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General Surgery

EVIDENCE-BASED STRATEGIES FOR SURGICAL SITE INFECTION PREVENTION: A COMPREHENSIVE REVIEW

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ABSTRACT Surgical site infections (SSIs) remain among the most common healthcare-associated infections (HAIs), affecting approximately 2 to 5 percent of surgical patients worldwide and accounting for over 20 percent of all HAIs. This comprehensive, evidence-based review synthesizes data from 45 randomized controlled trials (RCTs), 12 meta-analyses, and multiple open-access clinical guidelines to provide practical recommendations for SSI prevention across the entire perioperative period. Strong evidence supports interventions such as chlorhexidine-alcohol skin antisepsis (odds ratio [OR] 0.64, 95% confidence interval [CI] 0.51–0.81), maintenance of perioperative normothermia (absolute risk reduction [ARR] 13%, $p < 0.001$), timely antibiotic prophylaxis (relative risk [RR] 0.50, 95% CI 0.41–0.61), and preoperative smoking cessation (RR 0.45, 95% CI 0.30–0.67). Conversely, outdated practices like preoperative shaving (RR 1.62, 95% CI 1.11–2.36) and the use of adhesive drapes (RR 1.23, 95% CI 1.01–1.50) are linked with increased infection risk and should be abandoned. Bundled implementation of these evidence-based measures can reduce SSI rates by more than 50%, improve patient outcomes, and lower healthcare costs.

KEYWORDS : Surgical Site Infection, Infection Prevention, Chlorhexidine, Antibiotic Prophylaxis, Normothermia

INTRODUCTION

Surgical site infections (SSIs) are a frequent and serious complication following operative procedures, contributing to patient morbidity, prolonged hospital stays, and increased healthcare expenditure. According to the Centers for Disease Control and Prevention (CDC), SSIs are defined as infections occurring within 30 days postoperatively, or within 90 days if an implant or prosthesis is involved [1]. Globally, SSI incidence ranges between 2% and 5%, but varies significantly depending on the type of surgery. For instance, colorectal surgeries have some of the highest rates, exceeding 15%, whereas orthopedic surgeries generally have rates below 4% [2].

SSIs impose substantial economic burdens. Each infection adds significant amount of hospital costs and may extend the patient's length of stay by 7 to 10 days [3]. Additionally, SSIs correlate with elevated risks of reoperation, hospital readmission, and mortality-with relative risks of 2.5 and odds ratios of 2.2 for readmission and death, respectively [4]. These outcomes highlight the critical need for robust, evidence-based prevention strategies.

This review aims to synthesize current, high-quality evidence on perioperative SSI prevention, focusing on interventions applicable before, during, and after surgery. The goal is to present actionable recommendations grounded in clinical trials, meta-analyses, and guidelines, particularly those freely accessible to promote global applicability.

METHODS

Literature Search

A systematic literature search was conducted using PubMed Central, the Cochrane Library, and the Directory of Open Access Journals (DOAJ). Search terms included "surgical site infection prevention," "SSI bundle," "chlorhexidine antisepsis," "perioperative warming," and "antibiotic prophylaxis." Filters were applied to include studies on human subjects, published in English, accessible via open access, and within the timeframe of 2010 to 2023.

Study Selection

The Inclusion Criteria Encompassed:

- Randomized controlled trials (RCTs) with a minimum of 100 participants
- Meta-analyses and systematic reviews
- National and international clinical practice guidelines
- Large observational studies involving 1,000 or more patients

Exclusion Criteria Were:

- Animal or in vitro studies
- Case reports with fewer than 50 patients
- Articles without full-text access

Data Extraction And Quality Assessment

Two independent reviewers extracted data regarding study characteristics, interventions, and outcomes using standardized extraction forms. Quality assessment employed the Cochrane Risk of Bias tool for RCTs, AMSTAR-2 for systematic reviews, and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach for overall evidence rating.

RESULTS

Incidence of Surgical Site Infections by Procedure Type

SSIs vary widely depending on surgical procedure (Table 1). Colorectal surgeries carry the highest risk (15.2%) due to inherent bacterial contamination [5], while orthopedic procedures have lower rates (3.9%) [7].

Table 1: SSI Incidence By Procedure

Procedure Type	Baseline SSI Rate	Reference
Colorectal Surgery	15.2%	[5]
Hysterectomy	7.8%	[6]
Orthopedic Surgery	3.9%	[7]
Cardiac Surgery	4.5%	[8]
Cesarean Section	8.1%	[9]

Preoperative Interventions

Smoking Cessation

Smoking nearly doubles the risk of SSI, with a relative risk of 2.05 (95% CI 1.70–2.47) [10]. Evidence shows that cessation at least four

weeks before surgery significantly reduces SSI incidence, from 12% down to 2% [11]. Even stopping smoking on the day of surgery yields modest benefits. The mechanism involves improved tissue oxygenation and enhanced immune function [12].

Glycemic Control

Patients with diabetes who maintain preoperative hemoglobin A1c levels below 7% and intraoperative blood glucose under 180 mg/dL demonstrate reduced SSI rates [13]. Hyperglycemia impairs neutrophil activity and collagen synthesis, hindering wound healing [14]. Perioperative glucose control through insulin management is vital, especially for diabetic patients.

Nutritional Optimization

Hypoalbuminemia, defined as serum albumin below 3.5 g/dL, is linked with almost twice the risk of SSI (RR 1.8, 95% CI 1.3–2.5) [15]. Nutritional support including protein supplementation and immunonutrition (e.g., arginine, omega-3 fatty acids) can reduce inflammatory responses and improve surgical outcomes [15].

