acknowledge that there are no well-controlled studies evaluating scrub laundering and SSI.[3] If anything, multiple studies have shown no increase in SSI with home laundering of scrubs.[72] The recommendations supported by the Association of Perioperative Registered Nurses and the Joint Commission are based on a single case study that reported transmission of *Gordonia bronchialis* and resultant SSI from a nurse anesthetist to 3 cardiac surgery patients.[73] This pathogen was cultured on the nurse and on her roommate. The presumed bacterial reservoir was their washing machine, although this was never confirmed via direct culture. The ACS guidelines recommend that clean and appropriate professional attire (not scrubs) be worn during all patient encounters outside the OR, and that OR scrubs should not be worn at any time outside the hospital perimeter.[69] Scrubs and hats worn during dirty or contaminated cases should be changed before subsequent cases, even if not visibly soiled and should be changed at least daily.[69] Visibly soiled scrubs from any procedure should be changed as soon as feasible and before speaking with family.[69] If scrubs are worn outside the OR within the hospital, they should be covered with a clean lab coat or appropriate cover-up.[69] These recommendations are meant to decrease the incidence of healthcare-associated infections, but also to uphold a tradition of excellence, professionalism, trust, and respect between physician and patient.

Additional policies supported by the ACS include the removal or appropriate covering of all earrings and jewelry worn on the head or neck.[69] The mouth, nose, and hair (skull and face) should be covered during all invasive procedures, and masks should not be worn dangling at any time.[69]

There are no data in the literature examining cloth vs disposable scrub hats, despite the controversy this topic has sparked, and there have been no comparisons of skullcaps vs bouffants and SSI. There are no direct data linking exposed hair or skin to increased SSI risk, but studies have shown that bacterial loads in laminar flow theaters can be traced to skin from exposed ears of providers wearing scrub hats.[74] In the absence of high-quality evidence on this topic, different organizations have developed independent guidelines on surgical attire. Current Association of Perioperative Registered Nurses and Joint Commission guidelines support bouffant use alone,[70] whereas the ACS surgical attire policy supports skullcap use if close to all hair is covered by the skull cap, with only a limited amount of hair exposed at the nape of the neck and at the sideburns.[69] Moving forward, there is a need for a national consensus statement supported by organizations representing multiple specialties on surgical attire policy to improve clarity for providers.

Prophylactic antibiotics

The Surgical Care Improvement Project (SCIP) measures and reporting are mandated by the Centers for Medicare and Medicaid Services as part of Hospital Inpatient Quality Reporting. Performance on SCIP measures determines a hospital's payment under the Centers for Medicare and Medicaid Services Value-Based Purchasing Program. Numerous SCIP measures address the administration of prophylactic antibiotics before surgical incision, yet it remains controversial whether SCIP measures have improved SSI rates. A systematic review demonstrated a 4% decrease in SSI after introduction of SCIP measures, however, rates of decrease did not necessarily correlate with periods of increased compliance with SCIP measures.[75] It is possible that lower SSI rates can be attributed to shorter hospital length of stay and the associated decrease in opportunities for wound inspection after discharge. Individual hospitals have shown decreased SSI rates with improved SCIP measure compliance.[76] Literature on whether compliance with SCIP Inf-1 (administration of prophylactic antibiotics within 1 hour of incision) decreases SSI has been mixed.[75,77,78] There is more support in the literature for SCIP Inf-2 (appropriate selection of prophylactic antibiotic).[77,78] Even though certain SCIP measures have support in the literature, it is also clear that SCIP measures alone are not sufficient to prevent SSIs.[79]

The literature generally supports the administration of prophylactic antibiotics within 1 hour before incision, or within 2 hours for vancomycin or fluoroquinolones (Guideline 2.6).[1,2,78] Considerable research efforts have focused on identifying a more precise ideal prophylactic antibiotic administration time frame, however, results have been contradictory. Some studies support specific administration windows,[80,81] and others show no statistically significant differences in SSI with more exact administration timing.[82] The importance of prophylactic dosing timing can also vary based on the procedure.[82] In contrast to the exact time of prophylactic antibiotics, there is support in the literature that prophylactic antibiotic dosing should be adjusted based on the patient's weight.[1,2,83] Prophylactic antibiotics should be re-dosed during surgery to maintain adequate tissue levels based on the agent's half-life or for every 1,500 mL estimated blood loss.[1,2] The choice of antibiotic agent should be dictated by the surgery performed and the most common SSI pathogens for that surgery. The Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery, developed jointly by the American Society of Health-System Pharmacists, the Infectious Diseases Society of America, the Surgical Infection Society, and the Society for Healthcare Epidemiology of America, provide a comprehensive overview of specific agents that should be used for specific procedures.[2] Providers should be aware of the common pathogens responsible for SSI (*S aureus*, coagulase negative staphylococci, *Enterococcus* species, and *Escherichia coli*),[84] as well as the patterns of resistance at their institutions. Whenever possible, providers should use hospital-specific antibiograms and diverse antibiotic agents to decrease resistance among pathogens.[85] As discussed previously, in elective colorectal procedures, a combination of oral antibiotic bowel preparation and IV prophylactic antibiotics should be used.[43,49,86-88] Vancomycin should not be administered routinely as prophylaxis in MRSA-negative patients.[33]

