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Commentary

Update to the Centers for Disease Control and Prevention and the Healthcare Infection Control Practices Advisory Committee Guideline for the Prevention of Surgical Site Infection (2017): A summary, review, and strategies for implementation

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Surgical site infections remain a common cause of morbidity, mortality, and increased length of stay and cost amongst hospitalized patients in the United States. This article summarizes the evidence used to inform the Centers for Disease Control and Prevention and the Healthcare Infection Control Practices Advisory Committee Guideline for the Prevention of Surgical Site Infection (2017), and highlights key updates and new recommendations. We also present specific suggestions for how infection preventionists can play a central role in guideline implementation by translating these recommendations into evidence-based policies and practices in their facility.

Despite recent advances in infection prevention efforts, surgical site infections (SSIs) remain a common cause of morbidity, mortality, and increased length of stay and cost amongst hospitalized patients.[1] The Centers for Disease Control and Prevention (CDC) health care-associated infection (HAI) prevalence survey estimated that there were almost 160,000 SSIs amongst inpatients during 2011 in the United States, making SSI the most common HAI.[2] One study found that patients with an SSI were twice as likely to die, 60% more likely to spend time in an intensive care unit, and 5 times more likely to be readmitted to a hospital when compared with other patients undergoing surgery who did not have an SSI.[3] SSIs are also responsible for substantial additional hospital expenses, with the average cost per infection ranging from approximately $5,000-$13,000.[4] Overall, it is estimated that SSIs account for $3.5-$10 billion annually in health care expenditures based on the consumer price index.[5] Research also suggests that approximately 55% of SSIs may be preventable with appropriate implementation of evidence-based strategies.[4]

GUIDELINE DEVELOPMENT

The CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC) recently published an update to their guidelines for prevention of SSI.[5] These guidelines are not comprehensive, as stated by the authors, and prevention strategies from the 1999 guidelines still apply; however, the updated document provides recommendations for SSI prevention based on new evidence since the prior publication.[6] The previous version of the guidelines (1999)[6] was mostly informed by expert opinion, whereas the updated guidelines (2017)[5] are evidence-based and were developed based on a systematic review of more than 5,000 studies published between 1998 and 2014. The CDC HICPAC adopted the Grading of Recommendations, Assessment, Development, and Evaluation approach[7] to systematically evaluate the evidence used to inform the guidelines. As shown in Table 1, recommendations are categorized as either IA, IB, IC, II, or No recommendation/unresolved. A IA categorization means that it is a strong recommendation supported by high- to moderate-quality evidence suggesting net clinical benefits or harms, whereas a II categorization means that it is a weak recommendation supported by any-quality evidence suggesting a tradeoff between clinical benefits and harms. The aim of this report is to highlight key updates and new recommendations from the CDC Guideline for the Prevention of Surgical Site Infection (2017)[5] and to present them in the perspective of infection preventionists (IPs)

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Table 1
Categorization scheme for recommendations from the Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection (2017)*

Category	Rationale
IA	A strong recommendation supported by high- to moderate-quality evidence, suggesting net clinical benefits or harms
IB	A strong recommendation supported by low-quality evidence suggesting net clinical benefits or harms; or an accepted practice supported by low to very low-quality evidence
IC	A strong recommendation required by state or federal regulation
II	A weak recommendation supported by any quality evidence suggesting a tradeoff between clinical benefits and harms
No recommendation/ unresolved	An unresolved issue for which there is either low- to very-low-quality evidence with uncertain trade-offs between benefits and harms or no published evidence on outcomes deemed critical to weighing the risks and benefits of a given intervention

*Adapted from reference 7.

Table 2
Summary of updated, key recommendations from Centers For Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection (2017)

Recommendation	Strength of evidence*
Parenteral antimicrobial prophylaxis	
Administer antimicrobial agents only when indicated based on published guidelines	Category IB
Time administration such that bactericidal concentration is established in serum and tissues at initial incision	
For caesarean sections, administer the appropriate agent before skin incision (vs at cord clamping)	Category IA
Nonparenteral antimicrobial prophylaxis	
Consider use of triclosan-coated sutures	Category II
Glycemic control	
Implement perioperative glycemic control using blood glucose target levels <200 mg/dL in patients with and without diabetes	Category IA
Normothermia	
Maintain perioperative normothermia	Category IA
Oxygenation	
Administer increased fraction of inspired oxygen intraoperatively and in the immediate postoperative period following extubation for all patients with normal pulmonary function undergoing general anesthesia with endotracheal intubation	Category IA
Antiseptic prophylaxis	
Instruct patients to perform full body shower or bath the night before surgery (with either soap or an antiseptic agent)	Category IB
Intraoperative skin preparation should be performed with an antiseptic agent containing alcohol unless contraindicated	Category 1A
Consider intraoperative irrigation of deep or subcutaneous tissues with aqueous iodophor solution	Category II

*Adapted from reference 7.

