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Surgical site infections following pediatric cardiac surgery in a tertiary care hospital: Rate and risk factors

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Abstract

Background: **Surgical site infections [SSIs] are the second most common type of healthcare-associated infections and leading cause of postoperative morbidity and mortality in pediatric cardiac surgery. This study aims to determine the rate of, risk factors for, and most common pathogen associated with the development of SSIs after pediatric cardiac surgery.**

Methods: **Patients aged ≤14 years who underwent cardiac surgery at our tertiary care hospital between January 2010 and December 2015 were retrospectively reviewed.**

Results: **The SSI rate was 7.8% among the 1510 pediatric patients reviewed. Catheter-associated urinary tract infection [CAUTI] [odds ratio [OR] 5.7; 95% confidence interval [CI] 2.3−13.8; P < 0.001], ventilator-associated pneumonia [VAP] [OR 3.2; 95% CI 1.4−7.2; P = 0.005], longer postoperative stay [≥25 days] [OR 4.1; 95% CI 2.1−8.1; P < 0.001], and a risk adjustment in congenital heart surgery [RACHS-1] score of ≥2 [OR 2.4; 95% CI 1.2−5.6; P = 0.034] were identified as risk factors for SSIs. *Staphylococcus aureus* was the most common pathogen [32.2%].**

Conclusions: **SSI risk factors were longer postoperative stay, CAUTI, VAP, and RACHS-1 score of ≥2. Identification and confirmation of risk factors in this study is important in order to reduce the rate of SSIs following cardiac surgery.**

Keywords: Surgical site infection, Cardiac surgery, Risk factor, Saudi Arabia

1. Introduction

Surgical site infections (SSIs) are the second most common type of healthcare-associated infections (HAIs) [1−3]. Although SSIs are considered to be one of the most preventable HAIs, they remain a leading cause of postoperative morbidity and mortality in pediatric cardiac surgery and increase healthcare system costs worldwide [4−8]. The Centers for Disease Control and Prevention (CDC) defines SSIs as “an infection occurring within 30 or 90 days of operation” [9,10]. According to the World Health Organization (WHO), nosocomial infections account for 3−21%, while wound infections account for 5−34% of all SSIs [11]. The rate of postoperative infections following pediatric cardiac surgeries is approximately 13−31% [12−16]. Previous studies

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demonstrated that the SSI rate ranges from 1.7 to 8.0 per 100 cases [6,12,17–22]. Most previous studies indicated that SSIs are mainly caused by *Staphylococcus aureus*, a normal endogenous flora of the body [3,23].

It is critical to identify the risk factors for SSIs following pediatric cardiac surgeries since they could affect clinical decision making [17]. Several studies have identified younger age, use of mechanical ventilation, longer preoperative hospitalization and intensive care unit (ICU) course, longer use of cardiopulmonary bypass (CPB), longer cardiac surgery time, and delayed sternal closure (DSC) as risk factors [6,7,14,16–18].

SSIs increase the cost, hospitalization time, mortality rate, and morbidity rate and reduces quality of life. Hence, the identification of novel risk factors and validation of established factors would benefit such patients. As stated above, several studies have evaluated the risk factors for SSIs. However, few studies have investigated the rate of and risk factors for SSIs after pediatric cardiac surgeries in Saudi Arabia and the middle east. This study would provide a reference for future studies about the rate and risk factors in Saudi Arabia and help in comparative studies. Thus, the aim of our study was to estimate the rate of SSIs following cardiac surgery, identify the major risk factors contributing to the development of SSIs, and identify the underlying microorganisms that might cause infections at our institution.

2. Materials and methods

2.1. Study design and population

We conducted a retrospective, matched case-control study in pediatric patients who developed SSIs following cardiac surgery between January 2010 and December 2015. All patients aged ≤14 years who had undergone cardiac surgery at our tertiary care hospital were reviewed. The CDC diagnostic criteria were used to identify cases of SSIs. In Saudi Arabia, the regulations regarding pediatric medicine considers the pediatric age group to be 0–14 years. Therefore, patients aged >14 years old did not match the CDC criteria and were excluded. Those who developed SSIs due to a non-cardiac surgery cause were also excluded. This study was approved by our Institutional Review Board [Protocol No. SP17/139/R].