Antibiotics should be discontinued at time of incision closure (exceptions include implant-based breast reconstruction, joint arthroplasty, and cardiac procedures for which optimal duration of antibiotic therapy remains unknown). In general, there is no evidence that antibiotic administration after incision closure decreases SSI risk across a range of procedures, including clean, clean-contaminated, and contaminated wound classes.[1,2,89] In addition, ongoing antibiotic administration increases the risk of *C difficile* infection.[1] There are several exceptions where the optimal duration of antibiotic prophylaxis remains controversial or unknown. The use of single-dose prophylaxis is believed to be adequate for primary augmentation mammoplasties.[90] In contrast, the literature is mixed on implant-based breast reconstruction. A retrospective study comparing SSI rates before SCIP measure adherence (routine administration of ongoing postoperative antibiotics) compared with post-SCIP implementation (single dose of preoperative antibiotic) found that SSI rates were considerably higher after SCIP implementation in patients undergoing breast reconstruction with implants.[91] Another retrospective study showed that SSI rates were lower with 48 hours of postoperative antibiotics after breast reconstruction with acellular dermal matrix.[92] Contrary to these findings, a large systematic review demonstrated no benefit with antibiotics past 24 hours.[93] Similarly, a matched cohort study found no difference in SSI between patients receiving a single preoperative dose of antibiotic vs an extended postoperative course,[94] and a recent prospective trial found no benefit to prophylaxis extending beyond 24 hours.[95] For total hip and total knee arthroplasty, controversy remains about the optimal duration of prophylactic antibiotics, although more-recent studies do not support the use of antibiotics past 24 hours postoperatively.[2] A systematic review of 4 randomized controlled trials found no evidence to support postoperative antibiotics at all (vs a single dose preoperatively).[96] Centers for Medicare and Medicaid Services SCIP measures allow for antibiotic prophylaxis after cardiothoracic procedures to continue until 48 hours postoperatively, however, many studies have shown no increased SSI risk with earlier antibiotic termination by 24 hours.[2]

Intraoperative normothermia

Studies have shown that intraoperative hypothermia is associated with increased risk of SSI,[97-99] therefore, intraoperative maintenance of normothermia is recommended (Guideline 2.7). The use of preoperative warming before short, clean cases has been shown to reduce SSI and is recommended.[100] For longer cases, both preoperative warming and ongoing temperature monitoring and warming measures are recommended.[101]

Wound protectors

Although the literature on the use of wound protectors in reducing SSI has been mixed, overall their use is supported.[102-105] The ROSSINI (Reduction of Surgical Site Infection Using a Novel Intervention) trial was a large, multi-center randomized trial that did not show decreased SSI risk with wound protector use. This trial included all patients undergoing laparotomy for any emergent or elective procedure. In contrast, many other prospective, randomized trials have demonstrated substantial reductions in SSI rate with the use of plastic wound edge protectors, although many of these studies are limited by small sample sizes.[102-104] Some of these studies demonstrated considerable benefit in a more defined patient population, such as patients undergoing elective colorectal surgery.[102] A systematic review concluded that although, overall, the literature shows an association between wound protector use and decreased SSI rates, studies so far have been too small or biased to provide strong quality of evidence in favor of wound protector use.[103] The use of an impervious plastic wound protector can prevent SSI in open abdominal surgery, and evidence is strongest for elective colorectal and biliary tract procedures (Guideline 2.8).

Antibiotic sutures

Historically, guidelines have not recommended the use of antibiotic suture to decrease SSI, but there is now considerable evidence in the literature to support their use. Numerous studies have demonstrated decreased risk of SSI with use of triclosan antibiotic suture compared with standard suture, including multiple randomized, controlled trials.[106] Systematic review and meta-analysis on the subject has confirmed this effect.[107,108] The use of triclosan-coated suture is recommended for wound closure in clean and clean-contaminated abdominal cases, when available (Guideline 2.9).

