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Preventing Surgical Site Infections
Looking Beyond the Current Guidelines

Adam C. Fields, MD; Jason C. Pradarelli, MD, MS; Kamal M. F. Itani, MD

Surgical site infection (SSI) occurs in up to 5% of patients following an inpatient surgical procedure, increasing average hospital length of stay by 9.7 days, risk of mortality by 2- to 11-fold, and costs of hospitalization by more than $20 000 per admission.[1] SSIs are defined as either superficial (confined to the skin or subcutaneous tissue), deep (involving the muscle or fascia layers), or organ-space (involving the internal anatomic region where the operation was performed). Because more than half of SSIs are estimated to be preventable with evidence-based guidelines, SSI has been identified as an important quality indicator and is now a pay-for-performance metric.[1-3]

Emphasizing the importance of this patient safety issue, 4 major organizations—the American College of Surgeons (ACS) and Surgical Infection Society (SIS; 2016), the World Health Organization (WHO; 2016 guideline modified in 2018), and the Centers for Disease Control and Prevention (CDC; 2017)—published SSI prevention guidelines within 1 year of each other.[1-3] In this *JAMA* Insights article, the interventions with the strongest recommendations across these guidelines are summarized and emerging evidence to prevent SSIs is highlighted.

Strongest Guideline Recommendations to Reduce SSI

Among numerous evidence-based recommendations, the strongest agreement across the guidelines pertain to parenteral antimicrobial prophylaxis, alcohol-based skin preparation, perioperative glycemic control, temperature regulation to normothermia, and maintenance of normal tissue oxygenation (**Table**).[1-3] High-quality evidence supports parenteral antibiotic prophylaxis and alcohol-based skin preparation prior to skin incision. All guidelines strongly support the discontinuation of prophylactic antibiotics after skin closure in patients at low risk for surgical site infection.[4] Glycemic control to reduce SSIs was supported by all guidelines, with each specifying different glucose target levels. Each guideline recommends maintaining normothermia to prevent SSIs, with no recommended interventions to achieve this goal. Similarly, normal tissue oxygen levels were recognized as preventive against SSIs, although potential adverse events from administering increased levels of oxygen led WHO to revise its recommendation for this practice from *strong* to *conditional*.[3] The remaining recommendations did not achieve unanimous agreement among these 3 guidelines.

Interventions With Increasing Evidence to Reduce SSI

Several clinical interventions recommended in some—but not all—of the major guidelines have since gained additional evidence to support their use in reducing SSIs, such as preoperative bowel preparation, the use of care bundles, and application of negative-pressure wound dressings.

Although unaddressed by the CDC, preoperative bowel preparation before colorectal surgery was recommended in the ACS and SIS

Table. Current Guideline Recommendations for Surgical Site Infection Prevention

Recommendation	ACS and SIS[1a]	World Health Organization[3]	Centers for Disease Control and Prevention[2]
Parenteral antibiotic prophylaxis	Antibiotics should be given within 60 min of incision (re-dosing should be based on the half-life of the antibiotic and blood loss) Antibiotics should stop at closure of incision, with few exceptions Cardiac and orthopedic patients colonized with *Staphylococcus aureus* should be decolonized	**Moderate-quality evidence** Antibiotics should be given prior to incision (within 120 min of incision, with half-life of the antibiotic taken into consideration) Antibiotics should not be given after operation Nasal carriers of *Staphylococcus aureus* should be decolonized prior to surgery	**High-quality evidence** Antibiotics should be given so that bactericidal concentration of agent is present during incision Antibiotics should stop at closure of incision for clean/clean-contaminated incisions
Alcohol-based skin preparation	Alcohol-based preparations should be used unless contraindicated	**Moderate- to low-quality evidence** Alcohol-based solutions should be used rather than aqueous solutions	**High-quality evidence** Alcohol-based preparations should be used unless contraindicated
Perioperative glucose control	Target blood glucose levels should be between 110 and 150 mg/dL	**Low-quality evidence** Protocols for patients with and without diabetes should be used before the operation (timing and glucose targets are not defined)	**High- to moderate-quality evidence** Target blood glucose levels should be less than 200 mg/dL
Temperature regulation	Preoperative and intraoperative warming is recommended	**Moderate-quality evidence** Warming devices should be used during the surgical procedure	**High- to moderate-quality evidence** Perioperative normothermia is recommended
Tissue oxygenation	80% Supplemental oxygen should be given before the operation	**Moderate-quality evidence** 80% Fraction of inspired oxygen should be used intraoperatively 80% Fraction of inspired oxygen should be given for 2 to 6 h postoperatively	**Low-quality evidence** Unclear risk vs benefit for supplemental perioperative oxygenation

[a] The American College of Surgeons (ACS) and Surgical Infection Society (SIS) guideline does not provide strength of evidence.

