Pediatric cardiac surgical site infections: A single-center quality improvement initiative

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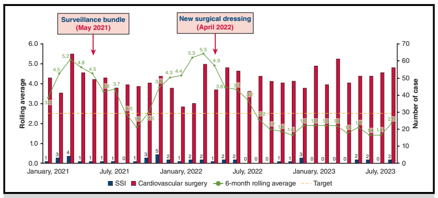
ABSTRACT

Objective: Pediatric cardiac surgery site infections (SSI) represent significant morbidity. Our institution reported elevated SSI rates of 3.48 per 100 cases over a 5-year period above target rates of 2.5 per 100 cases. Therefore, as a quality improvement initiative, we implemented interventions with the goal of decreasing SSI rates by 30%.

Methods: Pediatric cardiovascular surgery patients (January 2021 to August 2023) who had SSI within 30 days of index operation were included (n = 1514) based on the National Healthcare Safety Network definition. Descriptive statistics were used to compare our preintervention cohort (pre-IV) (January 2021 to April 2022; n = 753) and postintervention cohort (post-IV) (May 2022 to August 2023; n = 761).

Results: In the post-IV cohort, we found a significant decrease in total SSI (1.97 SSIs per 100 cases [15 out of 761]) versus pre-IV (3.85 SSIs per 100 cases [29 out of 753]), demonstrating a 48% reduction (*P* = .029). In our post-IV cohort, there was a significant reduction in superficial SSIs (pre-IV, 3.19 SSIs per 100 cases [24 out of 753] vs post-IV, 1.58 SSIs out of 100 cases [12 out of 761]; *P* = .04). Wounds presenting at 1 to 3 weeks were also reduced in our post-IV cohort (pre-IV, 2.66 SSIs per100 cases [20 out of 753] vs post-IV, 0.66 SSIs per 100 cases [5 out of 761]; *P* = .002). A significant reduction in SSIs in nonneonates was also noted (pre-IV, 2.79 SSIs per 100 cases [21 out of 753] vs post-IV, 0.92 SSIs per 100 cases [7 out of 761]; *P* = .007). Additionally, there was a significant reduction in SSIs associated with the Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery Congenital Heart Surgery 1 mortality category (*P* = .033) and the number of readmissions in the post-IV cohort (*P* = .042).

Conclusions: A new surgical site dressing and multidisciplinary surveillance plan effectively reduced the overall burden of SSI rates at our institution. Future studies will address risk factors in specific subpopulations to further reduce SSIs at our institution. (JTCVS Open 2024;22:438-47)



Reduction in surgical site infections in postintervention cohort.

CENTRAL MESSAGE

A new surgical dressing and enhanced multidisciplinary communication reduced pediatric cardiac surgery SSI rates at the Hospital for Sick Children by 48% and contributed to improved surgical outcomes.

PERSPECTIVE

Elevated SSI rates over a 5-year period at our institution led to the institution of QI initiatives with the goal of decreasing SSI rates by 30%. Our objective was to analyze rates of SSI at our institution as part of ongoing continuous QI interventions and identify future areas of improvement.

See Discussion on page 448.

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Ethical approval was granted by the institutional research ethics board (# 1000080949; October, 13, 2023) and consent was waived due to the retrospective nature of the study.

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Abbreviation and Acronyms

ECMO	=	extracorporeal membrane oxygenation
EMR	=	electronic medical records
ICU	=	intensive care unit
MRSA	=	methicillin-resistant *Staphylococcus aureus*
NP	=	nurse practitioner
QI	=	quality improvement
SSI	=	surgical site infection
STAT	=	Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery Congenital Heart Surgery

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Cardiac surgical site infections (SSIs) are associated with significant morbidity and mortality in pediatric patients. Rates of SSIs after pediatric cardiac surgery typically range from 2% to as high as 6% of patients and can result in increased length of admission, readmission to hospital, increased caregiver stress, and high health care cost.[1,2] In high-risk patients, SSIs can be associated with higher mortality (7%-20%).[3]

SSIs can be classified as superficial, deep, and mediastinitis, with *Staphylococcus aureus* being the most common organism isolated.[4] Infections typically present within the first 30 days following surgery. Identified risk factors for pediatric cardiac SSIs include Risk Adjustment for Congenital Heart Surgery score, preoperative hospitalization, low cardiac output state, genetic abnormalities, preoperative hemoglobin, nasal colonization of methicillin-resistant *S aureus* (MRSA), complexity of surgical procedure, operation time, cardiopulmonary bypass time, low rectal temperature, blood transfusion, mechanical ventilation, chest drainage tube duration, antimicrobial prophylaxis, and intensive care unit (ICU) length of stay.[3,5,6] Delayed sternal closure is not uniformly associated with increased SSI in the literature.[7,8]

Our institution is a tertiary high-volume referral center, and our 5-year SSI event rates were found to be elevated (3.48 SSIs/100 cases) above a target rate of 2.5 SSIs/100 cases, which was set by hospital administration. Given our relatively short length of stay for elective routine cardiac surgery cases (average, 2-4 days) and outpatient postsurgical care provided at affiliated centers, we implemented 2 major interventions with the goal of reducing SSIs by 30%. Our first intervention was to establish a surveillance bundle that built on our existing dedicated wound email by creating a customized shared patient wound list to allow for multidisciplinary follow-up and quick reference to the current wound care plan. This allowed for close surveillance of at-risk wounds. Our second intervention addressed primary prevention by the introduction of an antimicrobial dressing (Prineo; Ethicon) with standardized wound care protocol across our heart center (nursing protocols and surgical fellow handbook). To evaluate our interventions, we analyzed the pattern of pediatric cardiac SSIs at our institution, with the purpose of comparing the rate of SSIs at our institution before and after our 2 directed quality improvement (QI) interventions.