Table 3
Strategies determined to be unnecessary in the prevention of surgical site infections

Strategy	Strength of evidence
Antimicrobial prophylaxis after surgical closure (clean and clean-contaminated procedures)	Category IA
Topical antimicrobial agents applied to the surgical incision	Category IB
Autologous, platelet-rich plasma	Category II
Antimicrobial sealant following intraoperative skin preparation	Category II
Plastic adhesive drapes for antisepsis	Category II
Withholding transfusion of necessary blood products (question posed for patients undergoing prosthetic joint arthroplasty)	Category IB

with an emphasis on how IPs can promote the adoption of these evidence-based policies and practices into routine practice.

IMPLEMENTATION SCIENCE

Implementation science is defined as "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice."[8] As described by Saint et al,[9,10] there are 3 main components that influence a decision to adopt and implement an infection prevention policy, practice, or guideline recommendation: practice characteristics (including cost, evidence, and usability), the organization (including leadership, personnel, and resources), and the environmental context (including public reporting and pay-for-performance). This conceptual framework is informative, but Pronovost et al[11] went 1 step further to develop an action-oriented model. Their strategy for translating evidence into practice includes summarizing the evidence, identifying local barriers to implementation, measuring performance, and ensuring all patients receive the interventions by engaging, educating, executing, and evaluating.[11] For each new recommendation to prevent SSI, the suggestions provided here for guideline implementation are rooted in these theories of implementation science.

RECOMMENDATIONS

The CDC Guideline for the Prevention of Surgical Site Infection 2017[5] covers 14 main domains, including a new section on prosthetic joint arthroplasty. An overview of new or changed recommendations and their corresponding levels of evidence are shown in Tables 2 and 3. It should also be noted that 25 of the 42 statements assessed were classified as "No recommendation/ unresolved issue," suggesting that more high-quality research in this area is necessary. It is important to recognize that this does not necessarily mean a recommendation from the prior guideline has no merit or should be discontinued. Key recommendations and the evidence used to inform each statement are summarized in the section below. We also highlight what is new, what is missing, and how the specific recommendations in the updated CDC guideline[5] relate to existing guidelines endorsed by other organizations and associations (Table 4).

PARENTERAL ANTIMICROBIAL PROPHYLAXIS

Antimicrobial prophylaxis is an important strategy in SSI prevention. When indicated, a single dose of an appropriate antimicrobial agent should be administered before the initial

Table 4
Implementation strategies for updated, key recommendations from Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection 2017*

