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Research Article

A quality improvement program to reduce surgical site infections after cardiac surgery: A 10-year cohort study

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ABSTRACT

Objectives: To assess trends in surgical site infection (SSI) incidence in cardiosurgery following a quality improvement initiative in infection prevention and control (IP&C).

Methods: This is a historical cohort study encompassing a 10-year surveillance period (2014–2023) in a cardiosurgical department in a multi-organ transplant center. The study encompassed three periods: a baseline period (Phase_1: January 2014-December 2018); an implementation phase covering quality improvement initiatives targeting various aspects of IP&C including organizational factors, pre-operative, intra-operative, post-operative measures, and post-hospitalization care (Phase_2: January 2019-June 2021); a post-implementation phase (Phase_3: July 2021-September 2023). A general linear mixed model was used to assess differences in SSI rates between distinct phases, adjusted for length of hospitalization, American Society of Anaesthesiologists (ASA) physical status classification, and Diagnostic-Related Groups (DRG) weight. The latter two were used as random effects. Results are reported as odds ratios [OR] with 95% confidence interval [CI].

Results: All cardiac surgery patients were included (n = 5851). A total of 208 patients developed SSI (3.5 %). SSI incidence for phase_1, phase_2 and phase_3 were 4.5 %, 4.1 %, and 1.2 %, respectively. The mixed model regression analysis indicated that, compared with the reference period (Phase1), SSI risk did not drop during the implementation phase (OR 0.81, 95 % CI 0.59–1.13, P < 0.001 *vs.* reference period). A decrease in SSI risk was observed during the post-implementation phase (OR 0.19, 95 % CI 0.11–0.32)

Conclusions: A quality improvement initiative encompassing measurements at all levels potentially impacting SSI risk was implemented over a 2.5 years period. While no risk reduction was observed during the implementation phase, a significant reduction in SSI risk took place in the post-implementation phase.

Implications for Clinical Practice: This study suggests that considerable time may be required to achieve a substantial SSI risk reduction. We assume this may be attributed to the time required to achieve appropriate adherence with IP&C protocols.

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Introduction

Surgical site infections (SSIs) are a major concern in healthcare, particularly in cardiac surgery, due to their association with increased morbidity and healthcare costs [1–3]. Despite advancements in infection prevention and control (IP&C), SSI rates remain high, ranging from 3.5 % to 26.8 % [4–7].

Efforts to reduce SSIs must encompass the pre-operative, intra-operative, and post-operative phases [8] and be supported by institutional leadership from admission through discharge [9]. While some risk factors cannot be modified, bundled interventions targeting modifiable factors have proven effective in reducing SSIs [10].

Standardized, evidence-based interventions applied by all stakeholders are crucial; however, there is still variability in strategies among healthcare organizations [11]. Despite a focus on individual preventive measures, the combined impact of multiple interventions is not well understood [12]. The WHO advocates for team-based approaches to enhance efficiency and streamline care, which is essential in preventing SSIs [13].

Surveillance plays a critical role in identifying and managing SSIs [14]. Effective surveillance systems enable the early detection of infection outbreaks [15], assessment of intervention efficacy, and continuous improvement of infection control practices [16].

In 2014, our hospital's surveillance system revealed an SSI rate of 4.7 %, exceeding the international average of 3.0 % [16]. Over the subsequent four years, from 2014 to 2018, it became evident that the situation remained unfavorable. This prompted the implementation of a quality improvement (QI) program incorporating various infection control measures.

This study aims to evaluate SSI rates during and after the implementation period compared to the baseline phase, highlighting the importance of continuous surveillance and targeted interventions in reducing SSI rates and improving patient outcomes.

Methods

Study design & setting

This is a historical cohort study spanning a 10-year surveillance period (January 2014 to September 2023). The study was carried out at the cardiosurgical department at Istituto Mediterraneo per i Trapianti – ISMETT-IRCCS-UPMC in Palermo (Italy), a 107-bed, Joint Commission International (JCI) accredited center specializing in multi-solid organ transplantation. The hospital serves approximately 3400 patients annually, including over 190 transplant procedures and around 700 cardiac surgeries.

Patient population

The study included consecutive patients undergoing cardiac surgery. Inclusion criteria consisted of isolated coronary artery bypass graft surgery (CABG), valve surgeries including isolated aortic valve replacement (AVR), isolated mitral valve replacement (MVR), combined AVR and MVR, mitral valve repair (MV repair), combined CABG and valve procedures, heart transplant, and other cardiac surgeries (such as aortic surgeries). Percutaneous procedures were excluded.