METHODS

The study included all pediatric patients (aged 0-18 years) who underwent an index cardiac surgery between January 2021 and August 2023 at the Hospital for Sick Children. Within the study period, we identified all those who developed SSI (superficial, deep, or mediastinitis) within 30 days of the operation at either a sternotomy, thoracotomy, or surgical pacemaker incision, using the National Healthcare Safety Network criteria.[9] Patients with sterile dehiscence were excluded. Patients were identified using clinical cardiac surgery wound databases with retrospective chart reviews using the electronic medical records (EMR) system. Ethical approval was granted by the institutional research ethics board (#1000080949; October 13, 2023) and consent was waived due to the retrospective nature of the study.

Our institution has a multidisciplinary cardiac surgery SSI committee that is composed of clinical nurse champions, postoperative nurse practitioners (NPs), QI nurses, and cardiac surgeons. Activities of the cardiac surgery SSI committee were in conjunction with a larger hospitalwide perioperative SSI committee that looked to standardize and optimize perioperative practices. Previous interventions before the study period included the use of perioperative chlorhexidine wipes, MRSA preoperative screening, standardized skin asepsis by operating room nursing, subcuticular Prolene suture closure with externalized knots, standard dry surgical dressing, and standardized wound care protocol. In addition, an outpatient email for wound concerns was created in early 2020 for postoperative outpatient surveillance by postoperative NPs. Despite these initiatives, SSI rates remained elevated in 2019-2020 (4.16 SSIs/100 cases).

To understand the influence of our recent QI interventions (surveillance bundle and new surgical dressing), we examined cardiac surgery patients (n = 753) before the introduction of the new surgical dressing (preinterventions cohort, January 2021-April 2022) and all cardiac surgery patients (n = 761) following the introduction of the new surgical dressing (postinterventions cohort, May 2022-August 2023).

Patient characteristics, surgical information, and postoperative course were collected from the medical records. Age categories were defined based on the patient's age at the time of the procedure: neonates (age ≤1 month), infants (age ≥31 days and <1 year), toddlers (age ≥1 year and ≤3 years), children (age >3 years and <10 years), and teenagers (age ≥11 years and <18 years). To assess the incidence of SSIs, we collected data on the timing, presentation of wound complications, the Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery Congenital Heart Surgery (STAT) mortality categories, as well as the associated organisms. Wound complications are classified as superficial, deep, and mediastinitis within 30 days of the index cardiac procedure, as based on the National Healthcare Safety Network criteria, and were independently reviewed by a hospital infectious control practitioner.

Descriptive statistics were used to examine and compare the rates of SSI. Median (inter-quartile range) and mean ± SD were reported for continuous variables. A Shapiro-Wilk normality test was conducted to show that the data set was normally distributed. Categorical variables were compared between 2 groups using 2-sample proportion test based on the overall number of cases and Fisher exact test. Continuous variables were compared between 2 groups using both a Mann-Whitney *U* test and Student *t* test.

RESULTS

Overall Cohort

Our institution reported a 5-year SSI rate of 3.48 per 100 cases, which was above the target of 2.5 SSIs per 100 cases. We looked at the postpandemic cardiac surgery patients and evaluated the influence of our QI interventions on SSI rates. In the study period of January 2021 to August 2023, a total of 1514 patients underwent an index cardiac surgical procedure at our institution (Figure 1). We had adherence to existing perioperative infection bundles with >98% of patients having appropriate preoperative screening for MRSA, protocolized preoperative skin asepsis by our operating room nurses, and preincisional antibiotics.

Forty-four SSIs (2.91 SSIs/100 cases) were identified following an index cardiac surgery procedure between January 2021 and August 2023 (Tables 1 and 2). Of those patients developing SSI, 57% (25 out of 44) were male patients with a median age of 5.5 months (interquartile range, 10 days-4.7 years). Society of Thoracic Surgeons STAT categories were evenly distributed with 25% (11 out of 44) STAT 1, 23% (10 out of 44) STAT 2, 14% (6 out of 44) STAT 3, 32% (14 out of 44) STAT 4, and 2% (1 out of 44) STAT 5. Neonates accounted for 36% (16 out of 44) of SSIs, whereas children between ages 3 and 10 years accounted for 27% of SSIs (12 out of 44). Infants <5 kg accounted for 45% (20 out of 44) of SSIs, with 14 patients being ex-premature (32%). Superficial SSIs accounted for 82% (36 out of 44) of all SSIs with the majority occurring between 1 and 3 weeks postoperatively (57% [25 out of 44]) and *S aureus* was the causal organism identified in 24 out of 44 (54.5%) of all SSIs.

Influence of QI Initiatives

To understand the influence of our recent QI initiative on the incidence of SSI, we examined patient demographics and SSI characteristics between the preinterventions and postinterventions cohorts (Tables 1 and 2). Overall, we found a decrease in total SSIs rate in our postinterventions cohort (1.97 SSIs/100 cases [15 out of 761]) compared with our preinterventions cohort (3.85 SSIs/100 cases [29 out of 753]), demonstrating a 48% reduction in SSIs ($P = .029$) (Figure 1 and Table 2). See Figure 2 for the graphical abstract.

