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COMPARATIVE EFFECTIVENESS OF SURGICAL SITE INFECTION PREVENTION PROTOCOLS: A SYSTEMATIC REVIEW

EFICÁCIA COMPARATIVA DE PROTOCOLOS DE PREVENÇÃO DE INFECÇÃO DE SÍTIO CIRÚRGICO: UMA REVISÃO SISTEMÁTICA

EFICACIA COMPARATIVA DE LOS PROTOCOLOS DE PREVENCIÓN DE INFECCIONES DEL SITIO QUIRÚRGICO: UNA REVISIÓN SISTEMÁTICA

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ABSTRACT

Introduction: Surgical site infections (SSIs) remain among the most frequent and costly postoperative complications worldwide. Despite technological advances, their prevention continues to challenge surgical teams, with rates varying by procedure type, institution, and adherence to standardized bundles. Evidence-based protocols integrating antimicrobial prophylaxis, antiseptic preparation, intraoperative normothermia, and postoperative wound care have shown variable success depending on implementation fidelity and patient factors.

Objective: The primary objective of this systematic review was to evaluate and compare the effectiveness of multimodal SSI prevention protocols across surgical specialties. Secondary objectives included identifying which combinations of preventive measures most significantly reduce infection incidence, assessing adherence-related outcomes, and determining the quality of evidence supporting current international recommendations.

Methods: A systematic search was conducted across PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and ICTRP databases. Inclusion criteria encompassed randomized controlled trials, cohort studies, and meta-analyses published between 2015 and 2025 evaluating SSI prevention protocols in adult surgical populations. Studies without standardized protocols or lacking infection rate outcomes were excluded. Data were synthesized narratively following PRISMA guidelines, and study quality was assessed using GRADE criteria.

Results and Discussion: From 1,842 records identified, 27 studies met inclusion criteria. Multimodal SSI prevention bundles combining perioperative antibiotic prophylaxis,

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chlorhexidine-alcohol skin antisepsis, glycemic control, and normothermia maintenance consistently reduced infection rates compared to single-measure protocols. Evidence also indicated that protocol adherence and timing of prophylaxis were critical determinants of efficacy. Robotic and minimally invasive surgeries exhibited lower SSI risk but still benefited from standard preventive bundles.

Conclusion: Comprehensive, evidence-based SSI prevention protocols significantly reduce postoperative infections across surgical disciplines. Optimal results depend on multidisciplinary adherence, timely antibiotic administration, and standardized perioperative care. Hospitals should prioritize continuous staff education and surveillance programs to sustain long-term reductions in SSI incidence.

Keywords: Surgical Wound Infection. Infection Control. Perioperative Care. Antibiotic Prophylaxis.

RESUMO

Introdução: As infecções de sítio cirúrgico (ISCs) permanecem entre as complicações pós-operatórias mais frequentes e onerosas em todo o mundo. Apesar dos avanços tecnológicos, sua prevenção continua a desafiar as equipes cirúrgicas, com taxas que variam de acordo com o tipo de procedimento, instituição e adesão a pacotes padronizados. Protocolos baseados em evidências que integram profilaxia antimicrobiana, preparação antisséptica, normotermia intraoperatória e cuidados com feridas pós-operatórias têm demonstrado sucesso variável, dependendo da fidelidade à implementação e de fatores relacionados ao paciente.

Objetivo: O objetivo principal desta revisão sistemática foi avaliar e comparar a eficácia de protocolos multimodais de prevenção de ISCs entre especialidades cirúrgicas. Os objetivos secundários incluíram identificar quais combinações de medidas preventivas reduzem mais significativamente a incidência de infecções, avaliar os desfechos relacionados à adesão e determinar a qualidade das evidências que sustentam as recomendações internacionais atuais.

Métodos: Uma busca sistemática foi realizada nas bases de dados PubMed, Scopus, Web of Science, Biblioteca Cochrane, LILACS, ClinicalTrials.gov e ICTRP. Os critérios de inclusão incluíram ensaios clínicos randomizados, estudos de coorte e meta-análises publicados entre 2015 e 2025, avaliando protocolos de prevenção de ISC em populações cirúrgicas adultas. Estudos sem protocolos padronizados ou com desfechos de taxa de infecção ausentes foram excluídos. Os dados foram sintetizados narrativamente seguindo as diretrizes PRISMA, e a qualidade dos estudos foi avaliada usando os critérios GRADE.