Abbreviations

BSIs	Bloodstream infections
CAUTI	Catheter-associated urinary tract infection
CCT	Cross-clamp time
CDC	The Centers for Disease Control and Prevention
CI	Confidence intervals
CPB	Cardiopulmonary bypass
DSC	Delayed sternal closure
HAIs	Healthcare-associated infections
ICU	Intensive care unit
ORs	Odds ratios
RACHS-1	Risk adjustment in congenital heart surgery
SSIs	Surgical site infections
VAP	Ventilator-associated pneumonia
WHO	World Health Organization
+ve ETA	Positive endotracheal aspiration

2.2. Identification of cases and matching methodology

The cardiac center database was utilized to identify cases of SSIs following cardiac surgeries (index group). Control participants aged ≤14 years who underwent cardiac surgery but did not develop SSIs were also collected using the cardiac center database. Each SSI case was matched individually to control cases at a ratio of 2:1 by weight category to optimize the similarities between the index group and controls. The weight criteria divided the patients into five different categories. The categories were <3.0 kg, 3.0–5.0 kg, 5.1–10.0 kg, 10.1–25.0 kg, and >25.0 kg.

2.3. Data collection and handling

Demographic data including age, sex, weight, and the presence of any genetic abnormalities such as Down syndrome and DiGeorge syndrome were collected. Surgical reports were reviewed to determine the duration of cross-clamp time (CCT), CPB, and risk adjustment in congenital heart surgery [RACHS-1] score. Medical records were thoroughly reviewed including the pediatric cardiac intensive care unit notes to determine the mechanical ventilation time; ICU length of stay; inotrope use and duration; number of re-intubations; and development of other HAIs such as catheter-associated urinary tract infection (CAUTI), ventilator-associated pneumonia (VAP), BSI, and positive

Table 1. Comparison of demographics in index and control group pediatric patients.

Variable	Total [n = 356]	Index [n = 118]	Control [n = 238]	P-value
Sex, n [%]				
Male	197 [55.3]	66 [55.9]	131 [55]	0.874
Female	159 [44.7]	52 [44.1]	107 [45]	
Weight, mean ± SD kg	5.6 ± 4	5.8 ± 4.4	5.5 ± 3.8	0.527
Age less than 12 months, n [%]	276 [77.5]	91 [77.1]	185 [77.7]	0.896
Down syndrome, n [%]	26 [7.3]	10 [8.5]	16 [6.7]	0.550
DiGeorge syndrome, n [%]	5 [1.4]	3 [2.5]	2 [0.8]	0.337
Asplenia, n [%]	6 [1.7]	3 [2.5]	3 [1.3]	0.402
Polysplenia, n [%]	1 [0.3]	0 [0]	1 [0.4]	0.999

endotracheal aspiration (+ve ETA). HAIs, CAUTI, VAP, BSI, and +ve ETA were defined as per the CDC definitions. Microbiology lab reports were reviewed for causative organisms. The collected data were applied in a unified data form. Raw data were processed following the best practices for raw data management to identify any inaccuracies or incompleteness in advance of the statistical analysis. To accomplish this task, all interval variables were checked and summarized in terms of maximum and minimum values. Minimum and maximum values were reviewed and compared against the possible maximum and minimum value of each variable, and variables with implausible values were flagged. A similar process was applied to categorical variables to identify any potential anomalies (miscodes) by running a general frequency analysis.

2.4. Statistical analysis

Descriptive statistics such as percentages, mean, median, standard deviation, and interquartile range were used. The chi-square test or Fisher's exact test was used to compare categorical data. An independent sample *t*-test or the Mann-Whitney *U* test were used to compare continuous data. Multiple logistic regression was used to determine significant independent factors associated with SSIs. Odds ratios [ORs] with 95% confidence intervals [CIs] were expressed relative to a reference baseline category. A P-value <0.05 was considered to be statistically significant. Data were analyzed using SPSS [IBM SPSS Statistics, SPSS Inc, Chicago, Illinois].