Parenteral antimicrobial prophylaxis
Summarize the evidence • Review local guidelines, protocols, and processes for antimicrobial administration in the perioperative setting and identify necessary changes based on these updates. o Is there a local guideline, protocol, or policy to assist in antibiotic selection, dosing, or timing? Does it meet national guidelines? o Is there a policy stating the optimal duration of antibiotic prophylaxis? Are antibiotics routinely administered postoperatively and for how long? Identify local barriers to implementation • Understand perspective or all key stakeholders and identify areas of potential controversy. o How are differing recommendations on duration of prophylaxis by various professional societies being implemented in your surgical populations? Measure performance • Identify, collect, and disseminate process measure data such as: o The proportion of patients who received an appropriate antibiotic and dose within 60 min before incision, and o The proportion of patients for whom antibiotics were not continued postoperatively. Ensure all patients receive possible interventions • Collaborate with key stakeholders, including: o Antimicrobial stewardship teams, pharmacists, surgeons, anesthesiologists, and anesthesiology technicians. • Develop educational strategies directed at involved personnel as needed. • Possible interventions may include: o Antimicrobial prophylaxis protocol, o Individual feedback to providers, or o Information technology solutions, including best practice alerts or order sets for antibiotic discontinuation postoperatively.
Glycemic control
Summarize the evidence • Review local guidelines, protocols, and processes for perioperative glucose management. • Be knowledgeable of the potential gaps in the recommendations; for example, no guidance is give around preoperative glucose control and ideal glycated hemoglobin levels before surgery. • Identify opportunities for standardization and develop protocols to avoid both hyperglycemia and hypoglycemia in the perioperative setting. Identify local barriers to implementation • Identify parameters that require actionable measures on day of surgery as well as protocols for action. o How frequently should blood glucose be measured? o What actions should be taken for specific values or cut-offs? Measure performance • Monitor the measure above as an element of surveillance to compliance with adherence to glucose optimization, to evaluate the effectiveness of the strategy and provide feedback to surgical and perioperative colleagues. Ensure all patients receive possible interventions • Collaborate with perioperative colleagues, including those in surgery, anesthesiology, and nursing, as well as with pharmacy and endocrinology staff.
Normothermia
Summarize the evidence • Be aware of how these new recommendations fit with complementary guidance from other organizations. Identify local barriers to implementation • Determine whether adjunctive warming measures are available. Assign responsible parties to the role that ensure patient remains warm preoperatively, intraoperatively, and postoperatively. Measure performance • Consider intraoperative documentation of warming device and body temperatures at start and end of case, followed by documentation of warming in the postanesthesia care with body temperatures noted at the beginning and end of this period. • Optimal data collection occurs with electronic data mining of the health record and can provide a robust assessment with preoperative warming. • When the above is not feasible, perform a point prevalence assessment of the temperatures monitored on all patients in the presurgical waiting areas for a given date/time. Ensure all patients receive possible interventions • Coordinate with preoperative colleagues, including those in anesthesiology, surgery, and perioperative nursing to determine the best means to maintain normothermia while the patient awaits surgery. • Offer education as to the importance of preprocedural normothermia maintenance.
Oxygenation
Summarize the evidence • Partner with anesthesiology and perioperative staff as well as surgeons to identify opportunities to implement update recommendations at their own institutions. Identify local barriers to implementation • Encourage strategies to optimize tissue oxygenation through normothermia and normovolemia. Measure performance • Monitor the implementation of these strategies and provide feedback to the stakeholders who have the actionable responsibility to ensure implementation. Ensure all patients receive possible interventions • Careful assessment by anesthesiology is needed to identify patients most appropriate for this intervention.
Antiseptic prophylaxis
Summarize the evidence • Be aware of how the new guidelines differ from prior Centers for Disease Control and Prevention guidance. Identify local barriers to implementation • In institutions where standardization is important to implementation, consider a preoperative bathing program that includes chlorhexidine gluconate. Measure performance • Monitor compliance with institutional defined presurgical bathing recommendations. o Percentage of patients complying with instructions. o Have a strategy for just-in-time alternatives when presurgical bathing is incomplete. o Provide feedback to stakeholders, including surgeons and presurgical services teams. Ensure all patients receive possible interventions • Partner closely with their perioperative and surgical colleagues to develop practices that support preoperative bathing. • Considerations should be given to at-risk populations, compliance, and overall infections rates. • A risk-based approach to selecting a preoperative bathing program may warrant using a chlorhexidine gluconate-based product in certain settings.

*Adapted from reference 11.

surgical incision. Existing, comprehensive guidelines outline effective strategies for antimicrobial prophylaxis in surgery.[12-14] The updated CDC guideline[5] reinforces the use of a single intravenous dose of preoperative antimicrobial agents when indicated. These agents should be timed such that the bactericidal concentration is firmly established in the serum and tissues at the time of initial surgical incision; existing guidelines and scientific literature suggest dosing within 60 minutes before incision or 120 minutes for vancomycin and fluoroquinolones.[13,15,16] However, the updated CDC guideline does not further refine the appropriate timing, nor does it make additional recommendations for weight-based dosing or interoperative redosing. Several studies suggest redosing should be considered when the duration of the procedure exceeds 2 half-lives of the antimicrobial agent (eg, more than 3 hours for cefazolin) or if there is excessive blood loss (ie, >1,500 mL).[13,15,17-21]

The optimal timing of antimicrobial administration for cesarean section was also considered. A meta-analysis of 3 randomized controlled trials suggested a benefit of prophylactic antimicrobial administration before skin incision compared with immediately after clamping of the umbilical cord demonstrating a 53% reduction in postpartum endometritis and no difference in neonatal outcomes, including neonatal sepsis.[5,22-24] Other guidelines have concluded that additional antimicrobial administration after cord clamping is not recommended.[6]

