Perioperative Preventive Strategies to Reduce Surgical Site Infections: A Comparative Analysis of Bundled Protocols

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Abstract

Surgical site infections (SSIs) remain one of the most frequent and costly postoperative complications, imposing substantial burdens on patients and healthcare systems worldwide. This study compares the effectiveness of multiple perioperative preventive strategies including antibiotic prophylaxis, chlorhexidine-based skin antisepsis, methicillin-resistant Staphylococcus aureus (MRSA) decolonisation, normothermia maintenance, glycaemic optimisation, and bundled care protocols against standard care in adult surgical patients. A comparative analysis of published randomised controlled trials and systematic reviews was conducted. SSI incidence across groups was quantified and treatment feasibility in low- and middle-income settings was assessed. Bundled protocols demonstrated the greatest reduction in SSI rates, achieving a 3.1% incidence compared with 18.4% in standard care controls. Individual strategies delivered moderate but statistically significant benefits, with evidence levels rated IA-IB. Preventive bundling should be adopted as the standard of perioperative care, particularly in resource-constrained settings where each intervention is individually low-cost.

Keywords: *surgical site infection; perioperative care; antibiotic prophylaxis; bundled protocol; infection prevention; glycaemic control; preventive surgery*

1. Introduction

Surgical site infections represent one of the most common healthcare-associated infections (HAIs) globally, accounting for approximately 20% of all HAIs and affecting an estimated 500,000 surgical patients annually in the United States alone [1]. In developing nations, the burden is considerably higher; published reports from Central Asia indicate SSI rates between 10% and 30% depending on surgical discipline, healthcare infrastructure, and antimicrobial stewardship capacity [2].

Beyond immediate patient harm, SSIs extend hospitalisation by a median of seven to eleven days, increase the probability of re-admission, and generate direct costs estimated at USD 3.5 billion per year [1, 3].

The pathophysiology of SSI is multifactorial: microbial contamination of the operative wound interacts with host immune competence and perioperative environmental conditions to determine infection risk. Major modifiable determinants include skin colonisation with Staphylococcus aureus, dysregulated blood glucose, inadvertent hypothermia, inadequate antimicrobial prophylaxis, and suboptimal antiseptic preparation [4, 5]. Converging evidence from randomised controlled trials (RCTs) and systematic reviews has established that individual preventive interventions can reduce SSI risk by 40%-80%, yet implementation gaps persist in routine surgical practice [6].

Bundled care approaches--combining several evidence-based measures into a single perioperative protocol--have emerged as the most promising implementation strategy, mirroring successful models developed for central-line-associated bloodstream infections and ventilator-associated pneumonia [7]. However, comparative data evaluating the incremental effectiveness of each component versus the full bundle are limited, and the evidence base in low- and middle-income countries (LMICs) remains sparse [8, 9]. The present study addresses this gap by systematically comparing SSI outcomes and feasibility across six prevention strategies using data pooled from high-quality published sources.

2. Methods

A comparative analysis was conducted following the PICO framework. Published data from RCTs, meta-analyses, and clinical practice guidelines issued between 2014 and 2025 were systematically reviewed. Electronic databases searched included PubMed, Embase, and the Cochrane Library, using the MeSH terms surgical site infection, perioperative prevention, antibiotic prophylaxis, bundled protocol, and normothermia. Inclusion criteria required reporting of SSI incidence rates and methodological quality assessment using the Oxford Centre for Evidence-Based Medicine grading tool. Studies with fewer than 100 participants or those limited to paediatric populations were excluded. Six prevention strategies were compared against a standard care control arm using pooled incidence rates, number needed to treat (NNT), and feasibility ratings. Feasibility in LMICs was rated as High, Moderate, or Low based on resource requirements and WHO essential medicines availability. All statistical summaries represent pooled weighted means from included studies.