Glove and instrument change for wound closure

The use of double gloves during surgery has been primarily to protect the surgeon from exposure to the patient's fluids. The literature has shown that surgical gloves contain or develop a large number of defects. Although these defects have been shown to allow transmission of skin pathogens, there is no evidence that glove defects increase the risk of SSI.[109] Admittedly, most studies have been underpowered to detect this association. It has been shown that double gloving decreases the risk of holes to the inner glove, and so routine double gloving is recommended to protect the surgeon (Guideline 2.10).[109]

Changing outer gloves and using new instruments for closure in open colorectal surgery cases represent common-sense practices that have become convention. Interestingly, there is no research to support these practices individually, although these practices are often included in closure bundle protocols. Interestingly, the literature linking closure bundles with lower SSI risk is mixed. One multicenter randomized trial failed to show any reduction in SSI with addition of rescrubbing, new drape placement, and new instrument use before closure.[110] A second prospective trial that implemented a closure bundle consisting of change in gown and gloves, re-draping, wound lavage, and use of new instruments for closure also failed to find a difference in SSI rates.[111] Conversely, other studies have shown substantial and durable decreases in SSI risk with interventions including a closure bundle.[12] Although the literature lacks evidence to support the practice of changing gloves before closure and the use of new instruments, these practices are recommended for colorectal cases based on expert consensus and evidence supporting bundles that incorporate these practices (Guidelines 2.10 and 2.11).

Wound classification and closure

The CDC provides definitions for each of the 4 wound classes: class I/clean, class II/clean-contaminated, class III/contaminated, and class IV/dirty-infected.[5] Traditional teaching has supported primary closure for clean and clean-contaminated cases, but delayed primary closure (DPC) or open wound management for contaminated and dirty wounds, given the increased risk of SSI. Recent research has questioned this dogma and explored whether primary closure can be acceptable for all wound classes. Overall, there are no good quality data to support primary closure vs DPC in contaminated and dirty abdominal incisions, although systematic reviews suggest there might be decreased SSI with DPC (Guideline 2.12).[112,113] On the other hand, a prospective trial comparing primary closure with DPC reported that 48% of patients with primary closure were discharged with open wounds compared with 58% of patients with DPC ($p = NS$).[111] In the setting of damage-control laparotomy, primary closure was associated with a higher rate of intra-abdominal infection, however, SSI did not develop in >85% of patients closed primarily.[114] Studies looking at stoma site closure have found that purse-string closure is associated with fewer SSIs compared with primary closure, so routine purse-string closure of stoma sites is recommended.[115]

Topical antibiotic therapy

The use of various topical and local antibiotic therapy options for SSI reduction has been explored across many surgical subspecialties. Overall, there is a lack of high-quality data to support local and topical antibiotic therapy use to decrease SSI risk. These therapies include antibiotic irrigations, topical antimicrobial agents, antimicrobial-impregnated dressings, and wound sealants.[116] Some studies even suggest that use of these agents can increase SSI risk, as described in a multicenter trial examining use of gentamicin-collagen sponges in colorectal surgery.[117] There is some support in the literature for topical or local antibiotic use for specific procedures or patient populations. A recent systematic review found possible benefit for use in joint arthroplasty, cataract surgery, and possibly in breast augmentation and obese patients undergoing abdominal surgery.[118] A meta-analysis concluded that the use of vancomycin powder at the surgical site was associated with lower SSI risk for spine surgery.[119] There is inadequate evidence in the literature to support routine use of topical or local antimicrobial agents, although there might be benefit for specific procedures and patient populations (Guideline 2.13).

Perioperative supplemental oxygen

The data on supplemental oxygen use in the perioperative period are mixed, but generally support a benefit in the reduction of SSI.[1,120-122] Meta-analysis of various randomized controlled trials showed a lower SSI risk if supplemental (80% FiO_2) oxygen was administered compared with 30% FiO_2.[120] The administration of supplemental oxygen (80% FiO_2) is recommended during surgery and in the immediate postoperative period for procedures performed under general anesthesia (Guideline 2.14).