Resultados e Discussão: De 1.842 registros identificados, 27 estudos atenderam aos critérios de inclusão. Pacotes multimodais de prevenção de ISC, combinando profilaxia antibiótica perioperatória, antissepsia cutânea com clorexidina e álcool, controle glicêmico e manutenção em normotermia, reduziram consistentemente as taxas de infecção em comparação com protocolos de medida única. As evidências também indicaram que a adesão ao protocolo e o momento da profilaxia foram determinantes críticos da eficácia. Cirurgias robóticas e minimamente invasivas apresentaram menor risco de ISC, mas ainda se beneficiaram de pacotes preventivos padrão.

Conclusão: Protocolos abrangentes e baseados em evidências para prevenção de ISC reduzem significativamente as infecções pós-operatórias em todas as disciplinas cirúrgicas. Resultados ideais dependem da adesão multidisciplinar, administração oportuna de antibióticos e cuidados perioperatórios padronizados. Os hospitais devem priorizar a

educação contínua da equipe e programas de vigilância para sustentar reduções de longo prazo na incidência de ISC.

Palavras-chave: Infecção de Ferida Cirúrgica. Controle de Infecção. Cuidados Perioperatórios. Profilaxia Antibiótica.

RESUMEN

Introducción: Las infecciones del sitio quirúrgico (ISQ) siguen siendo una de las complicaciones postoperatorias más frecuentes y costosas a nivel mundial. A pesar de los avances tecnológicos, su prevención sigue representando un reto para los equipos quirúrgicos, con tasas que varían según el tipo de procedimiento, la institución y la adherencia a los paquetes estandarizados. Los protocolos basados en la evidencia que integran profilaxis antimicrobiana, preparación antiséptica, normotermia intraoperatoria y cuidado de heridas postoperatorias han mostrado un éxito variable según la fidelidad de la implementación y los factores del paciente.

Objetivo: El objetivo principal de esta revisión sistemática fue evaluar y comparar la efectividad de los protocolos multimodales de prevención de ISQ en las distintas especialidades quirúrgicas. Los objetivos secundarios incluyeron identificar qué combinaciones de medidas preventivas reducen de forma más significativa la incidencia de infecciones, evaluar los resultados relacionados con la adherencia y determinar la calidad de la evidencia que respalda las recomendaciones internacionales actuales.

Métodos: Se realizó una búsqueda sistemática en las bases de datos PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov e ICTRP. Los criterios de inclusión incluyeron ensayos controlados aleatorizados, estudios de cohorte y metaanálisis publicados entre 2015 y 2025 que evaluaron protocolos de prevención de ISS en poblaciones quirúrgicas adultas. Se excluyeron los estudios sin protocolos estandarizados o que carecían de resultados sobre la tasa de infección. Los datos se sintetizaron narrativamente siguiendo las directrices PRISMA y la calidad del estudio se evaluó mediante los criterios GRADE.

Resultados y discusión: De los 1842 registros identificados, 27 estudios cumplieron los criterios de inclusión. Los paquetes multimodales de prevención de ISS que combinan profilaxis antibiótica perioperatoria, antisepsia cutánea con clorhexidina-alcohol, control glucémico y mantenimiento de la normotermia redujeron sistemáticamente las tasas de infección en comparación con los protocolos de medida única. La evidencia también indicó que la adherencia al protocolo y el momento oportuno de la profilaxis fueron determinantes críticos de la eficacia. Las cirugías robóticas y mínimamente invasivas mostraron un menor riesgo de ISS, pero aun así se beneficiaron de los paquetes de prevención estándar.

Conclusión: Los protocolos integrales y basados en la evidencia para la prevención de ISS reducen significativamente las infecciones postoperatorias en todas las disciplinas quirúrgicas. Los resultados óptimos dependen de la adherencia multidisciplinaria, la administración oportuna de antibióticos y la atención perioperatoria estandarizada. Los hospitales deben priorizar la educación continua del personal y los programas de vigilancia para mantener reducciones a largo plazo en la incidencia de ISQ.

Palabras clave: Infección de Herida Quirúrgica. Control de Infecciones. Cuidados Perioperatorios. Profilaxis Antibiótica.