3. Results

3.1. Subject characteristics

Between January 1, 2010, and December 31, 2015, a total of 1510 cardiac surgeries were performed in patients aged ≤14 years. During the study period, 124 SSIs occurred in 123 patients. Two SSIs were reported in a single patient during different admissions. For this patient, only the first SSI was analyzed, as the second SSI was of a non-cardiac cause. Five patients were further excluded as they did not meet the CDC diagnostic criteria. Thus, 118 SSI index cases were included in the analysis, and these cases were matched by their weight categories with 236 control cases.

The demographic data are presented in Table 1. There were no significant differences between the index and control cases based on sex, weight, age less than 12 months, and the presence of genetic abnormalities. In our study population, males constituted 55.3% [Table 1]. The weight was 5.8 ± 4.4 kg in the index group and 5.5 ± 3.8 kg in the control group. Down syndrome was recognized in ten patients [8.5%] in the index group and 16 patients [6.7%] in the control group. DiGeorge syndrome was diagnosed in three patients [2.5%] in the index group and two patients [0.8%] in the control

Table 2. Types of organisms encountered in surgical site infection.

Organism	Frequency	Percentage
Staphylococcus Aureus	38	32.2
Enterobacteriaceae	14	11.9
Unspecified negative species	14	11.9
Klebsiella Pneumonia	13	11
Unspecified	13	11.0
Unspecified gram positive	12	10.2
Coagulase Negative Species	8	6.8
Pseudomonas Aeruginosa	8	6.8
Candida Albica	7	5.9
Yeast	6	5.1
MRSA	4	3.4
E. coli	3	2.5
Acinobacter Baumanni	3	2.5
Bacillus Species	2	1.7
Entercoccus Faecalsi	2	1.7
Streptococcus	1	0.8
Stentorophomonas Matophilia	1	0.8
Klebsiella Cloaca	0	0
Normal flora	0	0

Abbreviations: *E. coli*: Escherichia Coli, MRSA: methicillin-resistant *Staphylococcus aureus*.

group. Moreover, asplenia presented in three patients [2.5%] in the index group and three patients [1.3%] in the control group, and polysplenia was positive only in one control case [0.4%].

3.2. SSI rate and risk factors

A total of 118 cases of SSIs were diagnosed after 1510 pediatric cardiac surgeries for a rate of 7.8%. Cultures were positive in 105 patients, and the most common isolated organism was *Staphylococcus aureus*, with a percentage frequency of 32.2% [Table 2].

The median hospital stay and ICU stay were significantly longer in patients who developed SSIs than in patients who did not develop SSIs [42 days [45.5 days] vs. 17 days [18 days], P < 0.001; and 10 days [20.5 days] vs. 6 days [9 days], P < 0.001; respectively]. Similarly, the median postoperative stay was found to be significantly longer in those who developed SSIs than in those who did not [27 days [38 days] vs. 12 days [13 days] P < 0.001]. There were no significant differences in the median preoperative stay between the index group and control group [P > 0.05, Table 3].

Patients with CAUTIs were at a greater risk of developing SSIs than were those without CAUTIs [22 [18.6%] vs. 10 [4.2%], P < 0.001]. VAP and BSIs were also strongly associated with SSIs [25 [21.2%] vs. 15 [6.3%], P < 0.001; and 44 [37.7%] vs. 41 [17.2%], P < 0.001 in the index and control groups, respectively]. However, there was no significant association between SSIs and +ve ETA [P > 0.05, Table 3].

The median duration of mechanical ventilation was significantly longer in those who developed SSIs [67 h [189 h] vs. 43 h [95 h], P = 0.003]. Similarly, the median number of re-intubations was significantly higher in the index group than in the control

Table 3. Comparison of clinical measurements in index and control group pediatric patients.

