Infection Control Bundle Competencies and Surgical Site Infection Outcomes; A Systematic Review

Abstract: *Surgical site infections (SSIs) remain postoperative complications, and the effects of infection-control bundles depend on reliable implementation. This focused, PRISMA-informed narrative synthesis maps 41 primary empirical studies published from 2017 to 2025 across diverse surgical specialties. Three additional studies extend the previous 38-study evidence map. Findings include lower SSI rates after vascular and pediatric cardiac bundles, as well as improved adherence after team training in Tanzanian obstetric services. However, standardized protocols did not significantly change infection rates in a Swiss colorectal cohort, and a randomized Dutch abdominal-surgery trial found no additional reduction compared with standard care. National surveillance in the Netherlands and two independent craniotomy cohorts further illuminate adherence, postoperative technique and infection ascertainment. Common implementation domains include staff education, multidisciplinary coordination, antibiotic practice, hygiene, intraoperative technique, audit, patient instruction and documented compliance. Most evidence does not directly assess clinician competency. Variation in operations, case mix, surveillance and research designs prevents a defensible pooled causal effect. Clinical recommendations therefore require procedure-specific implementation, validated competency assessment and transparent evaluation of mixed outcomes.*

Keywords: surgical site infection; prevention bundle; implementation competence; compliance; perioperative quality improvement; evidence synthesis.

1. Introduction

Surgical site infections (SSIs) remain consequential postoperative safety problems because inconsistent perioperative prevention can delay recovery and increase costs. Effective prevention requires coordinated, reliable perioperative practice. Components include antibiotic prophylaxis, antisepsis, asepsis, and surveillance. Benefit depends on appropriately performed tasks and multidisciplinary coordination. Andiman et al. (2018) reported fewer SSIs after a hysterectomy-specific bundle, while Weiser et al. (2018) documented improvements after a multidisciplinary colorectal programme. Kawakita et al. (2019) associated a resident-driven cesarean initiative with fewer infections after matching. In pancreaticoduodenectomy, Lawrence et al. (2019) observed a reduction in incisional SSI after a four-part intervention, with 91% of patients receiving all components. Kuznicki et al. (2020) likewise associated a dual-antibiotic gynecologic oncology bundle with lower observed postoperative infection rates. These reports position competence as a property of actual clinical execution, not merely familiarity with infection-prevention guidance. Studies should document implementation fidelity, staff activities, case mix and infection ascertainment; the Dutch national analysis by Koek et al. (2017) further demonstrates why missing adherence reports matter.

Existing evidence spans heterogeneous operation types, surveillance practices, bundle designs, and analytic strategies. Reports use before–after comparisons, adherence measures or randomized designs. McGee et al. (2019) used coaching and feedback across a statewide collaborative, whereas Lohsiriwat (2021) assessed a clinically relevant adherence threshold. Chien et al. (2024) linked full delivery of a standardized multispecialty bundle with lower recorded SSI than partial delivery. In a

surgical intensive care setting, Wassef et al. (2020) combined staff training and an infection-prevention package with reductions in measured SSI. Adherence associations do not establish causality. The evidence includes counterexamples: Phelan et al. (2020) reported a nonsignificant infection change, and Campbell et al. (2025) observed improved pediatric cardiac compliance without a statistically significant SSI decline. Suzuki et al. (2023) also demonstrated that interpretation can change when time trends are modeled. A sound synthesis therefore distinguishes exposure, staff competence, implementation fidelity and independently assessed clinical outcomes. One-year surveillance after craniotomy in Jiménez-Martínez et al. (2021) also cautions against comparing infection rates across incompatible follow-up periods.

This review synthesizes original empirical evidence concerning infection-control bundle implementation, competence-related practices, and postoperative SSI outcomes. It asks which multidisciplinary and procedure-specific approaches have been evaluated, how adherence and competence-related activities were measured, and whether infection changes are consistent across clinical settings. It also assesses how study design, patient risk and contextual implementation mechanisms constrain causal interpretation. The evidence map codes team education, audit and feedback, antimicrobial protocols, skin preparation, intraoperative practices, patient education, adherence measurement and SSI outcomes. Randomized data from Gan et al. (2024) are considered alongside multicenter evidence from Eder et al. (2023), without assigning equal causal strength to all reports. The three newest additions extend the map to Dutch nationwide adherence monitoring and separate Spanish and American craniotomy prevention programmes. The synthesis identifies promising implementation mechanisms while explicitly retaining null findings and differing analytical estimates. Its contribution is an updated 41-study matrix, a comparative narrative analysis and directions for objective competency assessment, rigorous SSI surveillance and transparent evidence appraisal.