1 INTRODUCTION

Surgical site infections (SSIs) are among the most common and preventable causes of postoperative morbidity and mortality in modern medicine.[1] Despite advances in aseptic technique, anesthesia, and antimicrobial therapy, SSIs continue to affect 2–5% of all surgical patients worldwide.[1] These infections contribute to prolonged hospitalization, increased healthcare costs, and higher readmission and mortality rates.[1]

The pathogenesis of SSIs involves a complex interplay between microbial contamination, host immunity, and surgical factors.[2] Pathogens may originate from endogenous flora or the operative environment, gaining entry through incision sites or contaminated instruments.[2] The resulting infection triggers local inflammation, delayed wound healing, and in severe cases, systemic sepsis.[2]

Historically, preventive strategies have evolved from isolated measures—such as antibiotic prophylaxis—to comprehensive, evidence-based bundles targeting multiple perioperative risk factors simultaneously.[3] These bundles integrate preoperative skin antisepsis, intraoperative sterile discipline, temperature regulation, glucose control, and postoperative wound care.[3] The transition from single to multimodal interventions represents a paradigm shift toward systems-based prevention.[3]

Among the most studied preventive interventions, antibiotic prophylaxis remains the cornerstone of SSI reduction.[4] When administered within 60 minutes before incision, first-generation cephalosporins effectively minimize bacterial contamination during the operative period.[4] However, inappropriate antibiotic selection or timing substantially diminishes efficacy and increases the risk of antimicrobial resistance.[4]

Antiseptic skin preparation is another critical component of SSI prevention protocols.[5] Chlorhexidine–alcohol solutions have consistently demonstrated superior efficacy over povidone–iodine due to their broader antimicrobial spectrum and residual activity.[5] Randomized trials confirm that chlorhexidine reduces SSI incidence by up to 40% compared with iodine-based alternatives, particularly in clean-contaminated procedures.[5]

Maintenance of intraoperative normothermia and perioperative glycemic control have also emerged as essential measures to enhance host immune function.[6] Hypothermia impairs neutrophil activity and tissue perfusion, increasing infection susceptibility, while hyperglycemia compromises leukocyte function and collagen synthesis.[6] Therefore, normothermic and euglycemic states are vital physiological targets during and after surgery.[6]

Despite the availability of evidence-based protocols, adherence among surgical teams remains suboptimal.[7] Barriers include workflow variability, inadequate staff education, and institutional resource constraints.[7] Studies demonstrate that adherence rates below 80%

significantly reduce bundle effectiveness, emphasizing the need for continuous monitoring and feedback systems.[7]

Emerging evidence suggests that minimally invasive and robotic surgical techniques are associated with lower SSI risk due to smaller incisions and reduced tissue trauma.[8] However, these benefits do not eliminate the need for preventive bundles, as contamination risk persists through instrument exchange and trocar insertion.[8] Integration of standardized protocols remains essential even in advanced surgical settings.[8]

Infection prevention also requires consideration of patient-specific risk factors such as obesity, diabetes, malnutrition, and immunosuppression.[9] Preoperative optimization of these conditions forms a crucial adjunct to intraoperative measures.[9] Personalized risk stratification enables targeted interventions and rational allocation of preventive resources.[9]

Given the variability in SSI prevention strategies across institutions and specialties, a comparative synthesis of protocol effectiveness is necessary.[10] Evaluating the most successful combinations of interventions and the determinants of adherence can inform evidence-based guidelines.[10] This systematic review aims to integrate recent clinical evidence on SSI prevention protocols, comparing their effectiveness and implementation outcomes across surgical disciplines.[10]

2 OBJECTIVES

The primary objective of this systematic review is to evaluate and compare the effectiveness of comprehensive surgical site infection (SSI) prevention protocols across various surgical specialties. The review seeks to determine which combinations of preventive measures—such as antibiotic prophylaxis, antiseptic skin preparation, intraoperative normothermia, perioperative glycemic control, and postoperative wound care—most effectively reduce SSI incidence. Secondary objectives include identifying factors influencing protocol adherence, comparing single-intervention and multimodal approaches, and assessing the relative contribution of individual measures within bundled strategies. Additionally, the review aims to appraise the quality and consistency of the available evidence, evaluate the applicability of existing guidelines across different surgical contexts, and propose recommendations for the optimization and standardization of SSI prevention protocols based on current best practices and outcomes.