Data collection & definitions

Data recorded include SSI classifications (superficial, deep, mediastinitis, and unclassifiable infections due to ongoing standardization of subclass details), length of hospitalization (exposure time), diagnostic-related group (DRG) weight (a proxy for complexity of care), and American Society of Anaesthesiologists (ASA) physical status classification [17–20] (online_supplement_1).

SSIs are defined according to Centers for Disease Control and Prevention (CDC) criteria (online_supplement_2). SSI incidence is calculated in accordance with CDC. Characteristics of the surveillance system are reported previously [1]. SSI rates are reported per year.

Study periods

Following the objective of this study, we pooled yearly incidence data from the baseline period (2014–2018), the implementation period (2019-June 2021), and the post-implementation period (July 2021-September 2023).

- **Phase_1 (P1)** – Baseline period (2014–2018). IP&C efforts primarily focused on standard practices such as hand hygiene and MDRO colonization screenings. In the first four years of the surveillance program, SSI rates ranged 4.1 % to 5.1 %, thereby substantially exceeding the international average of 2.6 % in 2017 [21]. This prompted a literature review and comprehensive internal audit in 2018 to align our hospital practices with international recommendations. A QI initiative was prepared and the project goal was set to achieve an SSI incidence not exceeding the ECDC benchmark.
- **Phase_2 (P2)** – Implementation period (2019-June 2021). A QI initiative, steered by an infection control nurse and a cardio-surgeon, with oversight from a quality director, was implemented. This effort united a diverse group including cardiac surgeons, educators, anesthesiologists, nurses, nurses' aides, physiotherapists, and hospital leadership. To foster effective collaboration, we organized the team into smaller multidisciplinary working groups, each under the guidance of senior colleagues. These teams delved into various facets of the program, ensuring comprehensive analysis. Regular monthly updates were shared across the entire group to maintain seamless communication and monitor progress. Throughout P2, our focus, guided by the DMAIC model (Define, Measure, Analyze, Modify, Improve, and Control Model) [22], was dedicated to reducing SSI rates (Fig. 2). Various variables and interventions that were targeted to optimize IP&C standards are reported (Table 1). A root cause analysis for SSI was performed using an Ishikawa diagram (Fig. 3), focusing on three key aspects of the surgical journey: pre-operative, intra-operative, and post-operative phases. This analysis included organizational and cultural factors, as well as post-discharge considerations, though the latter was not prioritized. Subsequently, interventions were implemented to address identified practice gaps. An extensive educational phase was introduced to promote understanding and adherence to evidence-based protocols. World Health Organization's (WHO) 2018 global guidelines for the prevention of surgical site infection [23], as well as the study by Lazar et al. [8], on SSI prevention served as cornerstones for shaping internal policies and driving procedural modifications, alongside the development of a process flow chart to address challenges. However, audit methods lacked standardization, relying on blind observations and an internally developed checklist (online supplement_3). This phase marks a milestone in our implementation efforts.
- **Phase_3 (P3)** – Post-implementation period (July 2021-September 2023). Emphasis in P3 was on monitoring SSI rate and supporting the team to achieve high adherence with processes implemented in P2.

Statistical analysis

We employed a generalized linear mixed-effects model to investigate the factors associated with infection. The binary outcome variable was patient SSI status (infected/not infected).

We included two fixed-effect covariates: phase of the study (P1 serving as reference period) and length of stay (LOS). Additionally, we incorporated random intercepts for DRG weight and ASA score to account for potential clustering effects within these groups. Subsequently, we performed exploratory sub-analyses, one considering exclusively