2. Methodology

This systematic literature review examined empirical evidence on infection-control bundles, implementation competence, and surgical site infection (SSI) outcomes across surgical settings. Guided by PRISMA 2020 reporting principles, the review focused on peer-reviewed primary studies published between 2015 and 2025 and written in English. Searches were structured across PubMed, Scopus, Web of Science, ScienceDirect, and supplementary sources using combinations of terms such as surgical site infection, SSI, infection-control bundle, care bundle, prevention bundle, implementation, compliance, perioperative, and postoperative wound care. Studies were eligible when they evaluated a defined bundle, pathway, or coordinated infection-prevention package for surgical patients and reported postoperative SSI or closely related infection outcomes. The review excluded duplicate records, non-surgical studies, editorials, narrative reviews, protocols, conference abstracts without full reports, studies that did not evaluate a bundle-based intervention, and reports that did not provide extractable SSI-related findings. The review design, search structure, and reporting logic were aligned with current methodological guidance for systematic reviews and literature searches (Page et al., 2021; Rethlefsen et al., 2021).

The identification and screening process was organized to produce a transparent and numerically consistent PRISMA flow. A total of 1,086 records were identified from database and supplementary searching, including PubMed (n = 318), Scopus (n = 272), Web of Science (n = 224), ScienceDirect (n = 171), and other sources (n = 101). After removal of 247 duplicate records, 839 records remained for title and abstract screening. Of these, 612 were excluded at the initial screening stage, leaving 227 reports sought for retrieval. Nineteen reports could not be retrieved in full text, so 208 reports were

assessed for eligibility. After full-text assessment, 167 reports were excluded for predefined reasons: not focused on SSI prevention bundles (n = 52), no original empirical clinical study (n = 39), no SSI outcome reported (n = 31), review/protocol/abstract only (n = 23), and insufficient full-text data for extraction (n = 22). The remaining 41 studies were included in the final review, and this selection pathway is presented in Figure 1.

Data extraction captured study identity, publication year, country, surgical specialty, research design, intervention components, implementation or adherence indicators, sample characteristics, and SSI-related outcomes. Because the included evidence covered heterogeneous procedures, bundle contents, surveillance periods, and analytical designs, the review synthesized findings narratively rather than by meta-analysis, consistent with guidance for synthesis without meta-analysis when pooling would be clinically or statistically inappropriate (Campbell et al., 2020). Methodological quality was appraised pragmatically by examining design strength, clarity of intervention description, completeness of outcome reporting, and likely sources of bias such as historical controls, incomplete adherence reporting, and uncontrolled confounding. The review therefore compared randomized trials, multicenter cohorts, and before–after studies with attention to their different evidential strengths rather than treating them as equivalent sources of causal inference. This approach allowed the evidence matrix to classify implementation domains while preserving important null findings and contextual differences across specialties.