Skin Antisepsis

Chlorhexidine-alcohol solutions are superior to povidone-iodine for skin preparation, lowering superficial and deep incisional infection risk (OR 0.64, 95% CI 0.51–0.81). Chlorhexidine provides rapid antimicrobial action with residual effects, making it the preferred antiseptic agent [16].

Hair Removal

Preoperative shaving increases SSI risk due to microabrasions facilitating bacterial entry (RR 1.62, 95% CI 1.11–2.36). If hair removal is necessary, clippers should be used immediately before surgery to minimize skin trauma [17].

Intraoperative Interventions

Antibiotic Prophylaxis

The timely administration of prophylactic antibiotics is a cornerstone of SSI prevention. First-generation cephalosporins are commonly recommended for clean surgeries. Antibiotics should be administered within 60 minutes before incision (or 120 minutes before for vancomycin due to its longer infusion time) and redosed during prolonged procedures lasting over four hours or involving significant blood loss (>1500 mL). Prolonged postoperative antibiotic use beyond 24 hours does not confer additional benefit and increases risks of resistance [18,19].

Temperature Regulation

Maintaining perioperative normothermia (core temperature ≥36°C) is critical. Hypothermia reduces neutrophil function and impairs wound healing, increasing SSI risk. Forced-air warming devices and continuous temperature monitoring have been shown to reduce SSI rates by an absolute risk reduction of 13% ($p < 0.001$) [20].

Oxygen Supplementation

Administering high inspired oxygen fractions (80% FiO_2) during colorectal surgery reduces SSI risk by 39% (OR 0.61, 95% CI 0.42–0.88), likely by enhancing oxidative killing by neutrophils and improving wound oxygenation [21]. Routine application is recommended, especially in high-risk surgeries.

Fluid Management

Balanced crystalloids, such as lactated Ringer's solution, are preferred over normal saline to maintain optimal perfusion and acid-base balance [22]. Goal-directed fluid therapy, tailored to maintain hemodynamic stability without overload, is associated with reduced postoperative complications [23].

Surgical Technique

Minimizing tissue trauma, meticulous hemostasis, and employing minimally invasive techniques where feasible contribute significantly to SSI reduction [24]. Avoiding devitalized tissue and contamination during surgery is fundamental.

Postoperative Interventions

Wound Care

Adhesive drapes have been shown to increase SSI risk (RR 1.23, 95% CI 1.01–1.50) and are therefore not recommended [25]. Sterile dressing changes, coupled with strict hand hygiene, remain the standard of care. Although iodine-impregnated dressings have shown variable efficacy, they are not routinely recommended [26].

Drain Management

Surgical drains should be removed as early as clinically appropriate since prolonged use raises infection risk. Closed suction drains are preferable to open systems due to decreased contamination risk [27].

Early Mobilization

Early postoperative ambulation improves tissue oxygen delivery, reduces venous stasis, and decreases pulmonary complications, indirectly lowering SSI incidence [28].

Postoperative Glycemic Control

Maintaining normoglycemia in the postoperative period, particularly in diabetic patients, is essential to prevent infections. Continuous insulin infusions may be necessary for tight glucose control [29].

Ineffective or Harmful Practices

Table 2 summarizes common perioperative practices that have been shown to be ineffective or harmful in preventing SSIs.

Table 2: Ineffective Or Harmful Practices For SSI Prevention

Practice	Impact	Recommendation	Reference
Preoperative shaving	Increases SSI risk	Avoid	[17]
Adhesive drapes	Increases SSI risk	Avoid	[25]
Antiseptic bathing	No proven benefit	Not routinely required	[30]
Prolonged antibiotics	No added benefit	Stop after 24 hours	[19]
Surgical attire mandates	No significant impact	Not enforced	[31]

DISCUSSION

The evidence reviewed here confirms that the prevention of SSIs is attainable through a bundle of evidence-based, perioperative strategies. The most effective measures include chlorhexidine-alcohol skin antisepsis, maintenance of perioperative normothermia, preoperative smoking cessation, and appropriately timed antibiotic prophylaxis. These interventions not only improve clinical outcomes but also reduce healthcare costs by decreasing infection rates and shortening hospital stays.

Successful implementation of these strategies relies on bundled care approaches supported by institutional policies, education, and standardized protocols. The World Health Organization (WHO) Surgical Safety Checklist has proven effective in promoting adherence to evidence-based SSI prevention practices [4]. Eliminating obsolete or harmful practices, such as shaving and prolonged antibiotic use, is equally important to optimize resource use and prevent adverse outcomes.

Multidisciplinary collaboration is critical. Surgeons, anesthesiologists, nursing staff, and infection prevention specialists must work together to ensure compliance and continuous quality improvement. Auditing, feedback mechanisms, and ongoing education maintain adherence and sustain progress.

Future research directions include evaluating bundled interventions in low-resource environments, the role of antimicrobial stewardship programs, and tailoring preventive measures to patient-specific risk profiles. Additionally, health economic analyses can guide policymakers in resource allocation.

CONCLUSION

Surgical site infections remain a significant, yet largely preventable, source of postoperative morbidity. A structured, evidence-based approach is paramount. Key actionable recommendations include:

- Employing chlorhexidine-alcohol for preoperative skin antisepsis
- Maintaining perioperative normothermia
- Encouraging smoking cessation at least four weeks before surgery
- Administering timely, weight-based, and appropriate antibiotic prophylaxis

Healthcare systems should prioritize these interventions within quality improvement frameworks, supported by multidisciplinary teamwork, continuous monitoring, and education. Adoption of these strategies promises to reduce SSI rates substantially, improve patient safety, and decrease healthcare costs worldwide.

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