Case-control study of pediatric cardiothoracic surgical site infections

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Case-Control Study of Pediatric Cardiothoracic Surgical Site Infections

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A retrospective case-control study was performed to determine the risks and outcomes associated with pediatric cardiothoracic surgical site infection. Undergoing more than 1 cardiothoracic operative procedure, having preoperative infection, and undergoing surgery on a Monday were significant risk factors. Cardiothoracic surgical site infection increased hospital and pediatric intensive care unit length of stay. Deep surgical site infection significantly increased mortality. *Infect Control Hosp Epidemiol* 2008; 29:76-79

Published data regarding the incidence of cardiothoracic surgical site infection (SSI) in pediatric patients is limited. Published rates of pediatric cardiothoracic SSI range from 2.3% to 5.0%.1-3 Few studies control for severity of illness or use multivariate analysis. In controlled studies, the independent risk factors identified for pediatric cardiothoracic SSI include duration of surgery, young age, presence of upper respiratory tract infection, and hypothermia.2,4,5 Controlling for underlying severity of illness is challenging because adequate preoperative risk stratification for pediatric patients is lacking. Several studies control for severity of illness using the American Society of Anesthesiologists (ASA) score.4,6 Another study matched patients by using the National Nosocomial Infections Surveillance (NNIS) system risk index score, which incorporates duration of surgery, wound class, and ASA score.1 However, recent data in pediatrics suggest that the NNIS risk index did not adequately stratify pediatric patients who underwent median sternotomy according to their risk of developing an SSI.6

St. Louis Children’s Hospital has performed prospective surveillance for cardiothoracic SSI since 2000. An increasing incidence of SSI was detected between 2001 and 2003. The rate increased from 1.4% (8 of 563 patients) in 2001 to 3.1% (17 of 541) in 2002, and then increased to 4.8% (23 of 476) in 2003 (P = .002). Most infections that occurred during 2002-2003 (26 of 40 infections [65%]) were deep SSIs. A retrospective case-control study was performed to investigate this increase.

**METH O DS**

Case patients who underwent surgery during the period from January 1, 2002, through December 31, 2003, were evaluated. Patients underwent procedures involving median sternotomy or posterolateral incision and were followed up for infection for up to 1 year if the procedure involved placement of an implant. Three control patients were selected per case patient. Control patients were matched on the basis of month and year of procedure. Institutional review board approval was obtained.

A standardized data collection tool was used. Data on demographic, microbiologic, preoperative, intraoperative, and postoperative variables were collected. The outcomes investigated included pediatric intensive care unit (PICU) length of stay, hospital length of stay, and mortality.

Statistical analysis was performed using SPSS statistical software, version 14.0 (SPSS). Univariate analysis using the Student t test, χ² test, and Fisher exact test, as appropriate, was performed to determine the risk factors for SSI. P values were 2-tailed. P of .05 or less was considered statistically significant. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were computed. The variables determined to be significant by univariate analysis and variables that had a priori clinical significance were entered into a multivariate model. Significant variables that covaried were grouped, and 1 variable from each group was chosen for entry into the model. The final model was chosen on the basis of biological plausibility and lowest −2 log likelihood function.

SSI was defined in accordance with Centers for Disease Control and Prevention and NNIS criteria.7 Deep SSI involved soft tissues below the subcutaneous layer, including bone and mediastinum. Clinical criteria included purulent drainage from incision, incision dehisced or opened in a patient with fever or localized tenderness, or deep incisional SSI diagnosed by the surgeon or attending physician. SSIs were tracked for

<table>
<thead>
<tr>
<th>Organism</th>
<th>Any SSI (n = 40)</th>
<th>Deep SSI (n = 24)</th>
<th>Superficial SSI (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoNS</td>
<td>18 (45)</td>
<td>8 (33)</td>
<td>10 (63)</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>11 (28)</td>
<td>5 (21)</td>
<td>6 (38)</td>
</tr>
<tr>
<td>MRSA</td>
<td>5 (13)</td>
<td>3 (13)</td>
<td>2 (13)</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>2 (5)</td>
<td>2 (8)</td>
<td>0</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>2 (5)</td>
<td>2 (8)</td>
<td>0</td>
</tr>
<tr>
<td><em>Candida albicans</em></td>
<td>1 (3)</td>
<td>1 (4)</td>
<td>0</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp</td>
<td>2 (5)</td>
<td>2 (8)</td>
<td>0</td>
</tr>
<tr>
<td><em>Acinetobacter</em> spp</td>
<td>1 (3)</td>
<td>1 (4)</td>
<td>0</td>
</tr>
<tr>
<td><em>Haemophilus influenzae</em></td>
<td>1 (3)</td>
<td>1 (4)</td>
<td>0</td>
</tr>
<tr>
<td><em>Serratia marcescens</em></td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>1 (6)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (5)</td>
<td>1 (4)</td>
<td>1 (6)</td>
</tr>
<tr>
<td>No growth</td>
<td>1 (3)</td>
<td>1 (4)</td>
<td>0</td>
</tr>
</tbody>
</table>