A new and important update is the recommendation that prophylactic antimicrobial agents should not be extended postoperatively (ie, after closure of the surgical incision in the operating room) for any clean or clean-contaminated procedure regardless of the placement of a surgical drain. This recommendation supported is in the World Healthcare Organization (WHO) global guidelines for the prevention of SSI.[12] Evidence for this CDC update is based on a large meta-analysis that included 13,408 cardiac; thoracic; vascular; ear, nose, and throat; gynecologic; orthopedic; and general surgical procedures from 19 randomized controlled trials in which no benefit of postoperative antibiotics could be elucidated. The benefit of single-dose compared with prolonged postoperative antimicrobial prophylaxis may include improvements in cost and adverse events, including the emergence of multidrug-resistance or infection with *Clostridium difficile*. The use of postoperative prophylactic antimicrobial agents has been controversial in the past. As an example, a prior meta-analysis of antimicrobial use in cardiac surgery procedures identified that shorter duration of prophylaxis (≤24 hours postoperatively) was associated with higher rates of deep sternal wound infection compared with longer durations (relative risk, 1.83; 95% confidence interval, 1.25-2.66).[25] The American College of Cardiology Foundation and American Heart Association guidelines, which came out in 2011 before the aforementioned meta-analysis, do not address the issue of duration of antimicrobial prophylaxis.[26] Guidelines by the Society for Healthcare Epidemiology of America (SHEA) and the Infectious Disease Society of America recommend that surgical prophylaxis is stopped within 24 hours of the surgical procedure,[14] whereas the Institute of Healthcare Improvement recommends discontinuing antibiotics within 24 hours for most procedures and within 48 hours for cardiac patients.[27]

Strategies for implementation

IPs need to be aware of these new updates to assist in implementation as needed. It is also important to recognize areas of potential controversy, such as differing recommendations on duration of prophylaxis by various professional societies as described above. Collaborations with antimicrobial stewardship teams, pharmacists, surgeons, anesthesiologists, and anesthesiology technicians are all appropriate. IPs should be aware of local guidelines, protocols, and processes for antimicrobial administration in perioperative settings that should be reviewed for necessary changes based on these updates. Additionally, educational strategies should be directed at involved personnel as needed. Awareness, collection, and dissemination of process measure data (eg, antibiotic selection, dose, timing, and discontinuation) is important. These data must be shared with key stakeholders in an effort drive practice improvement. Strategies aimed at optimizing surgical prophylaxis goals may be implemented and progress should be measured with both process and outcome measure data. Such strategies may include education and feedback of outcome and process measure data to key stakeholders, the development and implementation of surgical prophylaxis protocols, as well as information technology solutions such as the use of order sets or best practice alerts to assist with antibiotic selection, timing, and appropriate discontinuation.

GLYCEMIC CONTROL

Hyperglycemia can adversely influence wound healing, immunity, and vascular function. It occurs commonly among patients with a range of surgical and trauma events[28-30] and is associated with increased rates of infection and death among all critically ill patients.[31,32] Intensive insulin therapy to maintain normoglycemia after surgery may improve perioperative outcomes,[33] including prevention of SSI.

To inform the new guidelines, a systematic review was conducted to evaluate the influence of perioperative blood glucose and glycated hemoglobin (hemoglobin A1c) levels on risk of SSI, and their optimal perioperative target levels in patients with and without diabetes. A study by Gandhi et al[33] randomized adult cardiac surgery patients with and without diabetes to receive either continuous insulin infusion to maintain intraoperative glucose levels between 4.4 mmol/L (80 mg/dL) and 5.6 mmol/L (100 mg/dL) or standard care. After surgery, both groups received insulin infusion. The primary outcome was a composite of death, sternal infections, prolonged ventilation, cardiac arrhythmias, stroke, and renal failure within 30 days after surgery. The authors concluded that intensive insulin therapy during surgery does not reduce perioperative morbidity or mortality among cardiac patients. The frequency of hypoglycemia was low in both groups. A second randomized controlled trial conducted by Chan et al[34] examined the association between different target glucose levels and the clinical outcomes of patients undergoing cardiopulmonary bypass. Patients were assigned to a target blood glucose level of either 80-130 mg/dL or 160-200 mg/dL during surgery and for 36 hours after surgery. The primary outcomes of interest included infection (composite outcome of diagnosis of pneumonia, urinary tract infection, sepsis, septic shock, wound infection, bloodstream infection, and catheter infection), duration of intubation, length of stay in the intensive care unit, length of stay in the hospital, hypoglycemia, renal or neurologic dysfunction, and blood transfusion. This study also found no differences between the 2 study groups for all clinical outcomes, including hypoglycemia (all P values $> .05$).