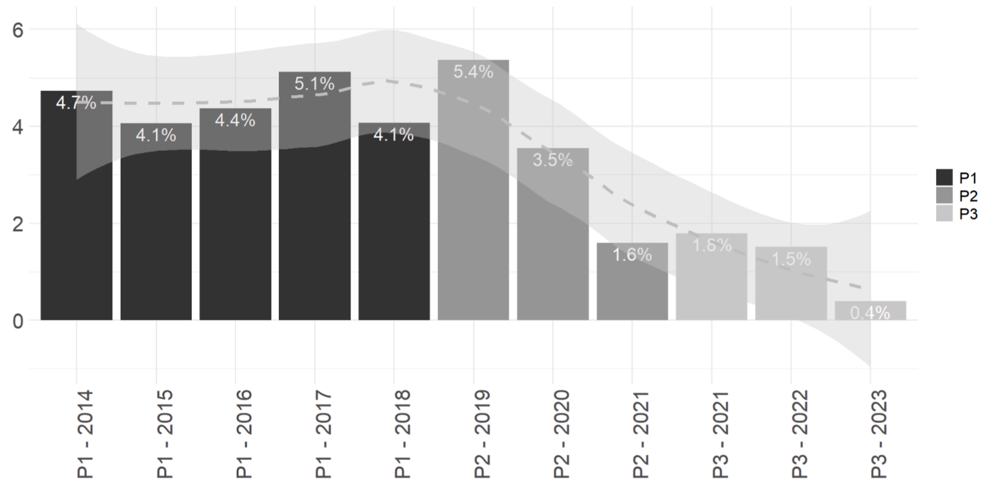

Fig. 1. Surgical site infection by phases / yearly rate (legend: P1, P2, P3, the three phases depicted on the chart; grey dashed line: smoothed trend line (with 95 % CI) shows an overall trend in surgical site infections over time.

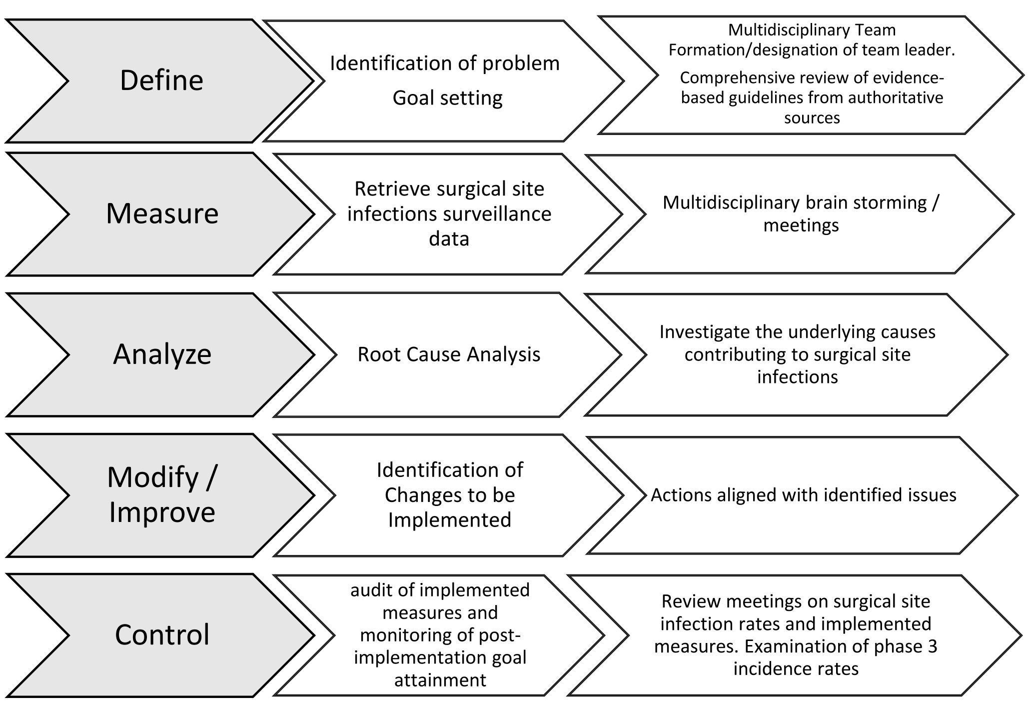

Fig. 2. Flow map of surgical site infection process by the DMAIC approach (Define, Measure, Analyze, Improve e Control).This figure outlines the steps of the surgical site infection process, following the DMAIC method: Define, Measure, Analyze, Improve, and Control. Each stage is mapped to show how the process is managed.

patients with superficial SSIs, and a second considering exclusively patients with deep SSIs or mediastinitis. Results of the model are reported with odds ratios (OR) and 95 % confidence interval (CI). All statistical analyses were conducted using R software version 4.1.0.

Results

A total of 5851 patients were included. ASA scores and DRG weight did not change over the study period (Fig. 4 & Fig. 5). Table 2 reports SSI rates and SSI classification across the distinct study phases. A total of 208 patients developed SSI (3.6 %). SSI incidence in P1 was 4.5 % (ranging 4.1 % to 5.1 % per year), 4.1 % in P2 (ranging 3.5 to 5.4 % per year), and 1.2 % in P3 (ranging 0.4 to 1.8 % per year). (Fig. 1).

