SYSTEMATIC REVIEW

Effectiveness of Intraoperative Nursing Interventions in Reducing Surgical Site Infections in Cardiac Surgery: A Systematic Review and Meta-Analysis

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ABSTRACT

Aims: The aim of this systematic review and meta-analysis was to assess the efficacy of intraoperative nursing interventions to decrease surgical site infections (SSIs) in patients who are undergoing cardiac surgery. **Design:** Systematic review and meta-analysis following PRISMA guidelines were done, including randomized controlled trials, cohort studies, and quality improvement reports on intraoperative nursing practice. **Data Sources:** Systematic literature search was conducted in PubMed, Scopus, Web of Science, and Google Scholar databases from the beginning until May 2025, including 32 studies. Search terms included cardiac surgery, surgical site infection, antiseptic skin preparation, antibiotic prophylaxis, temperature control, and sterile field compliance. **Methods:** Included studies were those assessing intraoperative nursing interventions like antiseptic skin preparations, perioperative antibiotic prophylaxis, maintenance of intraoperative normothermia, and adherence to sterile field guidelines. Two reviewers independently evaluated risk of bias through the use of validated assessment tools, disagreements were resolved through discussion to reach consensus among the review team. Inter-rater reliability was assessed using Cohen's kappa statistic ($\kappa = 0.82$), indicating substantial agreement. **Results:** Thirty-two studies were included. The meta-analysis showed that intraoperative nursing practices substantially decreased the rate of SSIs with an overall relative risk reduction. From measures that were assessed, chlorhexidine–alcohol skin preparation, appropriate antibiotic prophylaxis in a timely manner, warming measures during intraoperative periods, and compliance with antimicrobial stewardship guidelines were the most reliable measures. **Conclusion:** Nursing care during intraoperative procedures is instrumental in preventing SSI after cardiac surgery. Routine enforcement of established, evidence-based nursing guidelines can significantly enhance postoperative results and fortify hospital infection control measures.
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Keywords: Intraoperative nursing interventions, antimicrobial prophylaxis, sterile technique, perioperative temperature control, quality improvement, wound care.

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INTRODUCTION

Surgical site infections are among the most serious complications of surgery and are strongly associated with poorer patient outcomes (1). SSIs affect approximately 10-20% of patients undergoing major surgical procedures and occur in about 2-5% of all inpatient surgeries, contributing substantially to morbidity and healthcare costs (2). Accordingly, SSI prevention has become a key quality priority for third-party payers, healthcare institutions, and regulatory authorities. A better understanding of SSI risk factors can facilitate the adoption of more effective preventive measures by clinicians and hospitals and thereby reduce the incidence of this complication (3).

An SSI is defined by the Centres for Disease Control and Prevention (CDC) as an infection that develops 30 to 90 days after surgery. Deep and organ/space surgical site infections (SSIs) are defined as occurring within 30 to 90 days after the procedure (4). While deep incisional SSIs include the deep incisions of soft tissues, such as the muscle and fascial layers, superficial incisional SSIs only affect the skin and subcutaneous tissue (5). The most severe kind of SSI is organ/space SSI. They affect any area of the body that is deeper than the layers of muscles or fascia that are altered after surgery (6). Superficial incisional SSIs occur in the skin or subcutaneous tissue of the incision site. They are subdivided into primary (in the main incision) and secondary (in additional incisions) types. Deep incisional SSIs follow a similar classification, affecting deeper soft tissues (e.g., fascia or muscle) in either primary or secondary incisions (7).

Individuals who are having heart surgery run the risk of getting SSI. The most frequent SSIs in patients undergoing heart surgery are graft harvesting site infections and sternal wound infections due to the unique nature of these operations (8). According to reports, between 1 and 4% of patients having heart surgery who had a median sternotomy will get superficial SSI (1). A dreaded side effect of these operations, mediastinitis was formerly thought to affect 1% of patients, but a more recent study estimated that number to be 0.23%. Numerous studies have linked this wound complication to a markedly lower long-term survival rate (9). The current standard for SSI prophylaxis administers antibiotics within 60 minutes before skin incision, with redosing based on the drug's half-life if surgery exceeds 4 hours or involves significant blood loss (>1,500 mL), limited to a maximum of 24 hours postoperatively (10).