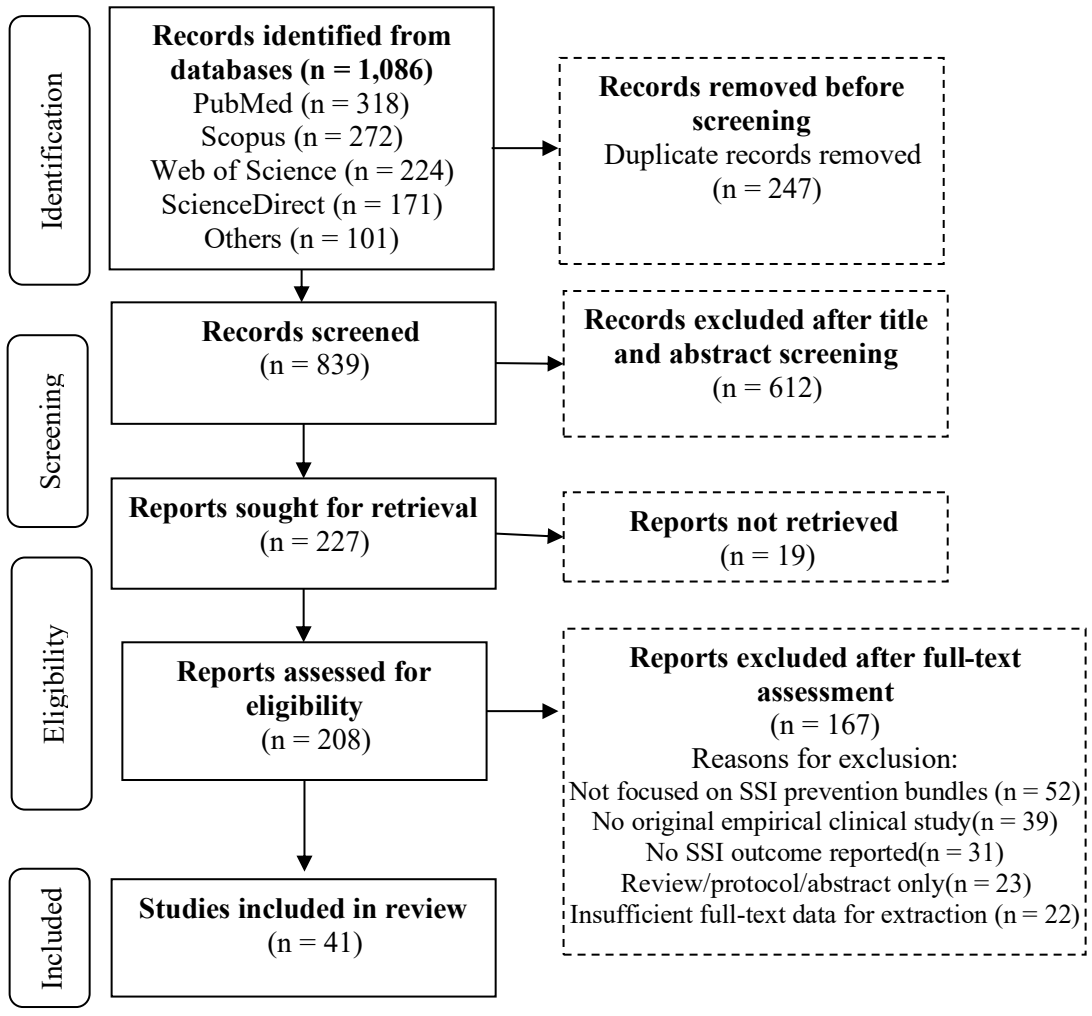


Figure 1: The Systematic Review Process

3. Conceptual and Analytical Innovation

An implementation-science distinction separates possession of an infection-prevention protocol from the competence required to perform each prescribed task correctly. Bundles encompass antibiotic timing, skin antisepsis, normothermia, glycemic control, clean surgical technique, postoperative wound care and communication with patients. Adoption does not establish practitioners' competence. In the earlier evidence map, Wassef et al. (2020) paired education with intensive-care infection-prevention actions, and McGee et al. (2019) described structured coaching across participating hospitals. New evidence reinforces this distinction: Ernest et al. (2021) linked interprofessional training and a safe cesarean package to much higher checklist use in Tanzanian facilities, whereas Caruso et al. (2019) evaluated an extensive postoperative bundle in a pediatric cardiac intensive care unit. Yet these designs changed several practices simultaneously; they do not isolate an independent training effect. A stronger conceptual approach distinguishes staff knowledge, demonstrable task competence, teamwork, documented adherence and patient-level SSI outcomes. Each construct requires a different measurement strategy, and links between them should be tested temporally. Competency audits should evaluate correct execution in actual clinical situations instead of relying on attendance sheets, staff self-report or global checklist completion. Koek et al. (2017) illustrate that completeness of adherence records itself becomes an implementation-quality concern. Infection surveillance must independently establish whether process improvements translate into fewer cases.