In the preinterventions cohort (n = 29) (Table 2), nonneonates accounted for 2.79 SSIs/100 cases (21 out of 753), with patients weighing >5 kg accounting for 2.52 SSIs/100 cases (19 out of 761) (Figure 3). Twenty-eight of the 29 SSIs involved the sternotomy incision, with 1 involving a pacemaker generator incision. Four of the patients had delayed sternal closure with 2 requiring extracorporeal membrane oxygenation (ECMO). The most common timing of wound presentation was 1 to 3 weeks (2.66 SSIs/100 [20 out of 753]) following the index procedure, with methicillin-sensitive *S aureus* identified as a causal organism in 1.86 SSIs/100 cases (14 out of 753). The average time in the ICU was around 9 ± 17.5 days. Readmission for the wound occurred in 1.6 SSIs/100 cases (12 out of 753) of the preinterventions cohort.

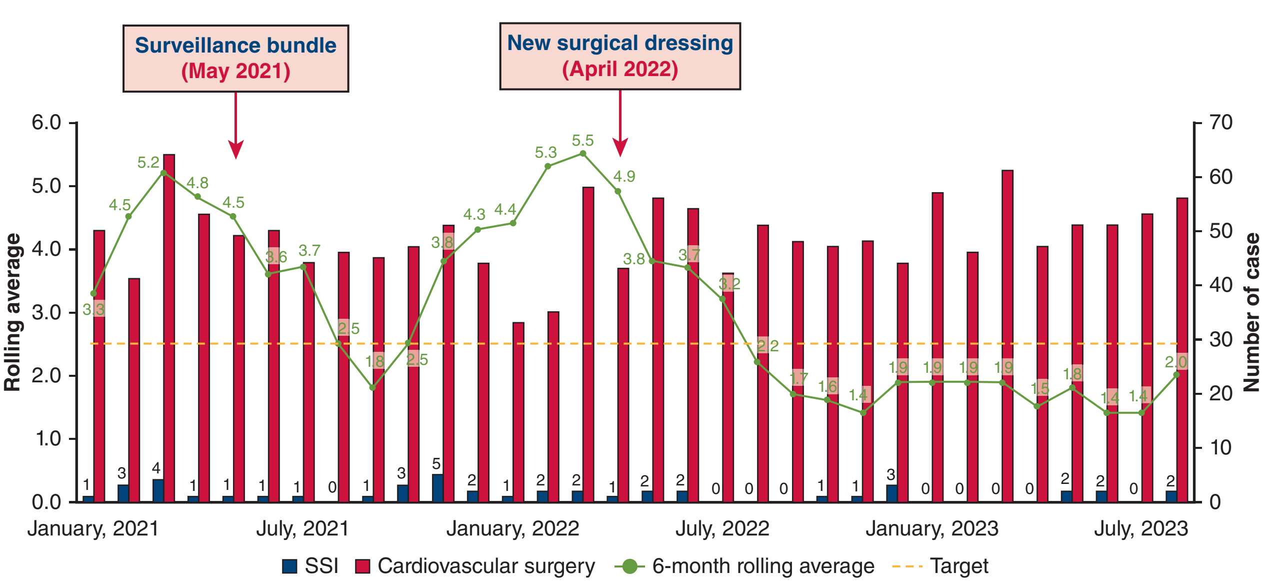


FIGURE 1. Surgical site infection (*SSI*) rates per 100 cases of cardiovascular surgery between January 2021 and August 2023. SSI rates are represented by 6-month rolling average (*green line*). *Blue bars* represent SSI numbers; *red bars* represent total monthly surgical cases. Our target rate is the *yellow dashed line*.

TABLE 1. Overall patient characteristics and perioperative variables

Variable	Total cohort (N = 44)	Preintervention (n = 29)	Postintervention (n = 15)	*P* value
No. of SSIs				
Cardiac surgery cases	1514	753	761	
SSI/100 cases	2.91	3.85	1.97	.029*
Characteristic				
Male gender	25 (56.82)	17 (58.62)	8 (53.33)	.759†
Prematurity (<37 wk)	14 (31.82)	10 (34.48)	4 (26.67)	.738†
Age at procedure (y)	0.46 (0.03-4.75)	1.00 (0.04-5.74)	0.05 (0.02-0.85)	.059‡
Weight (kg)	5.98 (2.9-15.9)	7.4 (3.5-20.0)	3.9 (2.9-7.7)	.144‡
Preoperative variables				
MRSA positive	0 (0.00)	0 (0.00)	0 (0.00)	1.000†
Hbg (g/L)	138 ± 25	140 ± 20.6	134 ± 33	.479§
LOS	0.5 (0-3)	0 (0-3)	2 (0-4)	.189‡
Skin prep	44 (100)	29 (100)	15 (100)	1.000†
Preincisional antibiotics	44 (100)	29 (100)	15 (100)	1.000†
Previous SSI	1 (2.27)	0 (0.00)	1 (6.67)	.341†
Surgical variables				
Procedure time, minutes	262.5 ± 136.6	281.3 ± 153.5	226.3 ± 97	.155§
Non CPB case	5 (11.36)	2 (6.90)	3 (20.00)	.319†
CPB time, minutes	119.1 ± 62.3	122.7 ± 71.8	111.3 ± 37.4	.513§
Aortic crossclamp time, minutes	63.5 ± 41.2	66.2 ± 46.3	58.4 ± 32.5	.735§
Blood transfusion	26 (59.09)	19 (65.52)	7 (46.67)	.334†
Foreign material/implant	37 (84.09)	24 (82.76)	13 (86.67)	1.000†
Delayed sternal closure	4 (9.09)	4 (13.79)	0 (0.00)	.285†
Open sternum (d)	2.5 (1.75-4.0)	2.5 (1.75-4.0)	0 (0-0)	.082‡
Perioperative ECMO	3 (6.82)	2 (6.90)	1 (6.68)	.557†
Postoperative variables				
ICU LOS (d)	7.5 ± 14.4	8.7 ± 17.5	5.3 ± 5.4	.354§
Hospital LOS (d)	19.4 ± 22.5	20.4 ± 26.7	17.4 ± 12.7	.618§
Mortality	5 (11.36)	4 (13.79%)	1 (6.67)	.647†

Values are presented as event rate (%/100 cases), n (%), median (interquartile 1-interquartile 3), or mean ± SD. *P* values are the comparison of preintervention and postintervention. *SSI*, Surgical site infection; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *Hbg*, hemoglobin; *LOS*, length of stay; *CPB*, cardiopulmonary bypass; *ECMO*, extracorporeal membrane oxygenation; *ICU*, intensive care unit. *Two-sample proportion test. †Fisher exact test. ‡Mann-Whitney *U* test. §Student *t* test.