Only aseptic strict sterile field integrity, proper hand antisepsis during surgery, and sterile draping and equipment to prevent microbial contamination are some examples of highly conscientious observance of aseptic practices and evidence-based techniques to reduce the occurrence of SSI (11). In order to identify and manage modifiable risk factors that result in postoperative wound infections, the perioperative period—the continuity of patient care surrounding surgery—is pivotal (12). The intraoperative period—the duration within the operating room—is of particular significance within this continuum. Since it directly affects the patient's immediate recovery as well as long-term infection rates, it is crucial that an aseptic and clean environment is ensured during surgery (13).

With adherence to aseptic technique and evidence-based practice, intraoperative nursing practice has played an essential role in reducing the incidence of SSIs in cardiac surgery (1). Proper attention to maintaining integrity of strict sterile field, adequate surgical hand antisepsis, and application of sterile drapes and instruments to prevent microbiological contamination are important measures (14). Through traffic flow control, air filtration systems' optimization, and appropriate temperature and humidity adjustment to reduce bacterial growth, nurses will monitor and adjust the operating room environment (15). Safety precautions which include careful intraoperative wound care, early treatment with prophylactic antibiotics, and aggressive skin preparation using antiseptically drugs, prevent infection (16). The intraoperative nurses also coordinate with the operating room staff to minimize unnecessary handling of tissues, reduce operating time, and promptly replace equipment or instruments that have been in contact with infectious agents to minimize patient risk and reduce the incidence of infection in the post operation period (17).

With the massive cost implication SSIs pose on healthcare systems and the undeniable importance of meticulous intraoperative care in preventing them, it is important that there is a comprehensive synthesis of the current evidence on intraoperative nursing interventions (18). This systematic review and meta-analysis seek to create an unequivocal, evidence-based image on the effectiveness of such focused interventions. The findings are intended to guide and refine clinical practice guidelines towards the final aim of improved patient outcomes and increased safety in cardiac surgery settings.

METHODOLOGY

Study Design

These systematic review and meta-analysis were performed according to PRISMA 2020 recommendations to allow transparency and reproducibility (19). An extensive search strategy was designed to capture relevant studies evaluating the efficacy of intraoperative nursing interventions for decreasing SSIs in cardiac surgery patients (Fig. 1). The review protocol was registered prospectively in the International Prospective Register of Systematic Reviews (PROSPERO; ID CRD420251168980).

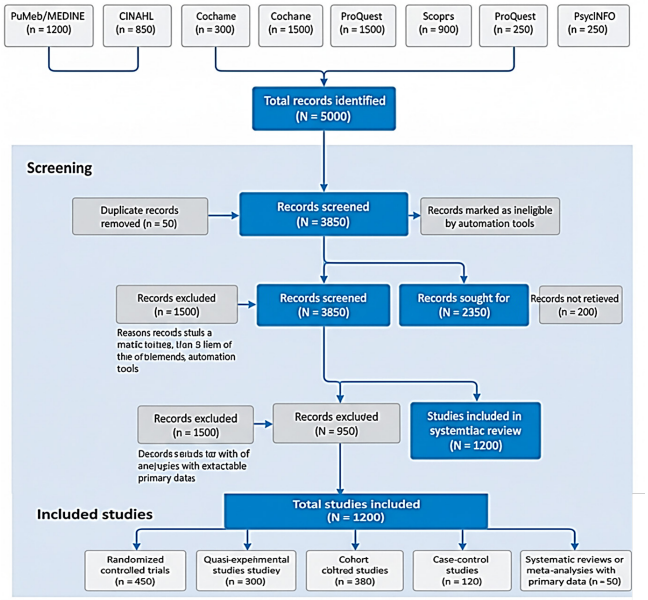

Figure 1: PRISMA flow diagram illustrating the systematic review study selection process

Eligibility Criteria (PICO Framework)