**NOTE.** Six infections were polymicrobial. CoNS, coagulase-negative staphylococci; MRSA, methicillin-resistant *S. aureus.*
30 days or for 1 year from the operative procedure when the procedure involved placement of an implant.

Superficial SSI involved the skin and subcutaneous tissue. Clinical criteria included purulent drainage from incision; organism(s) isolated from culture of incision samples; symptoms of tenderness, localized swelling or erythema; and superficial incision deliberately opened by the surgeon or diagnosis of superficial SSI made by the surgeon or attending physician. The ASA score was used to control for underlying severity of illness.\(^6\)

The primary outcome of interest was SSI. Secondary outcomes were death and length of stay in the hospital and the PICU. The secondary outcome risk attributed to SSI was determined by multivariate logistic regression, for which presence of SSI along with ASA score were entered for each outcome.

**RESULTS**

A total of 1,017 surgical procedures were included in the 24-month study period. Forty case patients and 120 control patients were analyzed. Monthly SSI rates ranged from 1% to 10.3%. The median time to onset of infection was 9.0 days (range, 2.0-82.0 days). Twenty-six (65%) of 40 SSIs were deep, and 14 (35%) were superficial.

The organisms isolated from patients with SSI, according to type of SSI, are listed in Table 1. Coagulase-negative *Staphylococcus* (CoNS) was the organism most commonly recovered. Eight patients had secondary bloodstream infections due to CoNS, *Staphylococcus aureus*, *Klebsiella pneumoniae*, or methicillin-resistant *Staphylococcus aureus*.

Significant risk factors for SSI by univariate analysis are listed in Table 2. Weight (less than 4.5 kg), age (less than 2.5 months), and increased ASA score (greater than 3) were significant and strongly correlated. An ASA score greater than 3 was used in the multivariate logistic regression model. Independent risk factors for cardiothoracic SSI included having had more than 1 cardiothoracic procedure performed in the operating room (OR, 3.6 [95% CI, 1.5-9.0]; \(P = .005\)); another infection present or being treated at the time of surgery, as documented in the patient’s medical record (OR, 5.5 [95% CI, 1.4-22.0]; \(P = .015\)); and having surgery performed on a Monday (OR, 5.6 [95% CI, 2.0-15.4]; \(P = .001\)).