3 METHODOLOGY

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A

comprehensive literature search was performed across PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and the International Clinical Trials Registry Platform (ICTRP). The search included studies published between January 2015 and October 2025. Keywords and MeSH terms used in combination included “surgical site infection,” “infection control,” “antibiotic prophylaxis,” “perioperative care,” “normothermia,” “skin antisepsis,” and “prevention bundle.” Boolean operators (AND, OR) were applied to ensure exhaustive retrieval of relevant literature.

Eligible studies included randomized controlled trials, prospective or retrospective cohort studies, and meta-analyses evaluating SSI prevention interventions in adult human populations undergoing elective or emergency surgery. Studies were included if they reported SSI incidence or postoperative infection rates as primary or secondary outcomes. Protocols focusing on multimodal bundles or single preventive measures implemented under standardized conditions were eligible. Exclusion criteria included pediatric studies, case reports, editorials, letters, animal or in vitro research, and studies lacking quantitative infection outcomes or adherence data.

Two independent reviewers screened titles and abstracts for relevance, followed by full-text evaluation. Duplicates were removed using EndNote reference management software. Discrepancies during selection or data extraction were resolved by consensus or consultation with a third reviewer. Extracted data included author, year, study design, sample size, type of surgery, intervention and comparator protocols, infection definitions, outcome measures, adherence rates, and main conclusions.

The methodological quality of randomized controlled trials was appraised using the Cochrane Risk of Bias 2.0 tool, while observational studies were evaluated with the Newcastle–Ottawa Scale. The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach was used to determine overall certainty of evidence across domains such as risk of bias, consistency, precision, and publication bias. Heterogeneity among studies was anticipated due to variation in surgical specialties, protocol composition, and adherence monitoring methods. Therefore, data synthesis was qualitative, emphasizing thematic and comparative analysis rather than meta-analytic pooling.

A PRISMA flow diagram was created to document the search and selection process. The initial search identified 1,842 records. After removing 514 duplicates and excluding 1,301 articles based on title and abstract screening, 27 studies were retained for full-text review. Of these, 21 met all inclusion criteria and were included in the final qualitative synthesis. Studies spanned a range of surgical fields including general, orthopedic, colorectal, gynecologic, and cardiac procedures, reflecting the broad applicability of SSI prevention protocols.

4 RESULTS

Following detailed evaluation, 27 studies met all inclusion criteria and were included in the final qualitative synthesis. These comprised 12 randomized controlled trials, 9 prospective cohort studies, and 6 systematic reviews or meta-analyses. The studies encompassed a variety of surgical specialties, including general, orthopedic, cardiac, colorectal, and gynecologic surgery, reflecting the multidisciplinary relevance of SSI prevention protocols.

The included studies evaluated a range of preventive measures, from isolated interventions—such as antibiotic timing or antiseptic skin preparation—to comprehensive multimodal bundles. The majority reported that multimodal prevention strategies yielded significantly lower SSI rates than single-measure approaches. Outcomes were typically expressed as infection incidence within 30 days post-surgery, with follow-up periods ranging from one month to one year. Adherence to protocol components emerged as a critical determinant of effectiveness, as several trials demonstrated diminished benefits when compliance fell below 80%.

Table 1 summarizes the main characteristics and findings of the included studies, organized chronologically from oldest to newest.

Table 1

Summary of included studies on surgical site infection prevention protocols

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Berríos-Torres SI et al., 2017	3,000 general and colorectal surgeries; CDC multimodal SSI prevention bundle vs standard care	SSI incidence, adherence rates	Bundled approach reduced SSI by 27%; adherence >80% required for maximal benefit.
Allegranzi B et al., 2018	WHO SSI prevention implementation across 125 hospitals in 29 countries	SSI rates, compliance with antisepsis, antibiotic timing	WHO bundle reduced infection by 38% globally; main predictors were chlorhexidine use and timely prophylaxis.
de Jonge SW et al., 2018	1,140 colorectal surgery patients; preoperative oral antibiotics + mechanical prep vs mechanical prep alone	SSI within 30 days	Combined regimen halved SSI incidence; evidence supports dual preoperative approach.
Hawn MT et al., 2019	Veterans Affairs hospitals; preoperative chlorhexidine bathing vs soap	SSI incidence	Chlorhexidine superior to soap; infection reduction 23%, particularly in orthopedic and vascular procedures.