Results of the general linear mixed model analysis are reported in Table 3a. Compared with the baseline period (P1), SSI rates did not drop during the implementation phase (OR 0.81, 95 % CI 0.59–1.13; $P = 0.219$). However, a significant decrease in SSI risk was observed during the post-implementation phase (OR 0.19, 95 % CI 0.11–0.32; $P < 0.001$). Table 3b reports the results of the model with exclusively superficial SSIs and Table 3c reports the results of the model only considering deep SSI and cases of mediastinitis. In both sub-analyses an identical pattern is observed, i.e., no effect in risk reduction during the implementation period, and a significant drop in SSI risk observed in the post-implementation period.

Discussion

A QI program targeting preoperative, intraoperative, postoperative, and organizational domains was implemented, resulting in a significant reduction in SSI rates. Over time, the SSI rate declined from an average

Table 1
Implemented measures − phase (P2).

Intervention group	Variable	Intervention	Start date	Audit
Pre-operative	Identification of preventable risk factors	Educational Brochure on smoke cessation,diabetes control and weight loss during the pre-admission consultation	April 2019	Feb 2019 Infection control nurse assessed 30 pre admission consultation
	Shower	Privileges to Nurse's Aide to document shower in EMR in order to track appropriate preparation	January 2020	23 cases June 2020 (Compliance at 88 %) 33 cases July 2020 (Compliance at 90 %) 30 cases August 2020 (Compliance at 83 %) 35 cases September 2020 (Compliance at 92 %)
	Shaving	Privileges to Nurse's Aide to document shave in EMR in order to track appropriate preparation	January 2020	23 cases June 2020 (Compliance at 53 %) 33 cases July 2020 (Compliance at 76 %) 30 cases August 2020 (Compliance at 72 %) 35 cases September 2020 (Compliance at 83 %)
	Timing between patient preparation and sternal incision	Call tree for patient preparation timing established among unit clerk, operating room and cardiothoracic unit. Documentation standardized	January 2020	
	Reducing skin flora	Standardization in practice on Chlorhexidine baths for infection control of multidrug-resistant organisms		
	Preoperative nasal MRSA screening	Documentation of Preoperative decolonization		
	Perioperative antibiotics	Documentation of Administration of Prophylactic antibiotics within the expected window of 30 to 60 min before incision (cefazolin)	June 2020	23 cases June 2020 33 cases July 2020 30 cases August 2020 35 cases September2020 (Compliance at 100 %)
Intra-operative	Advanced dressing	Change dressing from hydrocolloid to gauze	December 2019	21 cases January 2020 (Compliance at 100 %)
	OR antiseptic technique	Standardization of antiseptic technique (EBP) production of educational video share with Surgeons	December 2019	IP&C monitor (21 observations) compliance to appropriate technique January. February 2020 Blind observer May 2020
	Decreasing OR foot traffic	Policy introduction and shared among staff	May 2020	18 cases June 2020 (Compliance at 56 %)
	Normothermia maintenance	Policy introduction and shared among staff		23 cases June 2020 (Compliance at 89 %) 33 cases July2020 (Compliance at 91 %) 30 cases Aug 2020 (Compliance at 100 %) 35 cases Sep 2020 (Compliance at 97 %)
	Suture thread	Change of sutures used from Maxon to (POLYSORB). Reminder sent to surgeons	Dec 2019	18 cases Jun 2020 (Compliance at 100 %)
	Surgical hand antisepsis	Policy and documentation in EMR	May 2020	23 cases June 2020 (Compliance at 97 %)
	Glycemic control	Policy introduction and shared among staff		23 cases June 2020 (Compliance at 29 %) 33 cases July 2020 (Compliance at 78 %) 30 cases August 2020 (Compliance at 89 %) 35 cases September 2020 (Compliance at 83 %)
Post-operative	Patient hygiene	Change in practice: Hygiene carried out no earlier than 24 h post op	16–12-2019	
	Dressing change technique	Video shared with staff Change performed by surgeons Documentation in the EMR Implementation checklist Update policy dressing change	January 2020 June 2020 June 2020 June 2020 October 2020	62 cases(June −September 2020) compliance > 90 %
	Swab technique	Standardization among CTS EBP	October 2020	
	Mobilization of patient post incision Reducing wound dehiscence	Educational video on mobilization to reduce wound dehiscence	September 2021	

(*continued on next page*)