and WHO guidelines. Initially proposed in the 1970s as nonabsorbable bowel lumen antibiotics for colorectal surgery, oral antibiotic (OAB) prophylaxis has intermittently been recommended with or without mechanical bowel preparation (MBP) for SSI prevention. Early evidence for OAB and MBP failed to demonstrate clear benefits for either strategy. However, recent analyses have renewed interest in these SSI prevention strategies, showing reduced SSI rates when OAB is combined with MBP. A meta-analysis of 26 randomized clinical trials (RCTs) and 9 cohort studies comprising 47 610 patients demonstrated that combined OAB-MBP was associated with reduced SSI rates compared with MBP alone (4.6% vs 9.9%; risk ratio, 0.51 [95% CI, 0.46-0.56]).[5] OAB was also associated with significant decreases in rates of anastomotic leak and 30-day mortality without increasing rates of *Clostridium difficile* infection. In the 2019 American Society of Colon and Rectal Surgeons clinical practice guidelines, summarized by Fry,[6] combined bowel preparation with OAB and MBP is recommended.

Various care bundles incorporating individual measures of SSI prevention were developed to improve SSI rates. These individual clinical interventions were subsequently incorporated into enhanced recovery after surgery (ERAS) protocols. Overall, ERAS programs aim to reduce the stress of surgery on patients by maintaining near-normal physiology in the preoperative, intraoperative, and postoperative phases of care. ERAS bundles incorporate SSI prevention guideline recommendations, such as parenteral antibiotic prophylaxis and strict glycemic control, as well as interventions with newer evidence, such as OAB-MBP, goal-directed fluid therapy, and early enteral feeding. A meta-analysis of 27 RCTs assessing 3279 patients undergoing abdominal/pelvic surgery showed a significant reduction in postoperative SSI for patients enrolled in ERAS programs compared with conventional pathways (5.1% vs 6.8%; risk ratio, 0.75 [95% CI, 0.58-0.98]).[7] Despite concerns that the evidence behind some individual components of ERAS bundles is weak or nonexistent,[8] ERAS protocols have widely spread to many surgical specialties.

Postoperative negative-pressure wound therapy (NPWT) is a wound dressing system that applies subatmospheric pressure to the surgical site. Traditionally, NPWT was used for open surgical wounds, but more recently has been evaluated in clinical trials for closed incisions. High-quality evidence demonstrates that NPWT reduces bacterial contamination and increases vascular perfusion and lymphatic clearance around the surgical site. A meta-analysis of 3 RCTs and 6 observational studies evaluating 1187 patients with closed laparotomy wounds showed a lower rate of SSI with NPWT vs standard surgical dressings (12.4% vs 27.1%; odds ratio, 0.25 [95% CI, 0.12-0.52]), with minimal adverse effects.[9] In 2019, the US Food and Drug Administration provided clearance for the first NPWT system to reduce SSI.

Emerging Strategies to Reduce SSI

On the horizon for SSI prevention research are several novel approaches that are challenging surgical dogma and longstanding practices in surgery. For example, traditional surgical attire and various types of headwear are under investigation for their benefit in preventing SSI. In keeping with antimicrobial stewardship and the prevention of bacterial resistance and *C difficile* infection, the common practice of administering intravenous antibiotics for all operations is now being questioned based on early evidence that select cases with clean wound classification do not warrant antibiotic prophylaxis (eg, inguinal hernias, thyroidectomy). Although smoking is known to adversely affect surgical outcomes, including increased risk of SSIs, duration of usage and time of cessation prior to surgery could be further studied to better mitigate infection risks for patients. Investigations continue for treating patients colonized with antimicrobial-resistant bacteria. New surveillance methods, including mobile phone applications and artificial intelligence, may allow for earlier detection of SSIs or lessen infection risk by allowing for early intervention for individuals with high-risk wounds.

Conclusions

Interventions to prevent SSIs have improved patient safety in recent years. Nonetheless, SSI remains an important quality indicator that has implications for patients, surgeons, health care institutions, and payers. Since 4 major health care organizations published recommendations in 2016 to 2017, SSI research has advanced on a global scale, pushing forward the frontier of SSI prevention and improving patient care.

ARTICLE INFORMATION

Author Affiliations: Department of Surgery, Veterans Affairs Boston Healthcare System, Boston, Massachusetts (Fields, Pradarelli, Itani); Department of Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts (Fields, Pradarelli, Itani); Department of Surgery, Boston University School of Medicine, Boston, Massachusetts (Itani).

Corresponding Author: Kamal M. F. Itani, MD, Department of Surgery, Veterans Affairs Boston Healthcare System, 1400 VFW Pkwy, 112-C, West Roxbury, MA 02132 (kamal.itani@va.gov).

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