Based on the existing evidence and the concern for adverse outcomes associated with hypoglycemia with more aggressive glycemic control, perioperative implementation of glycemic control with blood glucose levels <200 mg/dL for patients with and without diabetes is advised in the 2017 guidelines. This updated recommendation now includes both patients with and without diabetes and provides a specific blood glucose target level. The guidelines do not provide recommendations related to the optimal timing, duration, or delivery method of perioperative glycemic control and this was classified as "No recommendation/unresolved issue." Similarly, no recommendation was made to address the optimal hemoglobin A1c target levels for prevention of SSI due to a lack of evidence. The WHO guidelines recommend using protocols to control perioperative

glucose but does not recommend a specific target citing inconsistent evidence.[12] The SHEA Compendium of Strategies to Prevent Healthcare-Associated Infections in Acute Care Hospitals[14] recommends postoperative glucose levels of 180 or lower, differing slightly from the updated CDC guidelines.[5] Several professional societies, including The American College of Physicians, The Society of Thoracic Surgeons, and The Endocrine Society provide additional guidance on this topic and some also recommend slightly lower absolute serum blood glucose target levels.[35-38] The Society of Thoracic Surgeons practice guideline recommends that hemoglobin A1c level should be obtained before surgery in patients with diabetes or those patients at risk for postoperative hyperglycemia[35] and the Endocrine Society Clinical Practice Guideline suggests that all inpatients with known diabetes or with hyperglycemia (>7.8 mmol/L) be assessed with a hemoglobin A1c level if this has not been performed in the preceding 2-3 months,[37] although few guidelines address the ideal target hemoglobin A1c nor what to do with higher than desired levels at the time of surgery.

Strategies for implementation

IPs should be aware of the updated guidelines and how these may differ from existing guidelines, such as the difference in blood glucose targets compared with the 2014 SHEA compendium.[14] They should also be knowledgeable of the potential gaps in the recommendations; for example, no guidance is given around preoperative glucose control and ideal hemoglobin A1c levels before surgery. IPs should collaborate with their perioperative colleagues in fields including surgery, anesthesiology, and nursing, as well as with pharmacy and endocrinology. Collaborative teams should work together to identify opportunities for standardization and to develop protocols to avoid both hyperglycemia and hypoglycemia in perioperative settings. These collaborative teams may also choose to address preoperative glucose control measures based on experience and other literature/guidelines. For example, a collaborative team may focus on the process for evaluating blood glucose in the perioperative setting. This could include identification of parameters that require actionable measures on day of surgery as well as protocols for action. How frequently should blood glucose be measured? What actions should be taken for specific values or cutoffs? IPs can monitor this measure as an element of surveillance to compliance with adherence to glucose optimization, to evaluate the effectiveness of the strategy and provide feedback to surgical and perioperative colleagues.

NORMOTHERMIA

Hypothermia may increase susceptibility to surgical wound infection by prompting subcutaneous vasoconstriction and consequent tissue hypoxia. Hypothermia may increase SSI rates by directly impairing neutrophil function.[14] There is also evidence to suggest that failure to maintain normothermia may increase blood loss leading to risk factors for SSI such as transfusion and wound hematomas.[39] Maintenance of perioperative normothermia is therefore an important consideration when working to prevent SSI.