Table 1 (*continued*)

Intervention group	Variable	Intervention	Start date	Audit
Organization-related interventions	Staff engagement	Working group, scheduled meetings	January 2019	Monthly meeting
	Infection cases discussion	Meeting with CTS and IP&C	January 2019	Weekly meeting
	Out-patient wound management post discharge	Presence of IP&C specialist during the post discharge consultation	January 2019	
	AHRQ tool	Introduction of analysis post-surgical infection	January 2019	
	Clean operating room environment	Foot traffic regulated by internal policy	January 2019	

EMR, electronic medical record; EBP, evidence based practice; MRSA, methicillin-resistant Staphylococcus aureus; AHRQ tool, the agency for healthcare research and quality; CTS, cardiothoracic surgeon; IP&C, infection prevention & control specialists; OR, operating room.

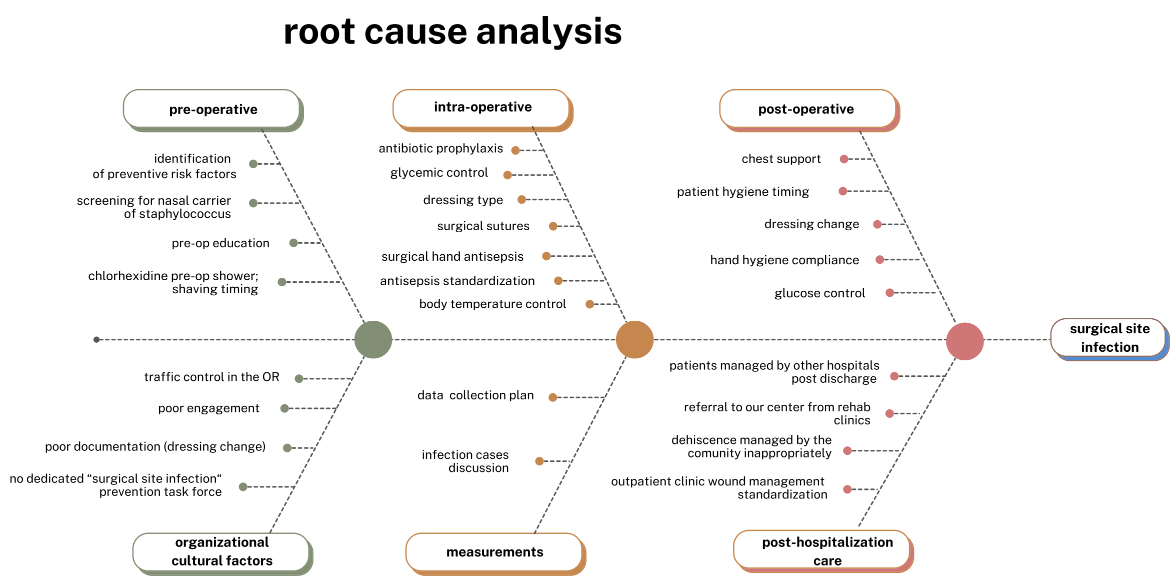

Fig. 3. Ishikawa diagram surgical site infection root cause analysis at ISMETT (institute for scientific-based care and research (IRCCS)) (legend: OR, operating room).

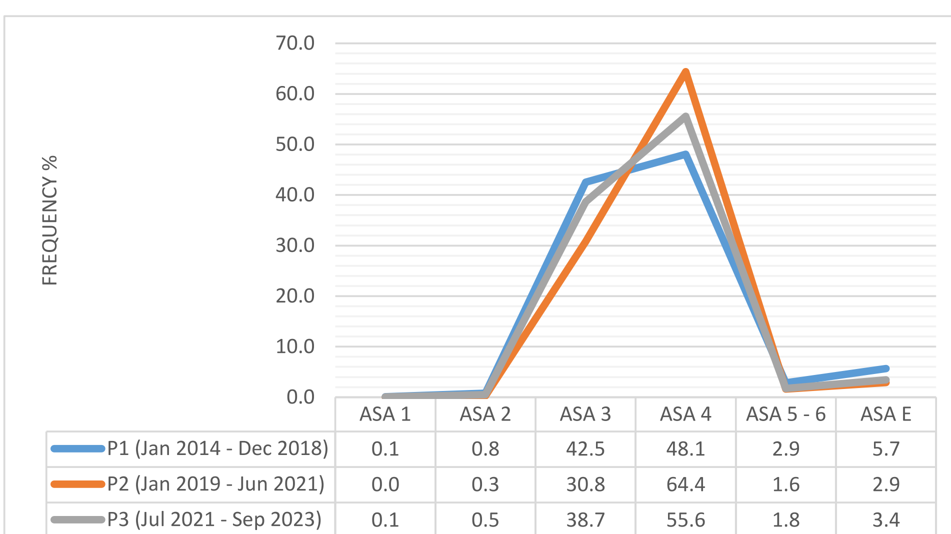

Fig. 4. Distribution of ASA frequency % / phases (legend: ASA, American Society of Anesthesiologists physical status classification system).