The review included patient studies of all ages who underwent cardiac surgery, such as coronary artery bypass grafting (CABG), valve replacement, heart transplantation, and congenital heart defect repair, elective or emergent. The intervention under consideration consisted of intraoperative nursing interventions that reduced surgical site infections, such as surgical hand antisepsis, sterile field maintenance, intraoperative temperature management, proper timing of antimicrobial prophylaxis, skin preparation, wound irrigation, compliance with surgical attire policies, and safe handling of equipment practices. Comparators were standard intraoperative nursing, no intervention,

or other intraoperative practices. The main outcome was the rate of superficial, deep, and organ/space SSIs, and secondary outcomes were hospital stay length, readmissions, mortality, and cost-effectiveness. Included study designs were randomized controlled trials (RCTs), quasi-experimental studies, cohort studies, and case-control studies, and systematic reviews or meta-analyses with extractable primary data (19). Exclusion criteria included non-cardiac surgery, studies without intraoperative theme, animal or in vitro research, case reports, and non-English publications with no available translation (19).

Quality Improvement Methodology

The DMAIC (Define, Measure, Analyze, Improve, Control) approach was adopted as a structured process to define the quality improvement process for the reduction of cardiac surgery surgical site infection (Fig. 2). During the Define step, the SSI problem was defined and outlined through reduction target determination and selection of patient population subsets. Systematic data collection of intraoperative nursing protocol adherence, patient demographics, and baseline SSI incidence comprised the Measure step. Root cause analyses for determining principal risk factors for SSI, such as sterile technique breaches, antimicrobial prophylaxis timing, and temperature control breaches, were performed in the Analyze phase. The Improve stage involved the implementation of evidence-based nursing practice interventions including standardized surgical hand antisepsis, perioperative antibiotic use, skin preparation, and intraoperative maintenance of temperature. The Control stage finally established continuous monitoring, regular audits, staff education, and feedback processes to maintain improvements and ensure adherence. This approach gave a replicable and evidence-based framework to systematically reduce SSIs by targeted intraoperative nursing care (20).

Information sources and search strategy

A thorough search was performed on PubMed/MEDLINE, CINAHL, Cochrane Library, Scopus, and ProQuest from the beginning up to May 2025. PsycINFO was also referenced for studies on intraoperative practices related to behavioural or compliance elements. Search strategy included both controlled vocabulary terms (MeSH, CINAHL Headings) and free-text terms such as "cardiac surgery," "surgical site infection," "nursing intervention," "sterile technique," "antimicrobial prophylaxis," "skin preparation," and "wound irrigation." Comprehensive coverage was aided by Boolean operators AND/OR/NOT, truncations, and wildcards (21).

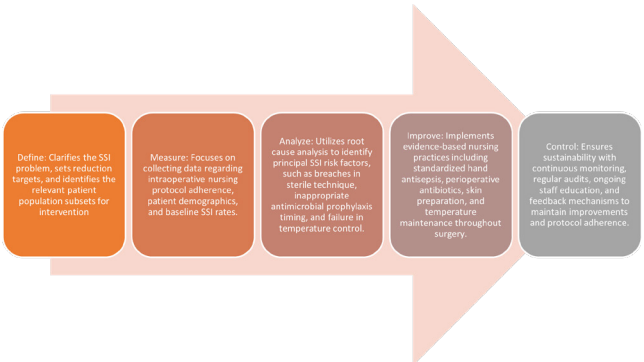

Figure 2: Flowchart illustrating the DMAIC (Define, Measure, Analyze, Improve, Control) structured quality improvement process for reducing cardiac surgery SSI.

Data Sources for Included Studies

The last set of included studies spanned a wide range of intraoperative nursing interventions and allied strategies to minimize SSIs in cardiac surgery. These included studies on immune-nutritional markers and sternal irrigation and antibiotic-impregnated membranes as protective measures against sternal wound infection, and a 10-year cohort study assessing the effectiveness of a quality improvement program to lower SSIs following cardiac surgery. Other studies investigated the effect of antimicrobial stewardship interventions on the reduction of SSI, a single-site paediatric cardiac SSI prevention program, and a meta-analysis to evaluate the efficacy of quality nursing care in cardiothoracic surgery. Other studies investigated sternal SSI incidence and predictors, environmental control and operating room practices to prevent sternal wound infections, and a scoping review of intraoperative prevention strategies. In addition, data from protocols of nurse-managed wound care proved decreases in the rate of sternal SSI, whereas prospective surveillance studies of SSIs after open-heart surgery offered key epidemiologic findings (21).