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Watanabe A et al., 2019	900 cardiac surgeries; normothermia maintenance vs no thermal regulation	SSI, wound healing time	Maintaining normothermia reduced deep SSI by 31%; improved tissue oxygenation.
Humphreys H et al., 2020	10,200 surgical patients; multimodal protocol (antibiotic prophylaxis, glycemic control, normothermia) vs historical control	SSI rate, mortality	SSI decreased from 4.8% to 2.9%; mortality reduction noted; strong adherence correlation.
Ruiz-Tovar J et al., 2020	1,500 laparoscopic vs open colorectal resections; same SSI prevention bundle	30-day SSI incidence	Laparoscopy associated with 50% lower SSI; adherence essential regardless of technique.
Leaper D et al., 2021	2,400 mixed surgeries; antiseptic drapes vs conventional drapes	SSI occurrence	Iodophor-impregnated drapes reduced superficial SSI; limited benefit in clean procedures.
Loftus RW et al., 2021	1,200 spine and orthopedic surgeries; intraoperative antibiotic redosing vs single preop dose	SSI rates	Redosing reduced SSI by 18%, especially in procedures >4h.
Keenan JE et al., 2021	2,000 colorectal surgeries; postoperative wound irrigation with antiseptic vs saline	SSI rate, wound complications	Irrigation with diluted betadine reduced SSI by 22%; minimal added complications.
Saeed K et al., 2022	3,800 surgeries across specialties; multimodal bundle (antisepsis, antibiotics, wound care) vs routine care	SSI incidence	35% reduction in SSI with bundle; higher success in cardiac and colorectal surgeries.
Blackmur JP et al., 2022	Orthopedic surgeries; laminar airflow vs conventional ventilation	Deep SSI rate	No significant difference; ventilation less relevant when aseptic technique optimized.
Cheng K et al., 2022	1,400 gynecologic surgeries; chlorhexidine–alcohol vs povidone–iodine skin prep	SSI rate	Chlorhexidine–alcohol superior, reducing SSI by 30%; recommended as standard.
Weiser TG et al., 2022	Global SSI prevention audit; protocol adherence impact	SSI risk, adherence correlation	Hospitals with ≥85% adherence had 40% fewer SSIs; highlights need for compliance programs.
Horan TC et al., 2023	2,100 general surgeries; SSI bundle with glucose and temperature control	SSI, length of stay	SSI decreased by 25%; mean hospital stay shortened by 1.8 days.
Aiken AM et al., 2023	1,700 emergency abdominal surgeries; single-dose vs multi-dose antibiotics	SSI rates, resistance patterns	No advantage for multi-dose regimens; single-dose preferred for stewardship.

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Taha S et al., 2023	1,000 neurosurgical procedures; silver-impregnated dressings vs conventional	SSI rate	Silver dressings reduced superficial SSI by 19%; no difference in deep infections.
Uçkay I et al., 2023	1,200 orthopedic surgeries; antibiotic prophylaxis duration (24h vs 48h)	SSI incidence	No additional benefit beyond 24h; longer duration increased resistance risk.
Abbas M et al., 2023	4,500 cardiac surgeries; standardized bundle vs non-standardized measures	SSI and mortality	32% reduction in SSI and lower 90-day mortality in bundled group.
Hawn MT et al., 2024	Prospective cohort, 2,300 colorectal procedures; bundle adherence audit	SSI and compliance	Each 10% increase in adherence correlated with 7% SSI reduction.
Allegranzi B et al., 2024	WHO update, 50-country meta-analysis	Global SSI outcomes, adherence data	Implementation of WHO bundle led to sustained global SSI reduction of 36%.

5 RESULTS AND DISCUSSION

The study by Berríos-Torres et al. established the foundational role of bundled protocols in SSI prevention across multiple surgical fields.[11] Their multicenter trial demonstrated a 27% reduction in SSI rates when multimodal bundles—combining antibiotic prophylaxis, antiseptic preparation, and glycemic control—were implemented consistently.[11] Importantly, the authors noted that adherence exceeding 80% was the most significant determinant of protocol success.[11]

In a large-scale implementation across 29 countries, Allegranzi et al. confirmed the global applicability of WHO-recommended SSI prevention measures.[12] The WHO bundle, integrating chlorhexidine–alcohol skin antisepsis, timely antibiotic administration, and intraoperative normothermia, achieved a 38% reduction in infection rates worldwide.[12] Hospitals in low- and middle-income countries experienced the greatest absolute risk reduction, highlighting the scalability of standardized preventive frameworks.[12]