When examining our postinterventions cohort SSIs (Table 2), there was not a significant reduction in neonatal SSIs (1.05 SSIs/100 cases [8 out of 761]); however, a 67% reduction in SSIs occurred in children older than age 1 month (preinterventions, 2.79 SSIs/100 cases [21 out of 753] vs postinterventions, 0.92 SSIs/100 cases [7 out of 761]; $P = .007$) (Figure 3). In children > 5 kg, SSIs were significantly reduced (preinterventions, 2.52 SSIs/100 cases [19 out of 753] vs postinterventions, 0.66 SSIs/100 cases [5 out of 761]; $P = .004$) (Figure 3). Superficial SSIs decreased by 50% (preinterventions, 3.19 SSIs/100 cases [24 out of 753] vs postinterventions, 1.58 SSIs/100 cases [12 out of 761; $P = .04$), without a significant decrease in deep and mediastinal SSIs (Figure 3). The timing of wound presentation decreased significantly in the 1 to 3 weeks category (preinterventions, 2.66 SSIs/100 cases [20 out of 753] vs postinterventions, 0.66 SSIs/100 cases [5 out of 761]; $P = .002$) (Figure 3). The number of methicillin-sensitive *S aureus* and MRSA-related SSIs were not different between the 2 cohorts (Table 2). Although the distribution of cases between Society of Thoracic Surgeons STAT categories 1 through 5 were similar in the preintervention and postintervention periods (Table E1), there was a significant reduction in SSIs associated with the STAT 1 mortality category (preintervention, 1.20 SSIs/100 cases [9 out of 753] vs postinterventins, 0.27 SSIs/100 cases [2 out of 761]; $P = .03$) (Table 2). There was no significant difference between procedural time, bypass time, aortic crossclamp time, or need for ECMO. The length of stay in the ICU and hospital was not different between the preintervention and postintervention cohorts. In the preintervention cohort, 4 SSIs occurred in patients with delayed sternal closure, whereas in the postinterventions cohort, 1 SSI occurred in a child with delayed sternal closure, but this was not statistically significant (Table 1).

There was a significant reduction in the number of readmissions for wound care in the postinterventions cohort (preinterventions, 1.59 SSIs/100 cases [12 out of 753] vs postinterventions, 0.53 SSIs/100 cases [4 out of 761]; $P = .042$) (Table 2). Overall mortality for these cardiac

TABLE 2. Surgical site infection (SSI) event rates (SSI/100 cases) in pediatric patients before and after intervention

Category	January 2021-August 2023	Preintervention	Postintervention	*P* value
SSI/100 cases	2.91	3.85	1.97	.029
No. of SSIs	44	29	15	
Cardiac surgery cases	1514	753	761	
Category of SSI				
Superficial	36 (2.38)	24 (3.19)	12 (1.58)	.040
Deep	2 (0.13)	1 (0.13)	1 (0.13)	.994
Mediastinitis	6 (0.40)	4 (0.53)	2 (0.26)	.406
Timing of SSI				
Median (interquartile range)	15 (10-26)	14 (11-22)	22 (8-29)	.629
<1 wk	4 (0.26)	1 (0.13)	3 (0.39)	.322
1-3 wk	25 (1.65)	20 (2.66)	5 (0.66)	.002
>3 wk	15 (0.99)	8 (1.06)	7 (0.92)	.779
Age group				
Neonate	16 (1.06)	8 (1.06)	8 (1.05)	.983
Nonneonate	22 (1.45)	21 (2.79)	7 (0.92)	.007
Infant	10 (0.66)	7 (0.93)	3 (0.39)	.198
Child	12 (0.79)	9 (1.20)	3 (0.39)	.557
Toddler	3 (0.20)	2 (0.27)	1 (0.13)	.749
Adolescent	3 (0.20)	3 (0.40)	0 (0.00)	.081
Weight category (kg)				
<3	12 (0.79)	7 (0.93)	5 (0.66)	.561
3-5	8 (0.53)	3 (0.40)	5 (0.66)	.477
>5	24 (1.59)	19 (2.52)	5 (0.66)	.004
5.1-10	7 (0.46)	6 (0.80)	1 (0.13)	.057
>10	17 (1.12)	13 (1.73)	4 (0.53)	.028
STAT mortality category				
1	11 (0.73)	9 (1.20)	2 (0.27)	.033
2	10 (0.66)	7 (0.93)	3 (0.40)	.203
3	6 (0.40)	2 (0.27)	4 (0.53)	.412
4	15 (0.99)	10 (1.33)	5 (0.66)	.196
5	1 (0.07)	0 (0.00)	1 (0.13)	.317
Organism				
Staphylococcus aureus	24 (1.59)	15 (1.99)	9 (1.18)	.207
MRSA	1 (0.07)	1 (0.13)	0 (0.00)	.315
MSSA	23 (1.52)	14 (1.86)	9 (1.18)	.282
CoNS	5 (0.33)	3 (0.40)	2 (0.26)	.646
Gram negative	2 (0.13)	2 (0.27)	0 (0.00)	.155
Culture not available	13 (0.86)	10 (1.33)	3 (0.39)	.049
Wound care adjuncts				
Neg P dressing	6 (0.40)	3 (0.40)	3 (0.39)	.990
Wound revision	12 (0.79)	7 (0.93)	5 (0.66)	.550
Wound readmission	16 (1.06)	12 (1.59)	4 (0.53)	.042