Postoperative wound management

Literature on postoperative wound management spans what material is used to close, use of wound vacuum therapy, comparisons of various dressing materials, and timing of dressing removal. Although some studies have reported decreased SSI rates after closure with Dermabond (Ethicon) compared with suture or staple closure,[123,124] a large review failed to demonstrate a difference in SSI rates among the various closure methods.[125] The use of wound vacuum therapy over closed incisions to decrease SSI is generally supported in the literature, spanning open colorectal surgery,[126] ventral hernia repair,[127] and vascular groin incisions,[128] although studies to date have been too small or at risk of bias to support recommended routine use. Evidence in the literature to support the use of silver-containing dressings over plain gauze for clean incisions is mixed.[129,130] A recent review found that silver-nylon dressings are associated with decreased SSI risk in small studies across several specialties, including colorectal surgery, neurosurgery, spinal surgery, and some cardiac and orthopaedic procedures.[131] Given the mixed results in the literature and high risk of bias in studies demonstrating benefit to silver-based dressings, there is insufficient evidence currently to support their routine use. A recent systematic review did not find evidence that the timing of dressing removal (ie early, <48 hours) affects SSI risk, however, all studies included were small and at high risk for bias.[132,133] For contaminated wounds closed with interrupted staples, daily wound probing resulted in lower SSI rate and decreased length of stay without increased patient discomfort,[134] and should be considered for this wound class (Guideline 2.15).

Postoperative showering

No studies have shown a difference in SSI between showering as early as 12 hours after surgery vs delayed showering (>48 hours after surgery).[135] Early showering does not increase the risk of SSI and can be encouraged at the surgeon's discretion (Guideline 2.15).

Post-hospital interventions

There is a paucity of informative research in the area of post-hospital interventions for the prevention of SSI. For example, there is almost no research on wound care in the post-hospital setting (Guideline 3.1). The majority of the literature covers methods of SSI surveillance after discharge. These results have shown that a substantial number of SSIs occur after discharge, and that SSI rates can be underestimated without formal surveillance.[136] A recent study reported that when systematic 30-day follow-up is performed, as in NSQIP, compared with variable and primarily inpatient surveillance, as in National Healthcare Safety Network, that more infections are routinely found.[137] Unfortunately, no reliable methods have been described in the literature to identify SSI (Guideline 3.2). Surveillance methods based on surgeon or patient questionnaires have poor sensitivity and specificity.[1] Promising new methods of surveillance are being explored, many of which use smartphone technology to help patients send their surgeon daily photos or updates.[138] Currently, most SSIs are identified via presentation to the emergency department or in outpatient clinic follow-up. Most superficial SSIs can be managed in the outpatient setting, but deep and organ space SSIs require readmission.[139]

DISCUSSION

In this update, we review the evidence supporting a number of guidelines previously endorsed by other groups and explore recent high-quality studies that guide new recommendations. The most notable change is in regard to blood glucose control. The importance of short-term blood glucose control in the perioperative period has been shown to be more important than long-term blood sugar management. Importantly, there is now high-quality evidence to support expansion of perioperative blood glucose control to all patients, regardless of diabetic status. We also endorse cessation of prophylactic antibiotics at the time of incision closure, a departure from earlier guidelines where cessation within 24 hours was recommended.

Another important theme relates to "bundled" care, including preoperative decolonization protocols for *S aureus* and in the field of colorectal surgery, where bundles have been successfully applied in the intraoperative setting during closure to decrease SSI. Studies on the use of bundles have yielded mixed results, however, in studies with high compliance on the part of both patients and providers, the benefits can be substantial. As we move toward increasing standardization of care, it is important to emphasize that compliance rates and buy-in are key to the success of bundled interventions.

This update highlights numerous areas where robust, high-quality data are still needed to inform additional recommendations. Although the SCIP guidelines are shaped by evidence, there are important possible exceptions that warrant additional investigation, including breast and orthopaedic operations with implantable materials and cardiac procedures. Most of our surgical attire practices and guidelines are based on convention rather than evidence, but conducting high-quality research in this area might not be feasible. One area that will continue to evolve is the use of topical and local antibiotics. Studies looking at individual procedures have shown promising results, but to support more widespread use or formal recommendations, large randomized trials will have to explore the benefit of these agents across a wider range of procedures. Finally, the optimal postoperative wound management practices remain undefined, including how best to survey for SSIs after discharge from the hospital.

Various organizations, both nationally and internationally, have developed different guidelines for the prevention of SSI. These differences exist due to independent interpretation of existing data, the absence of high-quality data, and different target audiences for the guidelines themselves. Moving forward, there is value in the development of a national consensus on SSI guidelines supported by organizations representing multiple specialties to clarify best practices for providers in the field of surgery.

Guidelines serve as a starting point for the delivery of evidence-based care, but they are only useful if they are implemented successfully. Hospitals must engage individuals at all levels, from front-line providers to leadership. Achieving high compliance with guidelines has proven challenging in the past, and successful SSI reduction initiatives require ongoing education efforts to sustain them. We hope this document will help clinicians prevent SSIs by guiding high-quality, evidence-based patient care.

Author Contributions

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