of 4.5 % during the baseline period to 1.2 % post-implementation. By the final year of observation, the SSI rate had dropped further to 0.4 %, significantly below the European average of 2.6 %. Sensitivity analyses demonstrated that this risk reduction was observed across superficial and deep SSIs, as well as mediastinitis cases, which have higher clinical significance due to increased morbidity.

While acknowledging the importance of non-modifiable risk factors discussed in a previous paper [1], the implementation of active surveillance allowed us to address this issue through a focused QI program aimed at reducing SSI rates. Effective SSI prevention strategies, as

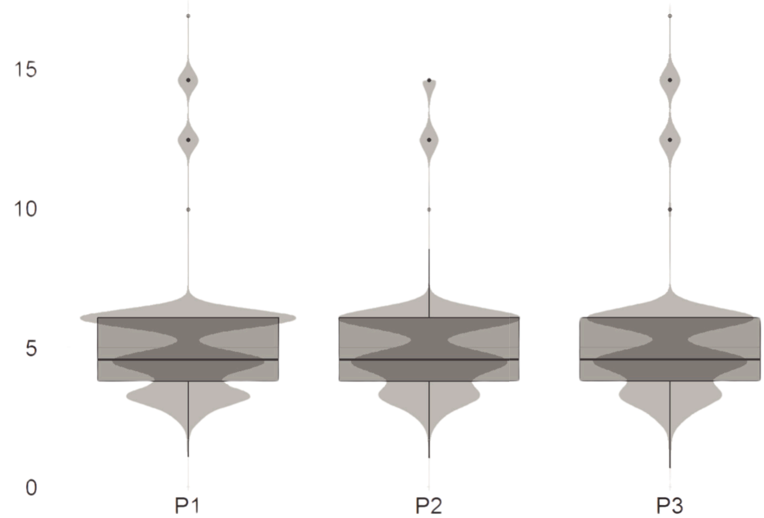

Fig. 5. Pilot violin/ boxplot – weight DRG distribution by phases; (legend: P1, P2, P3, the three phases; DRG, diagnosis-related group; box plot description, box represents the interquartile range (IQR) which includes the second and third quartiles (Q2 and Q3); midline: the line within the box denotes the median (Q2); the vertical axis shows the range and distribution of DRG values across different categories).

Table 2
Surgical site infection by phases/classification.

	cases		surgical site infection classification		
phases	n. patients	n. infection (%)	n. superficial (%)	n. deep/ mediastinitis (%)	n. not classified (%)
P1 (jan 2014 – dec 2018)	2904	130 (4.5 %)	35 (26.9 %)	88 (67.7 %)	7 (5.4 %)
P2 (jan 2019 – jun 2021)	1504	61 (4.1 %)	15 (24.6 %)	45 (73.8 %)	1 (1.6 %)
P3 (jul 2021 – sep 2023)	1443	17 (1.2 %)	2 (11.8 %)	15 (88.2 %)	0 (0.0 %)
total	**5851**	**208 (3.6 %)**	**52 (25.0 %)**	**148 (71.2 %)**	**8 (3.8 %)**

Table 3
Relationships between study phases and surgical site infection risk.

	P value	Odds ratio (95 % confidence interval)
3a – Total cohort (all SSIs, n = 208)		
Study period		
Phase 1 (baseline)		Reference period
Phase 2 (implementation phase)	0.219	0.81 (0.59 – 1.13)
Phase 3 (post-implementation phase)	< 0.001	0.19 (0.11 – 0.32)
Length of hospitalization (before SSI), per day increase	< 0.001	1.027 (1.021 – 1.033)
3b – Sub-analysis (only superficial SSIs, n = 52)		
Study period		
Phase 1 (baseline)		Reference period
Phase 2 (implementation phase)	0.145	0.64 (0.35 – 1.17)
Phase 3 (post-implementation phase)	< 0.001	0.08 (0.02 – 0.34)
Length of hospitalization (before SSI), per day increase	< 0.001	1.016 (1.009 – 1.022)
3c – Sub-analysis (only deep SSIs and mediastinitis cases, n = 148)		
Study period		
Phase 1 (baseline)		Reference period
Phase 2 (implementation phase)	0.307	0.82 (0.56 – 1.20)
Phase 3 (post-implementation phase)	< 0.001	0.25 (0.14 – 0.44)
Length of hospitalization (before SSI), per day increase	< 0.001	1.026 (1.020 – 1.032)