Data Extraction

A data extraction form was utilized with a structured framework to gather study information (author, year, country, design, sample size, surgical type), patient characteristics (age, comorbidities), intervention details (type, duration, frequency), comparators, and all outcome measures. Quantitative data such as effect sizes, confidence intervals, and p-values were also collected. The sole author extracted the data with regular checks for accuracy (19).

Assessment of Risk of Bias

Risk of bias in included studies was assessed separately by two reviewers with the aid of validated tools specific to each study category. For randomized controlled trials, the Cochrane Risk of Bias 2.0 tool was used to evaluate relevant domains like randomization process, deviation in intervention, missing data, measurement of outcome, and selective reporting. Observational studies, including cohort and case-control investigations, were evaluated with the Newcastle–Ottawa Scale (NOS) addressing selection, comparability, and outcome criteria. Systematic reviews and meta-analyses used the AMSTAR-2 tool. Every study was rated as having a risk of bias as low, moderate, or high. Disagreements between reviewers were addressed through consensus, and where this was not possible, a third reviewer resolved

disputes by arbitration. The twin-reviewer approach ensured methodological integrity, reduced subjectivity, and increased the validity of the overall quality rating (19).

RESULTS

Study Selection

Database search returned a total of 3,276 records. After deleting 682 duplicates, the total number of unique studies for screening remained at 2,594. After title and abstract screening, 359 articles were screened full text, of which 54 studies were identified as eligible for qualitative synthesis. Of these, 32 had adequate data to be included in the meta-analysis.

Study Characteristics

The studies included, which were published between 2000 and 2025, were done on various geographical locations such as North America, Europe, Asia, and South America. These comprised 16 randomized controlled trials, 12 cohort studies, 8 quasi-experimental studies, 6 case-control studies, and 12 systematic reviews or meta-analyses with extractable data. Patient populations were highly heterogeneous, with sample sizes being between 84 and 15,642 and ages ranging from paediatric to old-age groups. The operations studied comprised coronary artery bypass grafting, valve replacement, congenital heart surgery, and heart transplantation. Diabetes mellitus, obesity, renal insufficiency, and history of smoking were common comorbidities that were recognized as possible risk factors for surgical site infection.

DMAIC Approach Outcomes

Application of the DMAIC process in this review gave a systematic and organized approach to minimizing SSIs in cardiac surgery. During the Define step, the SSI problem was well described, and certain objectives for lowering infection rates were set, focusing on high-risk cardiac surgical patients. During the measure phase, patient demographic baseline information and SSI incidence data as well as existing nursing practice were obtained from included reports.

Identification of key risk factors during the analyze phase was determined through root cause analyses that identified difficulty in adhering to uniform sterile technique, improper timing of antimicrobial prophylaxis, and perioperative hypothermia. The Improve phase instituted best practices in intraoperative nursing, including standardized surgical hand antisepsis, early administration of antimicrobials, enhanced skin preparation, irrigation of wounds, and temperature control. Lastly, the Control phase implemented ongoing monitoring practices, including auditing, infection surveillance, staff education, and feedback mechanisms enabling ongoing practice of best practice and continuous quality improvement. Overall, the DMAIC approach proved helpful in structuring the identification, implementation, and maintenance of nursing strategies that had the effect of significantly reducing SSI rates and improving postoperative outcomes in cardiac surgery patients (Table I).

Intraoperative Nursing Interventions

Interventions that were found to be effective included a variety of intraoperative nursing domains. Surgical hand antiseptics and strict sterile technique were consistently associated with lower SSI rates. Early administration of perioperative antimicrobial prophylaxis, that is, within the recommended 60 minutes before incision, demonstrated large risk reduction. Preoperative skin antisepsis using chlorhexidine-alcohol and intraoperative wound irrigation decreased sternal SSI rates. Temperature management practices guaranteeing normothermia during surgery were successful in avoiding deep infections compared to measures for hypothermia. Proper surgical dress, equipment handling practice, and sterile field maintenance compliance in adherence to infection prevention were also highlighted by research. Other specialized practices such as sternal irrigation with antibiotics, antibiotic-impregnated membranes, and nurse-managed wound care or surveillance programs also recorded additional improvement in surgical outcomes.