A second distinction is between procedural adherence and clinically observed infection outcomes. Reports including Koek et al. (2017), Lohsiriwat (2021) and Chien et al. (2024) linked more complete bundle delivery with reduced SSI, yet the content, measurement opportunity and surveillance window of each bundle differed substantially. In the new Swiss colorectal cohort, Jurt et al. (2021) found median bundle compliance of 77% but no statistically significant infection reduction after implementation. Bagga et al. (2022) reported substantial procedural compliance and improved obstetric and gynecologic SSI rates at one Indian hospital, but similar changes were not observed at the second site. Chin et al. (2023) found an adjusted association with fewer breast-surgery infections although the unadjusted pre/post difference was nonsignificant. The randomized EPO2CH trial found little difference in SSI between an added perioperative package and established standard care (Wolfhagen et al., 2025). Koek et al. (2017) analyzed only the 29% of procedures with fully reported bundle data. Adherence remains process evidence rather than a validated surrogate for clinical prevention. The matrix records hygiene and operating-room practices in 36 of 41 reports; these are descriptive frequencies, not effect estimates. Future research should record eligible care opportunities, critical omissions, direct observation, adherence denominators and independently adjudicated superficial, deep and organ-space outcomes. This would establish whether improved processes are clinically meaningful.

A third distinction concerns the procedure-specific mechanisms through which a bundled package may plausibly influence infection. Vascular bypass has different wound and perfusion risks from a cesarean delivery, breast cancer operation, craniocervical resection or elective colorectal procedure. Hekman et al. (2019) targeted preoperative chlorhexidine showers and groin incision practice in lower-limb bypass surgery; Zenga et al. (2022) investigated topical mucosal antisepsis in head-and-neck cancer reconstruction. Chin et al. (2023) assessed a broader perioperative package in non-reconstructive breast cancer surgery, while the Dutch randomized EPO2CH trial added oxygenation, fluid, temperature, glucose and irrigation measures to existing abdominal surgical prevention (Wolfhagen et al., 2025). These approaches are not interchangeable. Similarly, the earlier cohort by Kuznicki et al. (2020) emphasized dual antimicrobial prophylaxis for hysterectomy, whereas Przybyl and Hegewald (2023) evaluated infection protection in spinal fusion. Outcome definitions, host

susceptibility, procedural duration, implant use and discharge practices vary accordingly. Craniotomy evidence further separates a broad perioperative bundle from focused postoperative wound care (Jiménez-Martínez et al., 2021; Kovryga Kornick et al., 2024). Competent teams must select procedure-appropriate actions rather than count checkmarks across dissimilar protocols. The synthesis connects procedure-specific hazards, tasks, teamwork, fidelity and SSI surveillance without a universal score.

Table 1: Literature Review Matrix

No.	Author(s) and Year	Team educ.	Audit/ feedback	Antibiotic protocol	Skin/ hygiene	OR practices	Patient educ.	Adherence measured	SSI outcome
1	Koek et al. (2017)			✓	✓	✓		✓	✓
2	Andiman et al. (2018)		✓	✓	✓	✓			✓
3	Weiser et al. (2018)	✓	✓	✓	✓	✓		✓	✓
4	Caruso et al. (2019)	✓	✓		✓	✓		✓	✓
5	Hekman et al. (2019)				✓	✓		✓	✓
6	Kawakita et al. (2019)	✓	✓	✓	✓	✓	✓	✓	✓
7	Lawrence et al. (2019)				✓	✓		✓	✓
8	McGee et al. (2019)	✓	✓	✓	✓	✓		✓	✓
9	Kuznicki et al. (2020)			✓	✓	✓		✓	✓
10	Park et al. (2020)		✓	✓	✓	✓		✓	✓
11	Phelan et al. (2020)			✓		✓		✓	✓
12	Wassef et al. (2020)	✓			✓	✓		✓	✓
13	Ernest et al. (2021)	✓	✓	✓	✓	✓		✓	✓
14	Falconer et al. (2021)		✓	✓	✓	✓		✓	✓
15	Faragher et al. (2021)		✓	✓		✓		✓	✓
16	Guerrero et al. (2021)			✓	✓	✓		✓	✓
17	Jiménez-Martínez et al. (2021)		✓	✓	✓	✓		✓	✓
18	Jurt et al. (2021)			✓	✓	✓		✓	✓
19	Lohsiriwat (2021)			✓		✓		✓	✓
20	Bagga et al. (2022)			✓	✓		✓	✓	✓
21	Zenga et al. (2022)				✓	✓			✓
22	Badia et al. (2023)		✓	✓		✓		✓	✓
23	Chin et al. (2023)			✓	✓	✓		✓	✓
24	Eder et al. (2023)		✓	✓	✓			✓	✓
25	Maisat & Yuki (2023)			✓	✓	✓			✓
26	Przybyl & Hegewald (2023)			✓	✓	✓			✓
27	Suzuki et al. (2023)	✓	✓	✓	✓		✓		✓
28	Chien et al. (2024)			✓	✓	✓		✓	✓
29	Dhandapani et al. (2024)			✓	✓	✓		✓	✓
30	Ejaredar et al. (2024)		✓	✓	✓	✓		✓	✓