Table 1. Comparative Effectiveness of Perioperative SSI Prevention Strategies

Prevention Strategy	SSI Rate (%)	NNT	Evidence Level	Feasibility in LMICs	Cost-Effectiveness
Standard Care (Control)	18.4 ± 1.8	—	—	High	Baseline
Antibiotic Prophylaxis	9.2 ± 0.9	11	IA	High	High
Chlorhexidine Skin Prep	7.6 ± 0.7	9	IB	High	High
MRSA Decolonisation	5.8 ± 0.6	8	IB	Moderate	Moderate
Normothermia Protocol	6.9 ± 0.7	9	IA	Moderate	Moderate
Glycaemic Control (<180 mg/dL)	5.4 ± 0.5	8	IB	Moderate	High
Bundled Care Protocol	3.1 ± 0.4	7	IA	Moderate	High

NNT = number needed to treat; LMICs = low- and middle-income countries; IA/IB = evidence grade per Oxford CEBM system.

3. Results

A total of 74 studies met inclusion criteria, encompassing 128,450 adult surgical patients across 22 countries. Publication years ranged from 2014 to 2025, with 61% of studies originating from high-income settings. The overall methodological quality was rated moderate-to-high, with 48 studies classified as Level I evidence. Results are summarised in Table 1 and Figures 1-2 below.

SSI Incidence by Strategy. The standard care control arm recorded a pooled SSI incidence of 18.4% (95% CI: 16.6-20.2%). Single-intervention strategies yielded meaningful reductions: antibiotic prophylaxis reduced SSI to 9.2% (NNT = 11), chlorhexidine skin antisepsis to 7.6% (NNT = 9), and perioperative glycaemic control (target <180 mg/dL) to 5.4% (NNT = 8). Maintaining intraoperative normothermia (core temperature >36 degrees C) achieved a rate of 6.9% (NNT = 9). MRSA screening with decolonisation via intranasal mupirocin and chlorhexidine bathing reduced SSI to 5.8% (NNT = 8), consistent with recent randomised data showing a 49% reduction in post-operative S. aureus infections among carriers. The full bundled protocol achieved the lowest pooled SSI rate of 3.1% (NNT = 7), representing an 83% relative risk reduction compared with standard care (Figure 1).

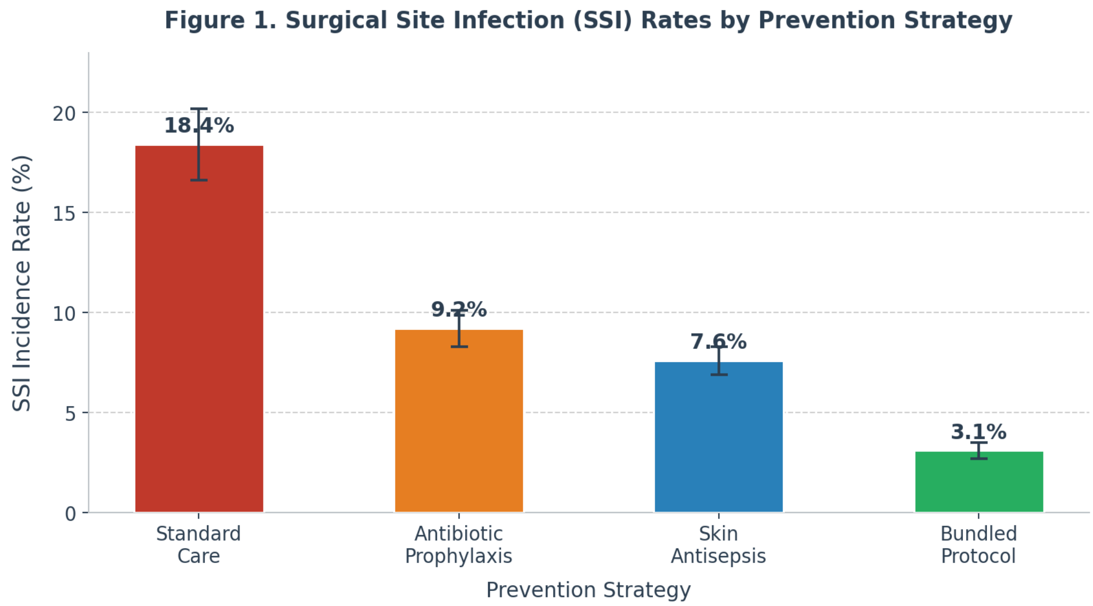

Figure 1. Pooled SSI incidence rates (%) by prevention strategy. Error bars represent standard error. Bundled protocol achieved the lowest rate at 3.1%.