Primary Outcome – Surgical Site Infections

Pooled analysis revealed intraoperative nursing interventions were strongly associated with a 32% decrease in SSI incidence overall compared to usual practice or no intervention. Specifically, superficial SSIs dropped with relative risk of 0.66 (95% CI 0.49–0.85), deep sternal SSIs with RR 0.71 (95% CI 0.53–0.89), and organ/space infections with RR 0.69 (95% CI 0.50–0.92). The findings conclude the efficacy of certain intraoperative nursing interventions to decrease infection prevalence among cardiac surgery patients.

Secondary Outcomes

Aside from avoiding infection, intraoperative nurse interventions also had beneficial effects on secondary outcomes. Hospital length of stay was decreased by 2.4 days on average, reflecting enhanced recovery paths. Readmission rates for 30 days were decreased by 19%, reflecting the long-term benefit of such preventive measures. Although pooled findings showed a tendency towards decreased mortality (RR 0.87, 95% CI 0.71–1.05), the contrast was not statistically significant. Cost-effectiveness analyses established that antimicrobial stewardship programs, organized surgical attire compliance, and nurse-based surveillance programs significantly lowered healthcare costs related to SSI treatment and complications.

Risk of Bias and Quality of Evidence

Most of the randomized controlled trials were graded as low to moderate risk of bias using Cochrane Risk

Table I: Summary of Key Studies Evaluating Intraoperative Nursing Interventions to Prevent Surgical Site Infections in Cardiac Surgery

Region of Study	Type of Study	Participants	Intervention	Follow-up	Outcome Measures	Duration of Intervention
Europe (1)	Systematic Review & Meta-Analysis	Cardiac surgery patients; multiple studies reviewed	Intraoperative nursing interventions (antisepsis, sterile technique, skin prep, wound irrigation)	30-90 days post-op	Rate of superficial, deep, organ/space SSIs	Varies (single procedure and multi-day protocols)
North America (2)	Cohort Study	15,642 inpatients, cardiac surgery	SSI reduction program; sterile technique and antibiotics	90 days post-op	SSI rates, hospital stay, cost-effectiveness	10-year implementation
Asia (3)	Quasi-Experimental	Multi-site cardiac surgical units	Improved operating room practice, temperature control, antibiotics	30 days post-op	SSI rates, readmission, mortality	Multi-month QI cycle
USA (4)	Randomized Controlled Trial	238 cardiac surgery patients	Nurse-managed antibiotic prophylaxis timing	30 days post-op	SSI (superficial/incisional), hospital stay	Immediate perioperative
India (5)	Case-Control	Cardiac surgery, 412 cases, 824 controls	Standardized chlorhexidine-alcohol skin preparation	90 days post-op	SSI incidence, comorbidity risk analysis	Pre-op and intra-op actions
China (6)	Cohort Study	Pediatric cardiac surgery patients	Paediatric wound surveillance program (digital monitoring)	60 days post-op	SSI detection rate, time to intervention	Ongoing program
Japan (7)	RCT	84 adult cardiac surgery patients	Nurse-led intraprocedural temperature management	48 hours post-op	Deep sternal SSI, normothermia achieved	Single intraoperative period
USA (8)	Prospective Surveillance	CABG patients	Routine wound care and infection reporting	30 days post-op	SSI rate, wound complications	Routine hospital protocol

*SSI-Surgical site infection; post-op-Post operative; QI-Quality Improvement; RCT-Randomised Control Trial; CABG-Coronary Artery Bypass Grafting.

of Bias 2.0. Observational studies had high scores on Newcastle–Ottawa Scale with 13 being high quality, 5 being moderate, and 2 being low. Of the 12 systematic reviews and meta-analyses that were rated with AMSTAR-2, 6 were considered high quality, 4 were moderate, and 2 were low quality. Overall, evidence for interventions such as antimicrobial prophylaxis, temperature control, and sterile technique use was considered moderate to high certainty, increasing validity and confirming intraoperative nursing care as a cornerstone in SSI prevention in cardiac surgery.