Values are presented as median (interquartile 1-interquartile 3), frequency (%), and event rate (%/100 cases). *P* values are the comparison of preintervention and postintervention. Statistical test used is a 2-sample proportion test. *STAT*, Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery Congenital Heart Surgery; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *MSSA*, methicillin-sensitive *Staphylococcus aureus*; *CoNS*, coagulase-negative *Staphylococcus*; *Neg P*, negative pressure.

surgery patients with an SSI was 11% (5 out of 44) and was not different across the 2 cohorts (Table 1). All deaths occurred in children younger than age 2 years, and all were STAT mortality category ≥4. Two deaths (preinterventions cohort) occurred in the perioperative period in the context of ECMO for low cardiac output. These 2 patients had a secondary diagnosis of mediastinitis, but the cause of death was not attributed to the SSI.

DISCUSSION

This study compared SSI rates of pediatric patients undergoing cardiac surgery at the Hospital for Sick Children

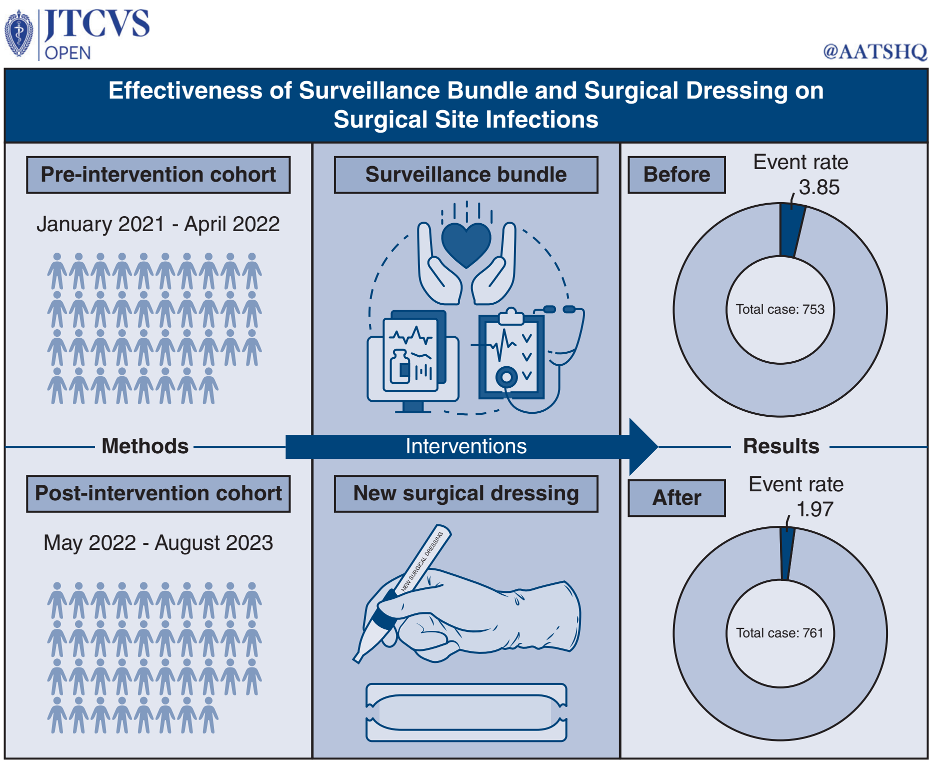


FIGURE 2. Graphical abstract.

before and after the recent introduction of new QI interventions (surveillance bundle and surgical dressing). Our study demonstrated a significant decrease in total SSI, with a 48% reduction in the postinterventions cohort compared with the preinterventions cohort. In the postinterventions cohort, there was a significant reduction in SSIs in infants and children older than age 1 month and >5 kg. There was also a significant decrease in SSIs occurring in STAT category 1 patients and an overall reduction in readmissions for wound care. Our interventions included consistent tracking and surveillance of patients in the outpatient setting (centralized EMR multidisciplinary patient list) and a change in surgical dressing with associated standardization of wound care across our heart center. Previous QI practices that were implemented at our center did not change our overall SSI rates, but certainly built a foundation and contributed to the decreased SSI rates seen in our postinterventions cohort.

Reported rates of SSI vary across pediatric heart centers. This variation can be influenced by factors such as the complexity of cases (STAT mortality categories), the reporting time frame (14 vs 30 days), and the ability to track wounds that are treated outside of the hospital setting. Patients who are followed by a family physician or cardiologist often do not return to the surgical center, which can contribute to lower reported rates of SSI. In our institution, we ensure follow-up reporting of all cardiac surgery patients with our other provincial referral centers and through caregiver communication utilizing our centralized email for wounds.