The guideline development committee examined 2 primary comparisons related to normothermia: warming versus no warming and perioperative warming versus intraoperative warming only.[5] SSI was the primary outcome for both comparisons. The systematic review for the guidelines included the following 3 randomized controlled trials. In a study by Kurz et al,[40] 200 colorectal surgery patients were randomized to either routine intraoperative thermal care (hypothermia group) or additional warming (normothermia group) to assess whether hypothermia increases susceptibility to surgical wound infection and lengthens hospitalization. The authors[40] found that surgical wound infections were more common in the hypothermia group (19% vs 6%; $P = .009$) and that duration of hospitalization was prolonged by 2.6 days (almost 20%) in the hypothermia group when compared with the normothermia group.[39] The second study, by Melling et al,[41] included 421 patients undergoing breast, varicose vein, or hernia surgery. These participants were randomly assigned to either routine care (no warming) or 1 of 2 warming groups (local or systemic). Patients in the 2 warming groups had fewer wound infections than those in the routine care group (5% vs 14%; $P = .007$). The trial conducted by Wong et al[42] enrolled 103 patients who were admitted to hospital for elective major abdominal surgery. Patients were randomized to 2 groups; both were warmed during surgery, but patients in the intervention group were warmed for an additional 2 hours before and after surgery. Additional warming was achieved by using a conductive carbon polymer mattress. Patients who received additional warming before and after surgery had lower blood loss (median, 200 mL vs 400 mL; $P = .011$) and lower complication rates (32% vs 54%; $P = .027$) when compared with patients who were warmed only during surgery.[42] The "complication" variable was a composite outcome of 10 complications, including SSI.

Based on this evidence, the updated CDC guideline[5] also recommends maintenance of normothermia. Although achieving normothermia was categorized as a strong recommendation, there is no guidance on the optimal timing and duration of warming, or the most effective strategies to reach the minimum temperature goal of 95.9°F (35.5°C) as advocated for in other guidelines.[8,14] These strategies can be warmed blankets or warming devices. The systematic review conducted to inform recommendations on maintaining normal body temperature in the WHO Surgical Site Infection Prevention Guidelines[12] included only the studies by Kurz et al[40] and Melling et al[41] described here. The WHO guidelines[12] recommend warming for the prevention of SSI and note possible benefits in cardiovascular outcomes and reduction in blood loss. Recommendations in the Association of Perioperative Registered Nurses Guideline for Prevention of Unplanned Patient Hypothermia[43] and The American Society of PeriAnesthesia Nurses Evidence-Based Clinical Practice Guideline for the Promotion of Perioperative Normothermia: Second Edition[44] were informed by all available evidence, including observational studies. These documents provide complementary guidance and may be consulted when developing an implementation plan for the updated CDC guideline.

Strategies for implementation

IPs have a role in supporting the work of maintaining normothermia by collaborating with preoperative colleagues in fields including anesthesiology, surgery, and perioperative nursing. No existing literature or guidelines outline the best means to maintain normothermia in the perioperative setting. IPs may facilitate identification and implementations of strategies that work best for their own facility or program such as the use of prewarmed blankets or other approved warming devices. IPs can offer education as to the importance of preprocedural normothermia maintenance. Following this is the partnership with anesthesiology for ensuring intraoperative normothermia and lastly ensuring postoperative normothermia during the immediate postanesthesia care period. Partnering with the surgical team to define the organizational standard process for implementation and then establishing measures of success will ensure protocols are actively followed. This might look like the placement of multiple warm blankets on a patient as soon as he or she changes into a surgical gown followed by intermittent temperature assessments to ensure that the patient remains warm. Intraoperative documentation of warming device and body temperatures at both start and end, followed by documentation of warming in the postanesthesia care unit with body temperatures

noted at the beginning and end of this period, offers assurance that processes are being followed. Auditing this information will allow organizations to target areas where the measure is not being adequately met. Optimal data collection occurs with electronic data mining of the health record and can provide a robust assessment with preoperative warming. When this is not feasible, an IP can perform a point prevalence assessment of the temperatures monitored on all patients in the presurgical waiting areas on a given date or for a given period of time. An IP can then provide the details to stakeholders such as the preoperative nurses and surgeons in their organization on the number of patients who remained warm while waiting preoperatively to determine whether a measure of success was met.

OXYGENATION

Tissue hypoxia at the site of a surgical wound may result in slower healing and an increased risk of SSI. Decreased tissue oxygenation may occur at the surgical site because of decreased delivery to the tissue or through interruption of local blood flow.[45] The use of perioperative supplemental oxygenation as a strategy to prevent SSI has been previously explored. Although several randomized trials support this strategy, the data in support have been mixed, resulting in the practice not receiving widespread adoption.[45] The 2014 SHEA Compendium for *Strategies to Prevent Surgical Site Infections in Acute Care Hospitals*[14] recommends the administration of supplemental oxygen during and postsurgery involving mechanical ventilation. The updated CDC guideline[5] supports the recommendations from the SHEA compendium and "strongly recommends" administering increased fraction of inspired oxygen (FiO_2) both intraoperatively and postextubation during the immediate postoperative period for patients with normal pulmonary function undergoing general anesthesia with endotracheal intubation. The WHO guidelines[12] also include a "strong" recommendation for oxygenation in this population. In all 3 guidelines, it is noted that maximal benefit of supplemental oxygenation is achieved when tissue oxygenation is optimized and thus strategies to maintain normothermia and normovolemia are critical.