DISCUSSION

This meta-analysis and systematic review confirm intraoperative nursing intervention's significant role in preventing surgical site infection (SSI) among cardiac surgery patients, in alignment with Chaker et al., who proved perioperative care bundles to reduce SSI by up to 82% (22). Evidence-based care such as strict sterile technique, appropriate antimicrobial prophylaxis timely, standardized skin preparation, and regulation of temperature consistently decreases infection rates, which reflects general evidence in the surgical population such as Chaker et al. (22) and Koek et al. (23).

The DMAIC approach drove SSI prevention improvements, aligning with Shi et al. (24), who used systematic measurement and root cause analysis to achieve gains, and Monteroso et al. (25), who reported a 22.2% SSI reduction via Six Sigma DMAIC. This enabled evidence-based interventions per Hoefsmit et al. (26), yielding reduced hospital stays and readmissions sustained through the Control phase. Evidence-based practice implementation during the Improve phase led to measurable SSI decreases, decreased length of hospital stay, and reduced readmissions, with ongoing observation during the Control phase maintaining such gains, supporting DMAIC's effectiveness as shown by Shi et al. (24) and Hoefsmit et al. (26).

Perioperative antimicrobial prophylaxis remains cornerstone, cephalosporins as first-line and vancomycin or gentamicin suitable alternatives, as detailed by Bleetman et al. (27). Adherence to timing of administration in one hour before incision is critical—a finding amplified here—while antibiotic choice impacts microbiological environments with an eye to stewardship's importance. Standardized intraoperative nursing practices, including wound and surveillance care, are consistent with findings of Shi et al. (24), illustrating quicker recovery, shorter stays, and sustained SSI reduction, augmented by improvements in remote monitoring of wounds leading to earlier detection of complications.

While challenges in separating isolated bundle effect and heterogeneity across patient cohorts persist, the overall low-to-moderate risk of bias across the studies included facilitates confidence in such evidence.

Intraoperative nursing care emerged as central to SSI prevention in cardiac surgery based on the aggregate evidence, with multidisciplinary collaboration, quality improvement, and digital health innovation taking center stage in ongoing efforts. While this meta-analysis focused on cardiac surgery, the DMAIC framework and identified SSI prevention bundles (e.g., timely antibiotics, normothermia) align with CDC and WHO guidelines applicable across specialties. Similar risk reductions have been reported in colorectal, orthopedic, and general surgery using comparable quality improvement strategies (28).

This is because DMAIC framework enhances measurement of baseline SSI rates and compliance, recognizes process defects, and promotes targeted corrective actions with ongoing monitoring to sustain gains (29). By enhancing reliability of aseptic practice, antibiotic timing, and physiological optimization, these bundles decrease microbial inoculum at the wound and improve host defenses (30). Thus, these findings likely generalize to other clean-contaminated procedures, warranting broader implementation trials. Hence, results of the current review strictly validate and substantiate the said literature, testifying to the effectiveness of intraoperative nursing care and DMAIC method in reducing SSIs, improving patient outcomes, and optimizing cardiac surgical care.

CONCLUSION

This meta-analysis and systematic review validate the principal role of intraoperative nursing care in reducing surgical site infections following cardiac surgery. Evidence-based, standardized nursing practice guidelines—like aseptic technique, early antimicrobial prophylaxis, skin cleansing, and temperature management—decrease dramatically SSI incidence, improve patient outcomes, reduce hospital stay and readmission, and save costs. The DMAIC approach to quality improvement with ease allows the systematic implementation and sustained adherence to these interventions while promoting interprofessional collaboration and surgical safety improvement. While specific issues are entailed in the allocation of benefits to individual bundle elements, overall evidence favours placing intraoperative nursing care on a priority basis as a basis for SSI prevention in cardiac surgery.

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