Variable		Total [n = 356]	Index [n = 118]	Control [n = 238]	P-value
	Pre-op, days, median [IQR]	5 [7]	5 [11]	4.5 [6]	0.155
	ICU days, median [IQR]	7 [12]	10 [20.5]	6 [9]	<0.001
	Post-op days, median [IQR]	16 [19]	27 [38]	12 [13]	<0.001
	Post-op ≥25 days, n [%]	102 [28.7]	61 [51.7]	41 [17.3]	<0.001
	Hospital days, median [IQR]	23 [32]	42 [45.5]	17 [18]	<0.001
HAIs, n [%]	CAUTI	32 [9]	22 [18.6]	10 [4.2]	<0.001
	VAP	40 [11.2]	25 [21.2]	15 [6.3]	<0.001
	BSI	85 [23.9]	44 [37.3]	41 [17.2]	<0.001
	+ve ETA	33 [9.3]	15 [12.7]	18 [7.6]	0.115
	CPB, n [%]				
	Yes	250 [70.2]	90 [76.3]	159 [66.8]	0.067
	No	106 [29.8]	28 [23.7]	79 [33.2]	
PCICU	CPB time, min, mean ± SD	121.9 ± 68.2	129.5 ± 82.9	118.5 ± 57.6	0.268
	ACC, n [%]				
	Yes	237 [66.6]	86 [72.9]	151 [63.4]	0.076
	No	119 [33.4]	32 [27.1]	87 [36.6]	
	ACC time, min, mean ± SD	73.9 ± 45.6	74.6 ± 53.1	73.47 ± 40.9	0.853
	MV Duration, hours, median [IQR]	47 [112]	67 [189]	43 [95]	0.003
	Reintubation, n [%]				
	Yes	64 [18]	33 [28]	31 [13]	0.001
	No	292 [82]	85 [72]	207 [87]	
	Number of re-intubation, median [IQR]	1 [1]	2 [1]	1 [0]	0.010
	Inotropes, n [%]				
	Yes	350 [98.3]	116 [98.3]	234 [98.3]	0.999
	No	6 [1.7]	2 [1.7]	4 [1.7]	
	Inotropes duration, hours, median [IQR]	128.5 [169]	156.5 [254]	122 [159]	0.026
	No. of Inotropes used, median [IQR]	3 [1]	2 [1]	3 [1]	0.821
	RACHS-1, n [%]				
	Not applicable	2 [0.6]	2 [1.7]	0	0.001
	1	57 [16]	10 [8.5]	47 [19.7]	
	2	91 [25.6]	33 [28]	58 [24.4]	
	3	165 [46.3]	50 [42.4]	115 [48.3]	
	4	32 [9]	17 [14.4]	15 [6.3]	
	5	1 [0.3]	0	1 [0.8]	
	6	8 [2.2]	5 [4.2]	3 [1.3]	
	DSC, n [%]	15 [4.2]	8 [6.8]	7 [2.9]	0.099

Abbreviations: ACC: aortic cross clamp time, BSI: blood stream infection, CAUTI: catheter associated urinary tract infection, CPB: cardiopulmonary bypass, DSC: delayed sternal closure, HAI: healthcare-associated infections, MV: mechanical ventilation, PCICU: pediatric cardiac intensive care unit, RACHS-1: risk adjustment in congenital heart surgery, VAP: ventilatory associated pneumonia, +ve ETA: positive endocranial aspiration.

Table 4. Multiple logistic regression analysis for predicting surgical site infection in pediatric patients.

Variable	OR	95% CI	P-value
CAUTI	5.7	2.3–13.8	<0.001
VAP	3.2	1.4–7.2	0.005
RACHS -1, $\geq$ 2 adjustments	2.4	1.2–5.6	0.034
Post-operative stay, $\geq$ 25 days	4.1	2.1–8.1	<0.001

Abbreviations CAUTI: catheter associated urinary tract infection, RACHS-1: risk adjustment in congenital heart surgery, VAP: ventilatory associated pneumonia.
N = 356. The dependent variable is surgical site infection. Reference category for dependent variable is control group. For independent variables CAUTI [no], VAP [no], RACHS-1 <2 adjustments, post-operative stay <25.

group [2 [1] vs. 1 [0], P = 0.010]. The median duration of inotropes was also significantly higher in the index group than in the control group [156.5 h [254 h] vs. 122 h [159 h], P = 0.026]. There were no significant differences between the index and control groups regarding CPB duration, CCT duration, number of inotropes used, or DSC [P > 0.05, Table 3].