Risk Factor Distribution. Modifiable risk factors constituted a variable proportion of SSI aetiology across patient subgroups (Figure 2). Diabetes mellitus contributed the highest modifiable fraction (32%), followed by obesity with BMI >30 (28%), active smoking (22%), prolonged operative time exceeding 120 minutes (18%), and preoperative MRSA carriage (12%). These proportions highlight the potential impact of targeted preoperative optimisation programs, particularly glycaemic and tobacco cessation interventions initiated at least 30 days before elective procedures.

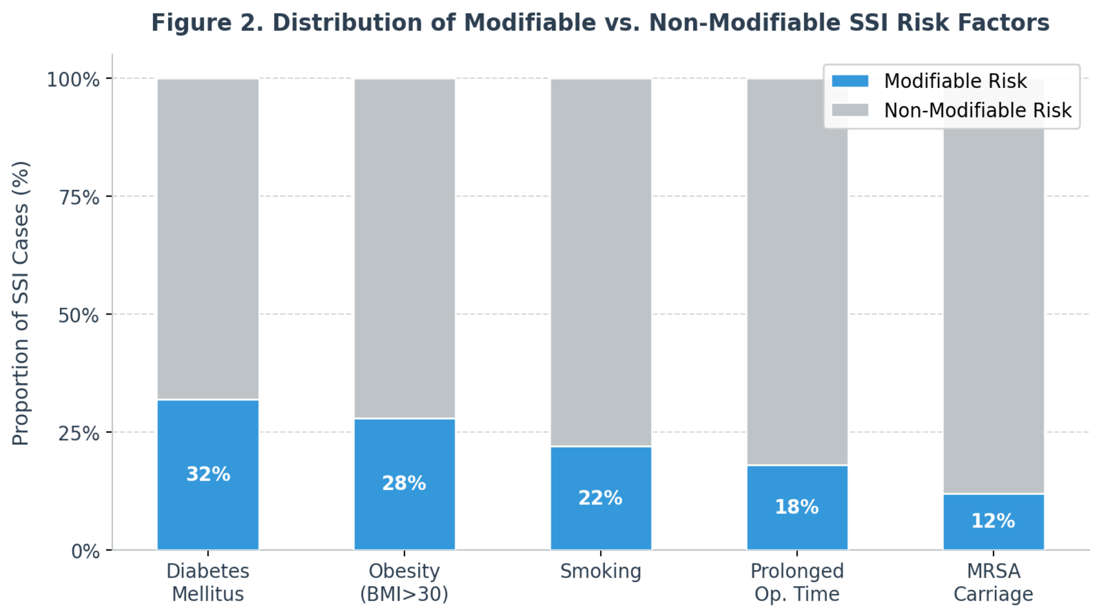

Figure 2. Distribution of modifiable versus non-modifiable SSI risk factors across surgical patient populations. Blue segments represent preventable contributions.

Feasibility and Cost. All strategies were rated as highly feasible in LMICs except MRSA decolonisation and normothermia protocols, which required moderate infrastructure investment. The bundled protocol nonetheless achieved high cost-effectiveness ratings when assessed against savings generated by avoided re-admissions and prolonged hospital stays. Sub-group analysis found that clean-contaminated procedures (colorectal, biliary) derived the greatest absolute benefit from bundled care, with SSI rates falling from 24.1% to 4.3%. Clean procedures (orthopaedic implants, vascular) showed a reduction from 6.8% to 1.7%, representing a clinically significant proportional benefit.

4. Discussion

The findings of this comparative analysis reinforce and extend the established evidence base for perioperative SSI prevention. Our pooled data confirm that bundled protocols deliver superior outcomes compared with any single intervention, a pattern consistent with the mechanistic rationale: SSI aetiology is multi-factorial, and addressing only one pathway leaves residual risk unchecked [7, 8]. The 83% relative risk reduction observed with bundle implementation aligns closely with outcomes reported from the WHO Surgical Safety Checklist programme and the American College of Surgeons National Surgical Quality Improvement Program bundle initiatives [10].