ASA score and DRG weight are random intercept effects. SSIs – surgical site infections.

emphasized by Horgan et al. [24], require a thorough understanding of the problem through consistent surveillance. International bodies and researchers advocate for the universal adoption of such surveillance in hospital settings due to its proven effectiveness in reducing SSI incidence [25]. However, sustaining improvements in infection prevention demands the establishment of robust structures and processes [26]. Our multidisciplinary QI program incorporated continuous SSI rate surveillance, enabling proactive monitoring and data analysis to enhance care quality. Regular feedback to teams and SSI rate communication to stakeholders were essential [23,27].

During the implementation phase, we did not observe a significant drop in SSI rates compared with the baseline period. However the SSI rate in the second year of the implementation phase was already substantially lower compared with the first year. Hence, the decrease in SSI rates observed in the post implementation period in fact already started during the implementation phase. While the literature often evaluates infection rates before and after QI initiatives [28], there are variations in analysis methods. Some studies, such as Franklin et al. [29], focus on the "early implementation" stage of interventions, leaving the intermediate phase understudied despite its potential significance. This gap in the literature suggests that exploring the intermediate phase could offer valuable insights into the dynamics of infection rates. The discrepancies in analysis methods and the oversight of the intermediate phase highlight the need for further research. Although this study did not specifically focus on the implementation phase, the significant reduction in SSI risk observed during the post-implementation phase is likely due to the time required for proper adherence to infection prevention and control (IP&C) protocols. Effective implementation demands extensive training, consistent practice, and adaptation to new routines, which are time-consuming. In P3, the implemented procedures were likely further strengthened and consolidated. For instance, in July 2021, a new diabetes management model for cardiac surgery patients was introduced [30]. This approach, which focused on systematic glycated hemoglobin assessment, was linked to fewer perioperative infections, likely contributing to the reduction in SSI rates. Continuous monitoring and reinforcement are also essential, as highlighted by Goorts et al. [31].

Braun et al. [32] reviewed the limited empirical evidence linking a culture of safety promoted by QI initiatives to a reduction in healthcare-associated infections (HAIs). Nevertheless, a substantial body of research indicates that fostering a robust safety culture correlates with improvements in IP&C practices and reduced HAIs. Authors often observe enhancements in safety culture indirectly, reflecting a mutually reinforcing relationship where effective interventions strengthen safety practices and a supportive safety culture facilitates their successful implementation.

The absence of a statistically significant decrease in SSI rates during the implementation phase was followed by a notable increase in SSI occurrences, particularly in 2019, when the rate was 5.4 %. Among the various measures implemented (Table 1), the introduction of new sutures for intraoperative closure was a significant factor. Using the AHRQ Surgical Site Infection Investigation Tool [33] to audit SSI cases and monitor incidence revealed multiple instances of wound dehiscence leading to subsequent infections. This finding allowed us to identify the problem and discontinue the use of those specific sutures. Continuous data monitoring and analysis, facilitated by tools like the AHRQ tool, are crucial for enhancing SSI prevention by identifying trends and uncovering issues such as wound dehiscence.

The strength of the study lies in the stability of ASA and DRG covariates over time, which suggests that the population's risk profile remained consistent and minimizes the likelihood of confounding effects. Although ASA classification was not a specific focus of this study, previous research establishes a correlation between ASA scores and the risk of operative site infections, particularly in vascular surgery and hip fracture patients [34,35]. The consistent distribution of DRG weights, as depicted in Fig. 5, indicates that the observed reduction in infection incidence cannot be attributed to treating less complex patients. This finding aligns with previous research highlighting the utility of DRG weights in assessing patient acuity and complexity [36–38], thereby strengthening the validity of the study's findings on infection reduction efforts.