Clinical and surgical care bundles have been implemented globally in surgical facilities to address the high incidence of SSI in both adults and children. A recent systematic review of randomized control SSI trials demonstrated the effectiveness of care bundles in reducing the rate of SSIs.[10] A study by Weiser and colleagues[11] demonstrated that a multidisciplinary care bundle implemented hospitalwide could greatly reduce SSI rates in patients at intermediate or high risk. In pediatric cardiac surgical literature, an interdisciplinary approach with multiple interventions successfully decreased the SSI rate from 1.9 to 0.3 SSIs per 100 cases,[12] and postoperative care bundles at another institution reduced SSI rates from 3.4 to 0.9 per 100 surgeries.[13] Our surveillance bundle included utilizing our email outpatient wound follow-up and coupling it to a customized EMR patient list that was accessible to NPs, quality leads, cardiac surgery fellows, and cardiovascular surgeons. As our patients move from the cardiac critical care unit to the cardiac ward, postoperative NPs primarily handle routine wound care with escalation to our cardiac surgery fellows as appropriate. In postoperative settings, wound care is managed collaboratively, and the effective communication of patients at-risk-of-wound-care plans is essential to identify early complications and mitigate morbidity. To help standardize practices across groups, we

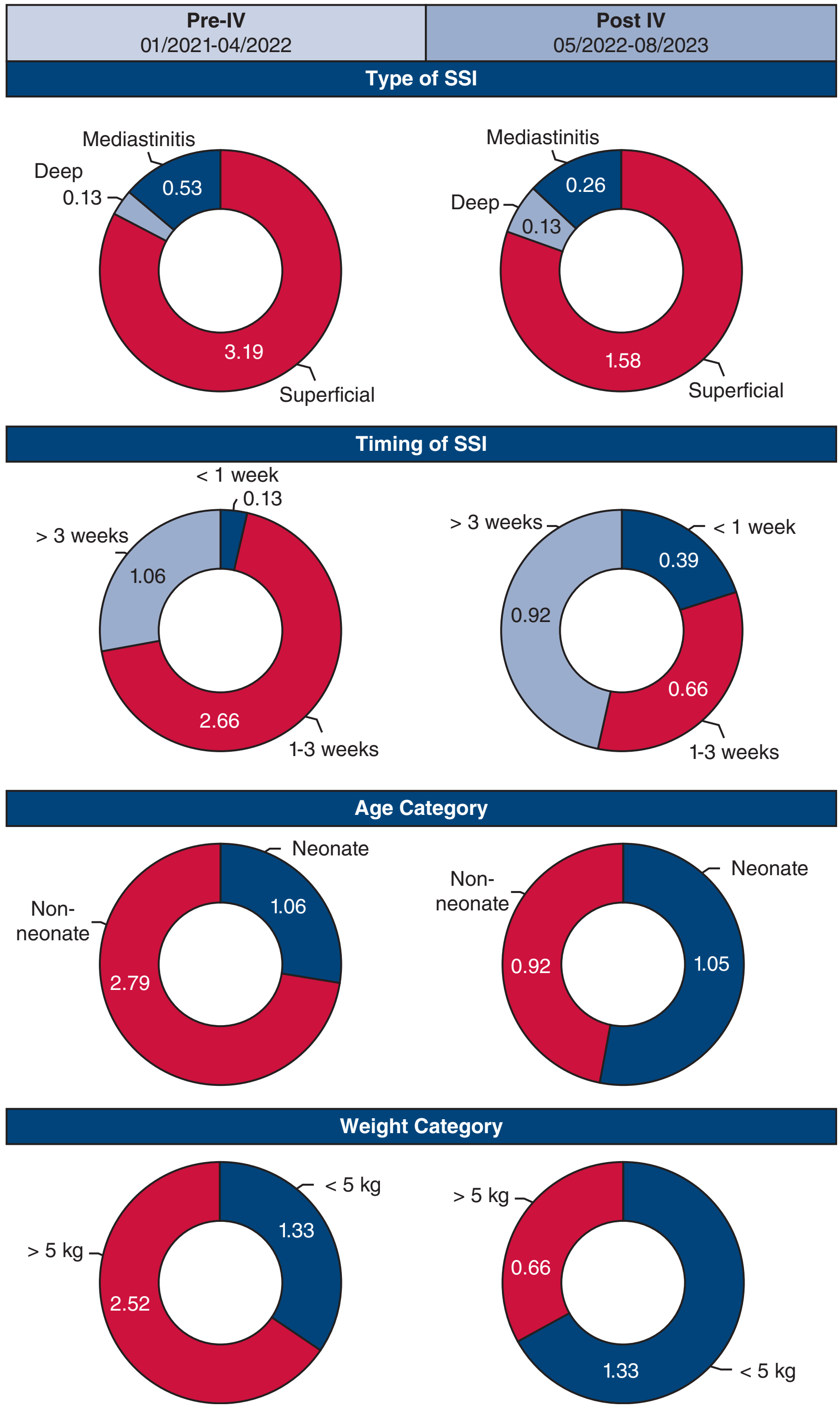


FIGURE 3. Comparison of surgical site infection (*SSI*) outcomes and characteristics in pediatric patients after cardiovascular surgery in before and after the quality improvement (*QI*) intervention. SSI event rate is reported as SSI per 100 cases. SSI per 100 cases is shown for each category. $P < .05$ denotes statistical significance.

adopted wound care protocols (parents and bedside registered nurses) and educational materials (wound care handbook for fellows) to harmonize wound care practices across the heart center. This improved multidisciplinary communication and ensured consistent follow-up of at-risk wounds, both in hospital and as outpatients. Through