The updated recommendation is based on a meta-analysis of 6 randomized controlled trials (N = 2622) representing a variety of surgical populations.[46-51] In each of the trials, participants received 80% (high) FiO_2 intraoperatively and at least for 2 hours following extubation in the postoperative period. High FiO_2 was associated with reduced odds of SSI (odds ratio, 0.63; 95% confidence interval, 0.43-0.92; $P = .02$).

The updated 2017 guidelines endorse the administration of increased FiO_2 for intubated patients undergoing general anesthesia with normal pulmonary function. This is a new recommendation and is specific to this patient population. Based on the available evidence, the updated CDC guideline[5] did not support a recommendation for the use of supplemental oxygenation for those patients undergoing general anesthesia without endotracheal intubation or for patients undergoing neuraxial anesthesia (ie, spinal, epidural, or local nerve blocks). Furthermore, the guidelines do not support increased FiO_2 during only the intraoperative period or only the postoperative period (compared with both during and postoperatively). A subanalysis of 1 of the included trials found an increased risk of mortality associated with high oxygenation for patients with cancer, potentially adding more controversy to this strategy for certain patient populations.[49]

Strategies for implementation

IPs should partner with anesthesiology and perioperative staff as well as surgeons to identify opportunities to implement update recommendations at their own institutions. Careful assessment by anesthesiology is needed to identify patients most appropriate for this intervention. Furthermore, strategies that aim to optimize tissue oxygenation through normothermia and normovolemia should be encouraged as previously described. Once strategies are identified, an IP can monitor the implementation of these strategies and provide feedback to the stakeholders who have the actionable responsibility to ensure implementation.

ANTISEPTIC PROPHYLAXIS

Preoperative bathing is an important part of preparing a patient for surgery. Because preoperative bathing reduces the overall bioburden of the skin before surgery, it is logical to conclude that this reduction in bacteria also reduces the risk of developing an SSI. The 1999 SSI Prevention Guidelines[6] recommended preoperative bathing with an antiseptic agent at least the night before and the morning of surgery as a Category 1B recommendation based on a study of 700 patients that showed those who received 2 chlorhexidine baths had significantly reduced skin bacteria counts when compared with those individuals showering with either povidone-iodine or triclocarban-medicated soap[52] despite evidence at that time noting that reductions in SSI could not be clearly associated with the practice of bathing with chlorhexidine.[53,54]

In the current review, the HICPAC guideline update group sought to clarify the benefits of preoperative bathing with a focus on the safety and efficacy of preoperative bath with respect to SSI. Several high-quality randomized controlled trials were reviewed comparing chlorhexidine gluconate solution to unmedicated soaps, no bathing and placebo to assess the influence on SSI. Meta-analyses of these studies did not demonstrate a difference in outcomes, including SSI, when comparing bathing with chlorhexidine to either placebo or unmedicated soap analyses[53-56] or chlorhexidine gluconate to no bathing groups.[57-59]

The 2017 CDC HICPAC guidelines[5] updated their recommendations to state that patients should be advised to perform full body bath or shower with either soap (antimicrobial or nonantimicrobial) or an antiseptic agent on at least the night before the operative procedure (Category 1B). However, no recommendation was made as to the timing or number of showers, or type of agent used for bathing. This remains an unresolved issue and further high quality research would be beneficial to seeking clarity on this topic.

Prior CDC guidance recommended to "thoroughly wash and clean at and around the incision site to remove gross contamination before performing antiseptic skin preparation" and to use an appropriate antiseptic agent for skin preparation, both Category IB recommendations.[6] The 1999 guidance focused on highlighting the mechanism and spectrum of common antiseptic agents used for intraoperative skin preparations, without making any specific product recommendation.[6]