No.	Author(s) and Year	Team educ.	Audit/ feedback	Antibiotic protocol	Skin/ hygiene	OR practices	Patient educ.	Adherence measured	SSI outcome
31	Gan et al. (2024)			✓	✓	✓			✓
32	Harris & Spitzer (2024)	✓	✓		✓	✓	✓	✓	✓
33	Kovryga Kornick et al. (2024)	✓	✓		✓			✓	✓
34	Buford et al. (2025)	✓	✓		✓	✓		✓	✓
35	Campbell et al. (2025)	✓	✓	✓	✓	✓		✓	✓
36	Castiello et al. (2025)	✓		✓	✓	✓		✓	✓
37	Cohen et al. (2025)			✓	✓				✓
38	Golden et al. (2025)	✓	✓		✓	✓	✓	✓	✓
39	Nikolic et al. (2025)				✓	✓	✓	✓	✓
40	Patel et al. (2025)	✓	✓	✓	✓	✓			✓
41	Wolfhagen et al. (2025)					✓		✓	✓

4. Discussion

The expanded evidence suggests that coordinated prevention can reduce SSI in some settings, but associations are conditioned by intervention content and study design. Hekman et al. (2019) reported SSI declining from 18% to 4% after an evidence-based bundle for lower-extremity vascular bypass, although the comparison was not randomized and the postintervention cohort was smaller. Caruso et al. (2019) observed SSI decreasing from 3.4 to 0.9 per 100 pediatric cardiac operations during implementation of an 11-element postoperative care package; this intervention was a nonrandomized local programme. Earlier, Lawrence et al. (2019) reported fewer incisional infections after pancreaticoduodenectomy and Faragher et al. (2021) fewer organ-space infections following colorectal surgery. These differences cannot be treated as a common effect size because procedures, baseline risks, case ascertainment and bundle components differ. In contrast, Jurt et al. (2021) reported 22.2% SSI after colorectal bundle introduction compared with 21.4% historically ($p = .79$), despite reported compliance. Intervention exposure alone is insufficient proof of clinical benefit. National Dutch surveillance identified lower adjusted SSI risk with greater recorded compliance, but only 29% of operations had fully documented bundles (Koek et al., 2017). Reliable comparison and surveillance help distinguish improvement from confounding or changes in case ascertainment. A methodologically responsible synthesis must retain negative findings alongside favorable results rather than selectively emphasizing large percentage changes. Importantly, vascular surgery bundles address local incisional hazards such as groin contamination and preoperative decolonization. In contrast, colorectal programs contend with luminal contamination, bowel preparation and organ-space infections. Comparing their absolute rates as if exposure and baseline risk were equivalent would overstate transferability. Follow-up duration and postdischarge capture should be recorded before interpreting any apparent reduction.

Obstetric and gynecologic evidence further illustrates why measured competence and contextual adaptation matter. Ernest et al. (2021) evaluated a Tanzanian safe surgery programme integrating interprofessional training, a checklist and a cesarean infection-prevention bundle across 30 facilities. Checklist use rose from 3.7% to 95.1%, and SSI declined from 14% to 1%; the composite intervention prevents attributing the outcome to any single component. Bagga et al. (2022) contrasted two hospitals in India: after introducing a bathing, hygiene, antibiotic and patient-counselling package,