Lastly, the multidisciplinary nature of the project likely contributed to the success in reducing SSI rates, as documented in the literature [38–40]. Forming a task force comprising surgeons, nurses, infection control specialists, physiotherapists, and nurses' aides was crucial for addressing the complex factors influencing SSIs. This collaborative effort led to the implementation of targeted strategies, such as enhanced preoperative protocols, improved surgical techniques, rigorous postoperative care, and continuous education and training for healthcare professionals. The task force's coordinated actions ensured evidence-based and consistently applied interventions, resulting in a significant reduction in SSI rates. This multidisciplinary approach underscores the importance of teamwork and continuous communication in achieving sustained improvements in patient outcomes. As highlighted by Sreeramoju et al.[38] in "Reducing Infections Together", adaptable approaches in healthcare improvement are essential. A systematic literature review by Horgan et al.[24] also emphasized that effective SSI reduction requires a multidisciplinary approach, strong hospital governance, a shared vision, and an effective improvement methodology [41]. The DMAIC framework, which depends on leadership support and teamwork, was crucial to our project's success as our interdisciplinary team refined processes under hospital leadership's guidance. Gillespie et al.[13] highlighted the importance of bundled care strategies in reducing SSIs through standardized protocols, though identifying the most effective components remains challenging. Similarly, Nessim et al. [42] emphasized structured team collaborations and clear responsibilities to ensure patient well-being.

Throughout the patient care continuum, from preoperative preparation to postoperative education, the study employed targeted strategies underpinned by structured team collaborations that delineated specific roles and responsibilities across different phases of care, highlighting individual clinician expertise and accountability for patient well-being [42].

Limitations

The study did not include data on the turnover of clinical staff or other external factors, which may have influenced the results.The low annual incidence of SSIs made meaningful time series analysis difficult. To address this, we pooled data across multiple years within each phase to achieve a sufficient sample size, which increased statistical power, revealed broader trends, and allowed for a more robust examination of intervention effectiveness. On a different note, despite the significant SSI reductions, linking individual measures to infection reduction is challenging due to potential confounders and the lack of a standardized auditing mechanism. However, stable DRG and ASA scores over time demonstrate that these improvements are not attributable to a decrease in case complexity (Figs. 4-5).

Conclusion

In conclusion, this study highlights the successful implementation of a QI program in a hospital setting, showcasing collaborative efforts across diverse disciplines to adopt evidence-based practices. Strategic planning involving all stakeholders has played a crucial role in advancing patient care consistently over time. Before replicating similar initiatives elsewhere, thorough assessment and auditing are recommended to sustain improvements and identify new areas for enhancement. The significant reduction in SSIs observed from 2020 can be attributed to the multimodal and multidisciplinary implementation of evidence-based prevention interventions by the collaborative team, supported by effective leadership. Moving forward, change initiatives should be guided by institution-specific data, tailored to address the unique characteristics and challenges of each institution. This targeted approach acknowledges the multifaceted nature of reducing surgical site infections and underscores the importance of institution-specific data in driving meaningful and effective change initiatives.

To sustain the reductions in SSI rates beyond the study period, future initiatives should be tailored to institution-specific data, addressing unique challenges. Ongoing training, reinforcement of policies, and effective compliance monitoring are crucial to maintaining the impact of the interventions. Additionally, regular assessments and audits will help ensure continued success, identify new areas for improvement, and support the long-term sustainability of infection prevention strategies.

Clinical trial registration

Not applicable.

Ethics statement

The study received approval from the Institutional Review Board (IRB) on March 4, 2021 (IRRB/09/21) and the local ethics committee (IRRB/09/21, CE 22 Sept. 2022).

Author agreement

All authors have made substantial contribution to conception and design of the study, collection of the data, statistical analyses, interpretation of the results, drafting or reviewing of the manuscript. All authors approved the final version of the manuscript submitted for peer review to ICCN.

CRediT authorship contribution statement

Elena Conoscenti: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Data curation, Conceptualization. **Giuseppe Enea:** Writing – review & editing. **Mieke Deschepper:** Formal analysis. **Diana Huis in 't Veld:** Writing – review & editing, Writing – original draft, Supervision. **Maria Campanella:** Writing – review & editing, Conceptualization. **Giuseppe Raffa:** Writing – review & editing. **Barbara Ragonesi:** Writing – review & editing. **Alessandra Mularoni:** Writing – review & editing. **Alessandro Mattina:** Writing – review & editing. **Stijn Blot:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Stijn Blot is Editor-in-Chief for Intensive & Critical Care Nursing and was not involved in the editorial review or the decision to publish this article. Other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2024.103926.

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