As presented previously, the new CDC guidelines[5] recommend performing intraoperative skin preparation with an antiseptic agent containing alcohol unless contraindicated, updating this recommendation to a Category 1A, indicating that high- to moderate-quality evidence is strongly in favor of net clinical benefit. This is in addition to the existing 1999 recommendation to "thoroughly wash and clean at an around the incision site to remove gross contamination before performing antiseptic skin preparation."[6] The evidence supporting this new recommendation comes from 14 randomized controlled trials comparing the following: aqueous iodophor 1 step versus 2 step, aqueous idophor to iodophor with alcohol, chlorhexidine-alcohol to aqueous iodophor, chlorhexidine-alcohol (1 or 2 step) to iodophor-alcohol (1 or 2 step).[5] Chlorhexidine-alcohol was clearly beneficial over aqueous iodophor, based on a meta-analysis of 5 randomized controlled trials. Different studies

each demonstrated reductions in SSI when chlorhexidine-alcohol was used as the intraoperative antiseptic agent compared with aqueous idophor.[60-64] When comparing chlorhexidine-alcohol to iodophor-alcohol, no differences were noted in SSI outcomes.[60,61] WHO guidelines state that bathing with either plain or antimicrobial soap before surgery is good practice; however, they report a lack of evidence to recommend chlorhexidine gluconate.[12]

Strategies for implementation

IPs should partner closely with their perioperative and surgical colleagues to develop practices that support preoperative bathing. Considerations should be given to at risk populations, compliance, and overall infections rates. A risk-based approach to selecting a preoperative bathing program may warrant using a chlorhexidine-based product in certain settings. For example, considerations should be given to this strategy in institutions with high prevalence of multidrug-resistant organisms, if it is anticipated that the patient may remain hospitalized in an intensive care unit for a period or if central venous access is anticipated to remain in place for a period of time, because chlorhexidine daily bathing has been shown to improve outcomes in these situations. In institutions where standardization is important to implementation it may also make sense to have a preoperative bathing program that includes chlorhexidine gluconate.

CATEGORY II RECOMMENDATIONS

The summaries and implementation strategies above all focus on strong Category I (IA, IB, and IC) recommendations; however, it should be noted that the new guidelines also include 5 weaker Category II recommendations. For example, in the Nonparenteral Antimicrobial Prophylaxis section, the guidelines state that the application of autologous platelet-rich plasma is not necessary[5]; however, it is suggested that triclosan-coated sutures may aid in the prevention of SSI.[5] In the Antiseptic Prophylaxis section, the application of a microbial sealant after intraoperative skin preparation and the use of plastic adhesive drapes with or without antimicrobial properties is deemed not necessary. Similarly, intraperitoneal lavage with aqueous iodopor solution in contaminated or dirty abdominal procedures was determined to be not necessary; however, consideration of intraoperative irrigation of deep or subcutaneous tissues with aqueous iodophor solution is recommended.[5] Implementation of these SSI prevention strategies should be made at the discretion of the infection prevention and control (IPC) team because there may be a trade-off between clinical benefits and harms.

SURVEILLANCE FOR SSIS

Although the importance of surveillance is not addressed in the updated guidelines, it has been addressed on other guidelines[14] and is a key role of IPs in the prevention of SSI. IPs should not only be intimately aware of the surveillance requirements and methodology but also should be a leader at their institution in this area. The CDC National Healthcare Safety Network developed surveillance definitions for SSI that are used across the country as a measure of hospital quality and for public reporting and as a metric for pay-for-performance.[65] A study by Kao et al[66] used American College of Surgeons National Surgical Quality Improvement Program data to assess the reliability of SSI rates as a measure of hospital performance and to explore what effect hospital caseload had on the reliability of the measure. They concluded that SSI rates are indeed a reliable measure of hospital quality, but only when an appropriate number of cases are reported.[67] Furthermore, improvements to the methodologies used to generate SSI rates are necessary. For example, a recent study[8] concluded that electronically available patient comorbidities should be used in SSI risk adjustment to adequately compare SSI rates across hospitals. As approaches to SSI surveillance and reporting continue to evolve, prevention efforts remain central components of all IPC programs in the United States.

CONCLUSIONS

SSIs pose significant patient morbidity and mortality and are among the most common HAIs. IPs have an important role in the prevention of SSI beyond SSI surveillance. IPs should have expert knowledge and understanding of the new CDC guidelines, along with existing and future prevention guidelines, and should serve as leaders in the implementation of best practices. Implementation of new and existing guidelines in SSI prevention requires thoughtful and careful collaboration with several interprofessional and interdisciplinary teams. IPs can serve as leaders in bringing these teams together to ensure best practice.

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