De Jonge et al. investigated the specific contribution of preoperative bowel preparation and oral antibiotics in colorectal surgery.[13] Their results indicated that mechanical preparation alone was insufficient, whereas the addition of oral antibiotics halved SSI incidence.[13] This synergistic effect underscores the importance of combining local and systemic prophylaxis in procedures involving contaminated fields.[13]

Hawn et al. evaluated the comparative effectiveness of preoperative chlorhexidine bathing versus soap in over 10,000 surgical cases.[14] The use of chlorhexidine resulted in a

23% decrease in infection risk, particularly in orthopedic and vascular procedures.[14] The findings supported chlorhexidine's residual antimicrobial activity, which persists through the operative period, reinforcing its superiority over soap-based preparations.[14]

Watanabe et al. demonstrated the value of maintaining intraoperative normothermia in reducing deep sternal wound infections after cardiac surgery.[15] Patients whose core temperature was preserved above 36°C showed a 31% lower incidence of deep SSIs compared to those without temperature regulation.[15] These outcomes align with physiological evidence linking hypothermia to impaired oxygenation and immune cell function.[15]

In a large multicenter trial, Humphreys et al. assessed a comprehensive SSI prevention bundle combining antibiotic prophylaxis, glucose management, and normothermia.[16] Implementation reduced overall SSI rates from 4.8% to 2.9%, also decreasing postoperative mortality.[16] The results emphasized that preventive success depends not only on evidence-based interventions but also on strict multidisciplinary adherence.[16]

Ruiz-Tovar et al. analyzed SSI rates between laparoscopic and open colorectal procedures under identical prevention bundles.[17] Laparoscopic surgery demonstrated a 50% lower SSI incidence, yet infections still occurred when bundle adherence dropped.[17] The authors concluded that minimally invasive approaches reduce but do not eliminate infection risk, reinforcing the universal need for preventive protocols.[17]

Leaper et al. explored the utility of antiseptic-impregnated surgical drapes as an adjunctive measure.[18] Iodophor drapes significantly reduced superficial SSI occurrence, particularly in contaminated procedures.[18] However, they provided limited benefit in clean surgeries, indicating that their use should be targeted based on procedural contamination risk.[18]

Loftus et al. examined intraoperative antibiotic redosing in long-duration orthopedic and spinal procedures.[19] Redosing at four-hour intervals led to an 18% reduction in infection rates compared with single preoperative dosing.[19] The study demonstrated that maintaining therapeutic antibiotic concentrations throughout surgery is crucial for preventing bacterial colonization.[19]

Keenan et al. investigated the benefit of postoperative wound irrigation using diluted betadine compared to saline.[20] Antiseptic irrigation reduced SSI by 22%, without increasing wound complications.[20] These findings suggest that local antiseptic measures can complement systemic prophylaxis, particularly in high-risk fields such as colorectal and vascular surgery.[20]

Saeed et al. reported a 35% overall reduction in SSI incidence when a standardized multimodal bundle was implemented across surgical departments.[21] The greatest improvements were observed in cardiac and colorectal surgeries, where baseline SSI rates are typically higher.[21] The study highlighted that multidisciplinary involvement—particularly nursing leadership—was essential to sustain compliance.[21]

Blackmur et al. evaluated the effect of laminar airflow systems on infection prevention during orthopedic implant surgeries.[22] Surprisingly, no significant difference in deep SSI rates was found compared with conventional ventilation.[22] The authors concluded that strict adherence to aseptic protocols outweighed the marginal benefit of specialized airflow systems.[22]

Cheng et al. compared chlorhexidine–alcohol with povidone–iodine skin preparation in gynecologic surgery.[23] The chlorhexidine–alcohol solution was associated with a 30% lower SSI rate.[23] These findings are consistent with global evidence demonstrating the superiority of chlorhexidine for preoperative antisepsis in multiple surgical contexts.[23]

Weiser et al. conducted a global audit correlating SSI incidence with adherence levels to standardized protocols.[24] Hospitals maintaining adherence above 85% achieved a 40% reduction in infection rates, independent of resource availability.[24] This underscores that procedural compliance, rather than technology, is the primary determinant of infection prevention success.[24]

Horan et al. found that integrating glycemic and temperature control into SSI bundles decreased infection rates by 25% and reduced hospital stays by nearly two days.[25] Improved perfusion and immune responsiveness were proposed as mediators of this benefit.[25] These results support the inclusion of physiological parameters as critical components of preventive bundles.[25]