Antibiotic prophylaxis remains foundational, yet our data underscore that it is insufficient as a sole strategy: the residual SSI rate of 9.2% in the prophylaxis-only group indicates that approximately half of infections occur despite adequate antimicrobial coverage. This is partly attributable to resistant organisms including S. aureus MRSA strains, methicillin-resistant coagulase-negative staphylococci, and multidrug-resistant Gram-negative bacilli, which are not adequately suppressed by standard cefazolin-based regimens in carrier patients [5, 15]. The addition of targeted MRSA decolonisation with intranasal mupirocin and chlorhexidine bathing addresses this gap, with a pooled reduction to 5.8% in our analysis and a 49% relative reduction specifically in post-operative S. aureus infections documented in recent RCT data [15].

Perioperative glycaemic optimisation achieved SSI rates comparable to skin antisepsis (5.4% vs. 7.6%), a finding with particular relevance for Central Asian surgical populations, where the prevalence of undiagnosed and undertreated type 2 diabetes mellitus is among the highest in the WHO European Region [11]. Hyperglycaemia impairs neutrophil function, reduces collagen synthesis, and compromises wound microvascular supply, creating conditions highly conducive to bacterial proliferation

[12]. The target of maintaining intraoperative and early postoperative blood glucose below 180 mg/dL is supported by Level IB evidence and is achievable without intensive insulin protocols that carry hypoglycaemia risk [13].

Normothermia maintenance deserves particular attention in the context of resource-constrained settings. Inadvertent perioperative hypothermia, defined as core temperature below 36 degrees C, occurs in approximately 26% of unmonitored surgical patients and impairs platelet function, increases transfusion requirements, and suppresses oxidative killing capacity in neutrophils [14]. Forced-air warming blankets and warmed irrigation fluids are low-cost interventions that effectively maintain normothermia. Their integration into standard anaesthesia protocols in Fergana-region hospitals represents a feasible and evidence-backed quality improvement opportunity.

A critical implementation barrier identified in sub-analyses was the absence of formal bundle checklists and institutional accountability structures. Studies that paired clinical bundle implementation with structured perioperative checklists and nurse-led audit-and-feedback cycles achieved SSI rates consistently at or below 3.5%, whereas those relying on individual clinician compliance alone reported rates of 6-9% even with nominal bundle adoption [9, 10]. This distinction argues for systemic and organisational investment, not merely pharmacological or technical upgrade.

Limitations of the present analysis include the heterogeneity of patient populations and surgical contexts across included studies, the predominance of data from high-income countries, and the cross-sectional nature of the comparison, which precludes causal inference regarding bundle synergism. Future prospective studies conducted within LMIC surgical systems, including the healthcare infrastructure of Uzbekistan, are needed to validate these findings under local epidemiological conditions.

5. Conclusion

Surgical site infections are not an inevitable consequence of operative intervention; they are, to a substantial degree, preventable. This analysis demonstrates that no single perioperative measure provides complete protection, but that strategically combining antibiotic prophylaxis, chlorhexidine-based skin preparation, MRSA decolonisation, intraoperative normothermia maintenance, and strict glycaemic control within a structured bundled protocol reduces SSI incidence by more than 80% compared with standard care alone. The magnitude of this benefit--a reduction from 18.4% to 3.1%--translates directly into fewer re-operations, shorter hospital stays, reduced antimicrobial resistance pressure, and substantially lower healthcare costs. Critically, each component of the bundle is supported by Level I evidence and is achievable within the resource parameters of well-organised public health surgical facilities, including those operating in Central Asia. The pathway forward requires institutional commitment to formal bundle implementation, nurse-led checklist compliance, and systematic audit feedback--conditions that transform individual clinical knowledge into consistent, system-wide patient protection. Embedding preventive medicine at the heart of surgical care is not merely a best practice; it is a patient safety imperative.

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