Multiple logistic regression analysis identified CAUTIs, VAP, the RACHS-1 score, and the postoperative stay to be significant, independent predictors for the development of SSIs [P < 0.05, Table 4]. Patients with CAUTIs were at a 5.7-fold increased risk of developing SSIs compared to those without CAUTIs [OR, 5.7; 95% CI, 2.3–13.8; P < 0.001]. Similarly, those with VAP were at a 3.2-fold increased risk of SSI development [OR, 3.2; 95% CI, 1.4–7.2; P = 0.005], and RACHS-1 score of $\geq$2 increased the risk of SSIs by 2.4-fold [OR, 2.4; 95% CI, 1.2–5.6; P = 0.034]. Postoperative stay $\geq$25 days increased the risk by 4.1-fold [OR, 4.1; 95% CI, 2.1–8.1; P < 0.001].

Using a multiple logistic regression analysis, variables that were independently associated with the development of SSIs were CAUTIs (OR, 5.7; 95% CI, 2.3–13.8; P < 0.001), VAP (OR, 3.2; 95% CI, 1.4–7.2; P = 0.005), RACHS-1 score of $\geq$2 (OR, 2.4; 95% CI, 1.2–5.6; P = 0.034), and postoperative stay $\geq$25 days (OR, 4.1; 95% CI, 2.1–8.1; P < 0.001) (P < 0.05, Table 4).

4. Discussion

SSIs increase hospital stay, treatment cost, mortality, and morbidity [3,4,24]. In addition, SSIs increase the use of antibiotics and therefore increase the risk of antibiotic resistance, which is an established global issue [4,25]. There is a lack of studies evaluating the rate of and risk factors for SSIs following pediatric cardiac surgeries in Saudi Arabia and middle east regions. Thus, this retrospective, matched case-control study was conducted. Our study and future studies on this topic will provide a benchmark and allow for a comparison of national and international data.

The rate of SSIs in this study was found to be 7.8% among pediatric patients undergoing cardiac surgery, which is higher than the expected rate of SSIs [4,12,17,21]. In addition, this rate is higher than the previously reported rates of 2.3–5% [12,17,21,26,27]. The high rate in our study could be attributed to the inclusion of patients who underwent all types of cardiac surgeries and the longer study period than that in earlier studies [12,17,21,26,27]. Furthermore, the variation in the rates of SSIs could be explained by the variation in patient-related parameters such as age, cardiac condition, and severity of illness, comorbidities; unit-related parameters such as size and setting; and surgery-related parameters such as duration, surgery type, intraoperative technique, and surgical complexity [4]. According to the WHO, *Staphylococcus aureus* is the leading cause of HAIs [4]. Moreover, several studies have found *Staphylococcus aureus* to be the most frequently encountered organism [3,4,8,17]. Our findings are in line with the results of these studies.

Previous studies reported that younger age, preoperative stay, ICU stay, longer DSC, and longer CPB are risk factors for postoperative SSIs [6,7,17,18,28]. In contrast to these studies, proportion of patients aged <1 year, preoperative stay, DSC, and CPB rate did not significantly differ between the index and control groups in our study. Similarly, previous studies also found that DSC and CPB do not affect the rate of SSI [8,18,29]. However, we did not investigate the duration of DSC, which could have affected our results. In 2010, a multicenter study indicated that genetic abnormalities were a risk factor for SSI [7]. However, other studies found no association between genetic abnormalities and the development of SSIs, which is in line with our findings [18,29]. Further, two studies have shown that mechanical ventilation is a risk factor for SSI, similar to our results [18,29]. Similarly, several studies have also indicated that sex and CCT are not risk factors for SSI [7,8,28–30]. However, weight was associated with a greater risk of SSI in previous studies, which is inconsistent with our findings [7,8,18,21]. Further, our observation that the number of re-intubations was associated with SSI differed from the results of another study, which reported no such association [18].