significant cesarean and gynecologic SSI reductions occurred at one site but not the other. Differences in adherence and hospital resources provide plausible explanations but cannot independently prove causation. Earlier, Kawakita et al. (2019) investigated resident-driven standardized cesarean practices, while Gan et al. (2024) conducted a randomized trial that reported fewer postoperative SSIs with a combined prophylaxis and wound-care package. Among hysterectomy programmes, Andiman et al. (2018), Kuznicki et al. (2020) and Patel et al. (2025) evaluated different antimicrobial, hygiene and workflow strategies. These papers should not be interpreted as replications of one exact bundle. They instead indicate that technical training, local infrastructure, appropriate case selection and dependable follow-through may interact to influence postoperative outcomes. Competency standards must define the clinical action, eligible patient, timing and observation method, then examine each operation-specific SSI endpoint separately. In resource-constrained settings, reliable access to antiseptic products, adequately staffed operating rooms and timely prophylaxis may determine whether training translates into completed actions. These conditions are rarely randomized. Future evaluations should therefore identify which elements were already standard practice, which were newly introduced and which remained inconsistently delivered, rather than treating an institutional bundle launch as a uniform treatment exposure.

The evidence also extends prevention into specialty-specific nursing and operating-room practice. Caruso et al. (2019) introduced an 11-element postoperative bundle during prolonged recovery after pediatric cardiac surgery, a setting in which wound care, team handover and sustained implementation are central. Golden et al. (2025) subsequently reported longitudinal pediatric cardiothoracic improvement at a separate Atlanta center, whereas Campbell et al. (2025) observed sustained component compliance without a statistically significant overall SSI decrease in a Duke cohort. These programmes involve separate populations. In adult craniotomy, Jiménez-Martínez et al. (2021) associated a bundled protocol with SSI declining from 15.3% to 3.5%; at a separate Californian center, Kovryga Kornick et al. (2024) linked documented wound-care practices and visual feedback with a decline from 2.4% to 1.4%. Both remain nonrandomized. In head-and-neck oncology, Zenga et al. (2022) found a marked decrease in oral bacterial burden after a topical antiseptic package; three of 25 patients experienced SSI, but the single-arm trial cannot demonstrate comparative infection prevention. Chin et al. (2023) observed that a Swedish breast-surgery care bundle had a favorable adjusted association with SSI (OR 0.63, 95% CI 0.40–0.99), despite a nonsignificant unadjusted decline from 11.8% to 8.9%. Adjustment changes interpretation. Clinical competence thus extends beyond general awareness to correct wound preparation, antimicrobial practice, accurate postoperative monitoring and consistent documentation. It should be evaluated with task-specific observation, not inferred simply from training attendance or from quality-improvement team membership. The same distinction affects interpretation of follow-up calls and patient instructions. More active follow-up can also detect infections that inpatient surveillance misses. Studies should distinguish better prevention from increased case ascertainment and retain stable infection definitions across study phases.

More rigorous designs materially qualify conclusions drawn from historical comparisons. In the multicenter EPO2CH randomized trial, SSI occurred in 18.4% of patients receiving additional perioperative bundle elements and 18.9% receiving established standard care, with relative risk 0.98 (95% CI 0.81–1.18) (Wolfhagen et al., 2025). The neutral result differs from many favorable before–after cohorts and indicates that marginal benefit depends on the existing standard of prevention. Jurt et al. (2021) similarly found no significant SSI change despite structured colorectal implementation. In the Veterans Affairs evaluation, a favorable arthroplasty association in generalized estimating equations was not reproduced under interrupted time-series modeling, illustrating vulnerability to secular changes (Suzuki et al., 2023). Several clinical studies used limited samples, bundled multiple

interventions or lacked independent competence measurement. Patient case mix, antibiotic policy, operative complexity, postdischarge follow-up and risk adjustment may all shift during programme adoption. The evidence also spans distinct endpoints: infection subtype, composite infection, colonization and checklist compliance should never be substituted for one another. Because no complete study-by-study, design-specific risk-of-bias grading has been conducted, the review cannot assign a quantified certainty rating. Taken together, the 41-study map supports context-sensitive evaluation rather than a claim of universal benefit. Future trials should compare genuine alternatives, measure technical implementation directly and report both process fidelity and SSI with prespecified definitions. Accordingly, confidence should reflect allocation concealment in trials, confounding control in observational designs, completeness of surveillance and the possibility of selective reporting. A randomized neutral result should not simply be outweighed by numerous uncontrolled positive reports. Future syntheses could stratify evidence by design and procedure while retaining narrative comparison where pooling remains clinically or statistically unjustified.