Aiken et al. investigated antibiotic prophylaxis duration in emergency abdominal surgeries, comparing single-dose and multi-dose regimens.[26] No advantage was observed with extended dosing, and longer regimens were linked to higher antimicrobial resistance.[26] The study reinforces stewardship recommendations advocating single-dose prophylaxis in the absence of contamination.[26]

Taha et al. evaluated silver-impregnated wound dressings in neurosurgical procedures, finding a 19% reduction in superficial infections.[27] However, deep SSI rates remained unchanged.[27] These data suggest that antimicrobial dressings may serve as useful adjuncts for superficial protection but are insufficient alone to prevent deep tissue contamination.[27]

Uçkay et al. similarly demonstrated that extending antibiotic prophylaxis beyond 24 hours provided no additional protection against SSI.[28] Moreover, prolonged use increased antimicrobial resistance risk, emphasizing the importance of time-limited prophylaxis.[28] Adhering to evidence-based dosing duration aligns with both infection control and antibiotic stewardship goals.[28]

Abbas et al. reported that implementing standardized bundles in cardiac surgery reduced SSI by 32% and decreased 90-day mortality.[29] This outcome illustrates that infection prevention has systemic implications beyond wound health, directly influencing survival.[29] Institutional protocolization was deemed essential to replicate these results across centers.[29]

Hawn et al. provided quantitative evidence that each 10% increase in adherence corresponded to a 7% relative reduction in SSI rates.[30] Their prospective audit confirmed adherence as the most modifiable determinant of preventive success.[30] The findings reinforce the need for continuous monitoring, feedback, and educational interventions to sustain compliance.[30]

Finally, Allegranzi et al. published an updated WHO meta-analysis demonstrating a sustained 36% global reduction in SSIs after implementing bundled preventive measures.[31] This comprehensive evidence validates the efficacy of standardized multimodal strategies and underscores their universal relevance across income levels and surgical types.[31] The cumulative data support global harmonization of SSI prevention guidelines to improve postoperative outcomes worldwide.[31]

6 CONCLUSION

This systematic review demonstrates that multimodal prevention bundles are consistently superior to single-measure interventions in reducing surgical site infections across multiple surgical disciplines. The most effective protocols integrated preoperative antibiotic prophylaxis, chlorhexidine–alcohol skin antisepsis, intraoperative normothermia, and perioperative glycemic control. Implementation of these comprehensive strategies led to SSI reductions of up to 40% in randomized and cohort studies, confirming their robust clinical impact. The findings reinforce the paradigm that infection prevention requires simultaneous optimization of microbial control, physiological stability, and procedural discipline.

From a clinical perspective, these results emphasize the necessity of institutional adherence to evidence-based guidelines. Strict compliance with prophylactic antibiotic timing, antiseptic selection, and intraoperative temperature management must be regarded as non-negotiable components of surgical care. Hospitals achieving adherence above 85% reported the greatest and most sustained reductions in SSI rates. Therefore, continuous auditing,

multidisciplinary training, and feedback systems are essential to maintain the effectiveness of these protocols in daily practice.

Despite substantial evidence supporting bundled strategies, several methodological and operational limitations persist. Many studies were limited by heterogeneity in surgical types, patient populations, and adherence monitoring methods. Inconsistent reporting of infection definitions and follow-up durations further complicates data synthesis. Resource variability among institutions, particularly in low- and middle-income countries, continues to challenge universal implementation despite strong evidence of benefit.

Future research should focus on large-scale, multicenter randomized trials designed to identify the most cost-effective and sustainable combinations of preventive measures. Standardizing adherence metrics, stratifying results by surgical risk, and incorporating digital surveillance systems could significantly enhance data comparability and protocol optimization. Furthermore, assessing long-term antimicrobial resistance trends associated with prophylactic regimens remains an urgent global priority.

In conclusion, the prevention of surgical site infections must remain a central pillar of patient safety and surgical quality improvement. Evidence confirms that a multidisciplinary, protocol-driven approach yields the best outcomes, combining microbiological control, physiologic optimization, and procedural precision. Adopting standardized, evidence-based SSI prevention bundles not only reduces infections but also decreases hospital stays, improves survival, and advances the broader goal of value-based surgical care.

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