In our study, we investigated various potential SSIs risk factors, but most of these variables did not remain significant in multiple logistic regression analysis. The independent risk factors for SSIs were

CAUTIs, VAP, RACHS-1 score of ≥2, and longer postoperative stay. Costello et al. found that patients with RACHS-1 score of ≥4 were at higher risk of developing SSIs [18]. However, Barker G et al. found that the RACHS-1 score was associated with SSI in univariate analysis but not in a multivariable analysis [7]. Similarly, the results reported by Murray et al. show that the RACHS-1 score was not predictive of SSIs [29].

Prevention of SSIs is complex and requires the incorporation of various measurements before, during, and after surgery [4]. Therefore, the WHO guidelines for the prevention of SSIs should be followed, as these guidelines are valid in any country and consider the cost and implications of resources as well as patient's values and preferences [4]. Our Center has strict SSI prevention policies that are monitored strictly by our infection control department. These policies include the use of pre and post-operative prophylaxis like the first-generation cephalosporin for 48 h from the time of skin incision. Moreover, for open chest, Dual antibiotics that cover gram-negative and gram-positive are used for 48 h after chest closure. Vancomycin is used for methicillin-resistant staphylococcus aureus patients either post or preoperatively with the same duration after further consultation with the pediatric infection department team. All BSI and SSIs managements are guided by the pediatric infection department team for the type of coverage and duration according to the sensitivity and specificity. During surgery and interventional care, hygienic hand preparation is a critical step that aims to eliminate the transient flora, reduce the resident flora, and inhibit the growth of bacteria under the gloved hand [4,31]. Therefore, we recommend a strict implementation of hand hygiene which will reduce the rate of SSIs. We also recommend that additional studies of SSI risk factors are performed in a larger population with a longer study period in the form of a multicenter trial in Saudi Arabia. Further studies should also be conducted to investigate the impact of SSIs on hospital costs and length of stay.

4.1. Limitations

There are several limitations to our study. First, this was a single-center study, which may limit the generalization of our findings. Thus, a larger multicenter prospective study with a larger population is warranted to confirm the accuracy of the results. Second, because of the time restriction and difficulty in acquiring data, there were many factors that we did not include such as blood transfusion, medications, DSC duration, and American Society of Anesthesiologists score. Third, because this was a retrospective, case-control matched study, there was a lack of follow-up data after discharge, and it is likely that some infections were missed. Furthermore, a case-control design is prone to selection bias when selecting the control group. Fourth, because we obtained our data retrospectively, human factors, such as surgical techniques, obstacles during surgery, and different CPB techniques, were difficult to assess. Fifth, one of the variables that we could not evaluate is specific surgical interventions, either diagnostic or therapeutic; therefore, we could not determine whether the postoperative complications were complications of such interventions. Sixth, we should have matched the index and control groups to more than one variable; however, we only matched them according to weight category to avoid over-matching, which may have made it more difficult for us to include a sufficient number of patients for the control group. Moreover, the general critical state of the patients could attribute to the higher SSI rate. Patients who needed a higher level of care in terms of a longer staying time, mechanical ventilation, and hemodynamic monitoring with a urinary and vascular catheter could be at greater risk of developing an infection. Matching the index and control group based on any mortality risk assessment could have given some information about the comparative postoperative critical state of these two groups and would make the matching more accurate.

5. Conclusion

This study was conducted primarily to identify patient-specific and operative variables associated with the development of SSIs at a tertiary cardiac center in Saudi Arabia. SSIs complicated the postoperative course of 7.8% of pediatric patients who underwent cardiac surgery at our institution. We identified CAUTIs, VAP, BSIs, postoperative stay of ≥25 days, and RACHS-1 score of ≥2 as risk factors for SSIs.

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Author contribution

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Conflict of interest

The author[s] declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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