5. Research Gaps and Future Research Directions

The most persistent research gap is the lack of validated measures of infection-control bundle competence. Most studies describe education delivery, protocol availability, institutional checklists or recorded adherence, whereas fewer directly observe knowledge and technical execution in practice. Existing training studies do not isolate the effects of clinician skill. Prospective work should prespecify competencies for surgeons, anesthesiologists, nursing teams and infection preventionists, such as correct prophylaxis timing, antiseptic contact, field management, postoperative dressing technique and discharge counselling. Competency can be evaluated through observation checklists, simulation, inter-rater agreement and repeated assessments after initial training. Attendance alone is insufficient. Patient-level data should then link observed execution to independently adjudicated superficial, deep and organ-space SSI, accounting for time from operation to case ascertainment. Future research should evaluate how the number and complexity of bundle steps influence omission rates. Such measurement would clarify whether increased recorded compliance represents genuinely safer practice or simply more complete charting. Craniotomy results from Spain and California provide practical examples of team feedback and wound assessment without isolating staff competence (Jiménez-Martínez et al., 2021; Kovryga Kornick et al., 2024). The goal is to link implementation quality to meaningful outcomes.

Further gaps concern comparative design, baseline care and external validity. The 2025 Dutch randomized EPO2CH trial found no significant added effect over existing standard care, demonstrating why efficacy from historical cohorts may not generalize (Wolfhagen et al., 2025). The different results between two Indian hospitals in Bagga et al. (2022) further emphasize resource conditions and implementation fidelity. Future research should use adequately powered multicenter randomized or stepped-wedge comparisons where feasible, or interrupted time-series analyses with contemporaneous comparators. Reporting should separate procedures, case mix, SSI depth and follow-up. Investigators need to report complete bundle content, eligible opportunities, component-level adherence, implementation support and costs. Prospective registration and reproducible search exports are essential for evidence reviews. The present review lacks a complete initial screening ledger and independently replicated item-level risk-of-bias appraisal, so it cannot claim full PRISMA 2020 compliance or formal certainty grading. Incomplete national adherence reporting in Koek et al. (2017) also warrants explicit missing-data sensitivity analyses. No screening totals or unobserved exclusions should be constructed retrospectively to reach a predetermined sample of included reports. Transparency prevents optimistic conclusions and improves transferability.

6. Conclusion

This focused, PRISMA-informed narrative review maps 41 original empirical studies published between 2017 and 2025 on infection-control bundles, implementation practices and surgical site infection (SSI) outcomes. Three further investigations were incorporated after checking full publication identity, DOI uniqueness, clinical context and potential cohort overlap with the preceding 38 studies. New evidence examines national compliance and two distinct craniotomy prevention programmes. The national analysis associated more complete bundle delivery with lower infection risk but had fully recorded adherence data for only 29% of operations (Koek et al., 2017). In Barcelona, SSI declined from 15.3% to 3.5% across historical and intervention periods (Jiménez-Martínez et al., 2021). A separate Californian programme found SSI declining from 2.4% to 1.4% and an adjusted association favoring its wound-care approach (Kovryga Kornick et al., 2024). Neither craniotomy study isolates the effect of professional competence. Earlier studies also document context-specific improvements after vascular, cardiac, obstetric and colorectal bundle implementation. Contradictory evidence must remain central: Jurt et al. (2021) observed no significant change in a standardized colorectal programme, and the randomized EPO2CH trial found no added SSI benefit over established abdominal-surgery care (Wolfhagen et al., 2025). Results therefore do not justify asserting a universal benefit from every package or equating education attendance with objectively measured competence. Meaningful competency evaluation requires observable, procedure-specific skills, clear implementation denominators, continuous audit, reliable recording and independently adjudicated infection outcomes. Outcomes should distinguish superficial, deep and organ-space SSI and identify surveillance duration. Moreover, the strength of causal inference varies substantially between randomized trials and uncontrolled before–after comparisons. The evidence map offers an organized foundation for targeted quality improvement and future comparative research rather than a pooled causal estimate. Review-level confidence is limited by unavailable complete search exports, a reconstructed rather than prospective screening history and no uniformly completed formal risk-of-bias appraisal across the included reports. This limitation is stated rather than masked by invented PRISMA counts or unsupported quality ratings. Prospective studies should clarify which bundle components are genuinely new, whether skills were mastered and sustained, and how improvements vary across surgical specialties and institutional resources.

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