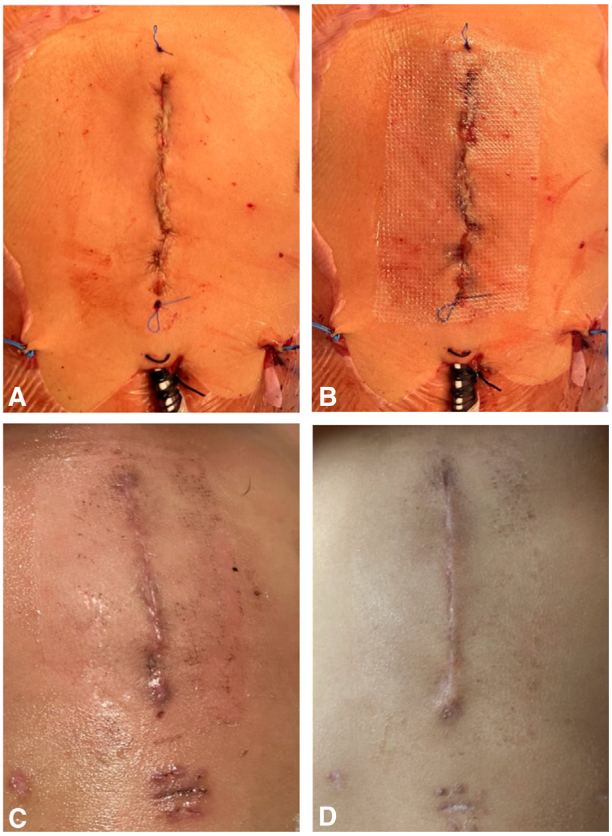


FIGURE 4. Standardized wound closure for cardiac surgery patients. A, Wound closure with externalized Prolene subcuticular closure. B, Prineo (Ethicon) application in the operating room. C, Postoperative day 14: Removal of Prineo and Prolene sutures. D, Postoperative day 19: Wound healing with routine wound care.

standardization and improved communication, our improvements may be attributed to a Hawthorne effect through increased vigilance in follow-up.

We introduced a new surgical dressing to try to minimize dressing changes in the first few days of wound healing and simplify wound care for parents as outpatients as these were hypothesized to be contributing factors (Figure 4). Given that superficial SSIs represent the majority of SSIs, we chose an antimicrobial dressing (Prineo), which is a skin closure system that combines a topical skin adhesive (Dermabond; Ethicon) with a mesh. It is reported to have antimicrobial properties within the first 72 hours of wound healing through the use of the mesh, which potentially promotes faster wound healing by reducing tension in wound edges. Multiple adult surgical studies have shown its benefit in orthopedic and cardiac-related SSIs by reducing overall SSIs and promoting better wound healing.[14,15] In our study, we found that the change in surgical dressing was associated with decreasing rates of SSIs, in conjunction with our first surveillance intervention. We implemented the dressing as a pilot study in May 2022 and for 3 months used it on selected patients (>2 kg, primary chest closure in operating room, patients with cardiac critical care uit or cardiac ward postoperative destination) and after demonstrating a reduction in SSIs, we included eligibility to all cardiac surgery patients, except for those <2 kg or when deemed clinically not appropriate. Typical clinical scenarios where Prineo was not used were if a patient had a documented severe adhesive tape reaction (n = 1), or if patient had poor skin integrity at time of sternal closing and was deemed to benefit from a closed incision negative pressure dressing instead (n = 4). Because our institution does not have dedicated personnel to close wounds in the operating room but rather has rotating clinical fellows and residents, we theorized that the Prineo dressing could reduce technical variation in general because the dressing promoted wound integrity by the mesh and adhesive application.

Complications resulting from the Prineo dressing were low. We had one patient with suspected dermatitis after Prineo application. The dressing was removed, and topical corticosteroids were applied and there was a complete resolution of the reaction. The use of Prineo did not interfere with emergency chest reopening. It is easily cut with a scalpel blade or can be peeled off after the application of petroleum jelly.

Our greatest influence was on superficial wounds in lower-risk category patients who typically present at 1 to 3 weeks postoperatively. The incidence of SSIs in neonates and those with deep or mediastinal SSIs were not statistically significantly different between preinterventions and postinterventions cohorts, there was a reduction in SSI rates in nonneonates and infants >5 kg. The lack of influence on neonatal SSIs may be due to underlying patient factors such as low cardiac output, prematurity, nutrition, and degree of critical illness in general. These specific subpopulations may benefit from prophylactic closed incision negative pressure dressings, and we are currently investigating potential risk factors in specific subpopulations to improve SSI rates.

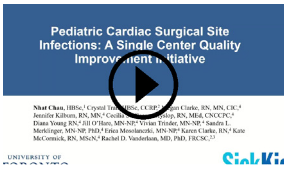
The prevalence of MRSA infections has been historically low at our institutions and preoperative screening of patients through a checklist is used to guide targeted preoperative MRSA testing in high-risk patients. All patients not meeting the preoperative testing criteria then undergo MRSA screening once admitted to the ICU. Decolonization is not routinely done preoperatively. Our only MRSA infection was acquired in the community postdischarge. We currently are monitoring the prevalence of MRSA infections within the hospital to understand when more aggressive preoperative screening and decolonization may be warranted.

CONCLUSIONS

A new microbial barrier surgical site dressing and multidisciplinary surveillance plan effectively reduced the overall burden of SSI rates at our institution. Further studies centered around elucidating risk factors leading to SSIs in specific subpopulations are underway to allow targeted interventions to further reduce SSIs at our institution.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/pediatric-cardiac-surgical-sit-7579.



Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Catania VD, Boscarelli A, Lauriti G, Morini F, Zani A. Risk factors for surgical site infection in neonates: a systematic review of the literature and meta-analysis. *Front Pediatr*. 2019;7:101. https://doi.org/10.3389/fped.2019.00101
2. Ciofi Degli Atti ML, Serino L, Piga S, Tozzi AE, Raponi M. Incidence of surgical site infections in children: active surveillance in an Italian academic children's hospital. *Ann Ig*. 2017;29(1):46-53. https://doi.org/10.7416/ai.2017.2131
3. Sochet AA, Cartron AM, Nyhan A, et al. Surgical site infection after pediatric cardiothoracic surgery: impact on hospital cost and length of stay. *World J Pediatr Congenit Heart Surg*. 2017;8(1):7-12. https://doi.org/10.1177/2150135116674467
4. Reeves N, Torkington J. Prevention of surgical site infections. *Surgery (Oxford)*. 2022;40(1):20-24. https://doi.org/10.1016/j.mpsur.2021.11.008
5. Katayanagi T. Nasal methicillin-resistant S aureus is a major risk for mediastinitis in pediatric cardiac surgery. *Ann Thorac Cardiovasc Surg*. 2015;21(1):37-44. https://doi.org/10.5761/atcs.oa.14-00157
6. Prendin A, Tabacco B, Fazio PC, de Barbieri I. Management of pediatric cardiac surgery wound: a literature review. *Acta Biomed*. 2021;92(4):e2021203. https://doi.org/10.23750/abm.v92i4.11269
7. Von Stumm M, Leps Y, Jochheim L, et al. Impact of delayed sternal closure on wound infections following neonatal and infant cardiac surgery. *PLoS One*. 2022;17(5):e0267985. https://doi.org/10.1371/journal.pone.0267985
8. Kumar SR, Scott N, Wells WJ, Starnes VA. Liberal use of delayed sternal closure in children is not associated with increased morbidity. *Ann Thorac Surg*. 2018;106(2):581-586. https://doi.org/10.1016/j.athoracsur.2018.03.053
9. Centers for Disease Control and Prevention. NHSN; 2024. Accessed April 16, 2024. https://www.cdc.gov/nhsn/index.html
10. Wolfhagen N, Boldingh QJJ, Boermeester MA, de Jonge SW. Perioperative care bundles for the prevention of surgical-site infections: meta-analysis. *Br J Surg*. 2022;109(10):933-942. https://doi.org/10.1093/bjs/znac196
11. Weiser MR, Gonen M, Usiak S, et al. Effectiveness of a multidisciplinary patient care bundle for reducing surgical-site infections. *Br J Surg*. 2018;105(12):1680-1687. https://doi.org/10.1002/bjs.10896
12. Hodge AB, Thornton BA, Gajarski R, et al. Quality improvement project in congenital cardiothoracic surgery patients: reducing surgical site infections. *Pediatr Qual Saf*. 2019;4(4):e188. https://doi.org/10.1097/pq9.0000000000000188
13. Caruso TJ, Wang EY, Schwenk H, et al. A postoperative care bundle reduces surgical site infections in pediatric patients undergoing cardiac surgeries. *Jt Comm J Qual Patient Saf*. 2019;45(3):156-163. https://doi.org/10.1016/j.jcjq.2018.05.009
14. Gunga Z, Marchese MV, Pfister R, et al. Topical skin adhesive PRINEO as the ideal wound closure system in cardiac surgery to limit surgical site infection. *J Wound Care*. 2023;32(Supp 8a):S24-S30. https://doi.org/10.12968/jowc.2023.32.Sup8a.S24
15. Choi KY, Koh IJ, Kim MS, Park DC, Sung YG, In Y. 2-Octyl cyanoacrylate topical adhesive as an alternative to subcuticular suture for skin closure after total knee arthroplasty: a randomized controlled trial in the same patient. *J Arthroplasty*. 2021;36(9):3141-3147. https://doi.org/10.1016/j.arth.2021.04.033

Key Words: pediatric cardiovascular surgery, surgical site infections

TABLE E1. Overall population characteristics of pediatric cardiac surgery patients over the study period

Variable	Total cohort	Preintervention	Postintervention	*P* value
Cardiac surgery cases	1514	753	761	
Characteristic				
Male gender	798 (52.71)	406 (53.92)	392 (51.51)	.599*
Age at procedure (y)	0.59 (0.17-4.58)	0.63 (0.23-5.01)	0.59 (0.13-4.00)	.058†
Weight (kg)	7.0 (4.0-16.2)	7.2 (4.2-18.7)	6.9 (3.9-14.9)	.054†
STAT mortality				
Category 1	230 (15.19)	120 (15.94)	110 (14.45)	.524*
Category 2	466 (30.78)	219 (29.08)	247 (32.46)	.314*
Category 3	320 (21.14)	164 (21.78)	156 (20.50)	.623*
Category 4	430 (28.40)	212 (28.15)	218 (28.65)	.913*
Category 5	44 (2.91)	25 (3.32)	19 (2.50)	.364*
Not applicable	19 (1.25)	10 (1.33)	9 (1.18)	.822*
Surgical variable				
Procedure time				
Non-CPB case	296 (19.55)	134 (17.80)	162 (21.29)	.183‡
CPB time	114.4 ± 59.5	118.3 ± 63.1	110.4 ± 55.2	.004‡
Aortic crossclamp time	71.6 ± 53.6	72.6 ± 58.4	70.5 ± 48.3	.171‡
Delayed sternal closure	77 (5.09)	36 (4.78)	41 (5.39)	.694*
Perioperative ECMO	25 (1.65)	14 (1.86)	11 (1.45)	.675*
Postoperative variable				
Mortality	49 (3.24)	20 (2.66)	29 (3.81)	.281*

Values are expressed as median (interquartile 1-interquartile 3), mean ± SD, or frequency (%). *P* values are the comparison of preinterventin and postintervention. *STAT*, Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery Congenital Heart Surgery; *CPB*, cardiopulmonary bypass; *ECMO*, extracorporeal membrane oxygenation. *Fisher exact test. †Mann-Whitney *U* test. ‡Student *t* test.