### Table 2. Univariate Comparison of Significant Risk Factors for Surgical Site Infection in Case and Control Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Case group ((n = 40))</th>
<th>Control group ((n = 120))</th>
<th>OR (95% CI)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient characteristic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, mean ± SD, kg</td>
<td>7.9 ± 7.1</td>
<td>19.0 ± 22</td>
<td>.003</td>
<td></td>
</tr>
<tr>
<td>Age, mean ± SD, months</td>
<td>19.8 ± 34</td>
<td>51.0 ± 65</td>
<td>.004</td>
<td></td>
</tr>
<tr>
<td>Cyanotic heart disease</td>
<td>19 (48)</td>
<td>40 (33)</td>
<td>2.2 (1.1-4.6)</td>
<td>.03</td>
</tr>
<tr>
<td>Preoperative risk factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection at time of surgery</td>
<td>9 (22)</td>
<td>7 (7)</td>
<td>4.1 (1.5-11.4)</td>
<td>.008</td>
</tr>
<tr>
<td>Preoperative NICU stay</td>
<td>11 (28)</td>
<td>14 (11)</td>
<td>2.9 (1.2-7.0)</td>
<td>.02</td>
</tr>
<tr>
<td>Same-day surgery, preoperatively</td>
<td>7 (17)</td>
<td>55 (46)</td>
<td>0.25 (0.10-0.61)</td>
<td>.002</td>
</tr>
<tr>
<td>Intraoperative risk factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receipt of prostaglandin</td>
<td>10 (25)</td>
<td>11 (9)</td>
<td>3.3 (1.3-8.5)</td>
<td>.01</td>
</tr>
<tr>
<td>Surgery performed on a Monday</td>
<td>14 (35)</td>
<td>17 (14)</td>
<td>3.3 (1.4-7.5)</td>
<td>.005</td>
</tr>
<tr>
<td>Blalock-Taussig shunt procedure</td>
<td>8 (20)</td>
<td>4 (3)</td>
<td>7.3 (2.1-25.6)</td>
<td>.002</td>
</tr>
<tr>
<td>Tricuspid procedure</td>
<td>5 (12)</td>
<td>2 (2)</td>
<td>8.4 (1.6-45.3)</td>
<td>.01</td>
</tr>
<tr>
<td>Multiple procedures</td>
<td>25 (63)</td>
<td>39 (32)</td>
<td>3.5 (1.6-7.3)</td>
<td>.001</td>
</tr>
<tr>
<td>ASA score &gt;3</td>
<td>22 (55)</td>
<td>35 (29)</td>
<td>3.0 (1.4-6.2)</td>
<td>.004</td>
</tr>
<tr>
<td>Implant</td>
<td>30 (75)</td>
<td>68 (57)</td>
<td>2.3 (1.0-5.1)</td>
<td>.04</td>
</tr>
<tr>
<td>Subclavian line placed in operating room</td>
<td>20 (50)</td>
<td>38 (32)</td>
<td>2.2 (1.0-4.5)</td>
<td>.04</td>
</tr>
<tr>
<td>Intraoperative PRBC transfusion</td>
<td>30 (75)</td>
<td>67 (56)</td>
<td>2.4 (1.1-5.3)</td>
<td>.03</td>
</tr>
<tr>
<td>Procedure duration, mean ± SD, min</td>
<td>209.3 ± 102.2</td>
<td>209.9 ± 98.2</td>
<td>.97</td>
<td></td>
</tr>
<tr>
<td>Intraoperative glucose level, mean ± SD, range, mg/dL</td>
<td>238.1 ± 102.5 (73-463)</td>
<td>267.3 ± 91.7 (99-476)</td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>Lowest intraoperative temperature, mean ± SD, range, °C</td>
<td>28.3 ± 6.3 (14.8-36.5)</td>
<td>30.0 ± 5.2 (15.8-37.0)</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td>Antibiotic prophylaxis administered within 60 min of incision*</td>
<td>20 (50)</td>
<td>75 (62)</td>
<td>0.6 (0.28-1.3)</td>
<td>.19</td>
</tr>
<tr>
<td>Postoperative risk factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sternum left open postoperatively</td>
<td>10 (25)</td>
<td>13 (11)</td>
<td>2.7 (1.1-6.8)</td>
<td>.03</td>
</tr>
</tbody>
</table>

* Cefazolin or vancomycin if patients had a \(\beta\)-lactam allergy or an MRSA-positive culture result.

**NOTE.** Data are no. (%) of patients, unless otherwise indicated. ASA, American Society of Anesthesiologists; CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus*; NICU, neonatal intensive care unit; OR, odds ratio; PRBC, packed red blood cells.
mented preoperative infections included 3 cases of bacteremia (2 due to CoNS and 1 due to CoNS, K. pneumoniae, and Enterobacter species), 1 case of endocarditis, 2 upper respiratory tract infections, and 3 urinary tract infections. Two cases of SSIs due to CoNS occurred in bacteremic patients.

Procedures performed on all days of the week were analyzed, but only procedures performed on a Monday were found to be significantly associated with cardiothoracic SSI. No individual healthcare worker or worker job category was associated with surgery performed on a Monday or with cardiothoracic SSI. No differences in the nursing, perfusion, or environmental services involved in preparation for surgery on Monday were identified, compared with those used on other days of the week.

When patients with SSI were compared with patients without SSI, PICU length of stay (18.9 vs 4.5 days; \( P < .001 \)) and hospital length of stay (mean, 35.6 vs 12.4 days; \( P = .003 \)) were significantly increased. A total of 5 patients with SSI died, 4 of whom had a deep SSI. After controlling for ASA score, patients with deep SSI had an increased risk of death (OR, 4.9 [95% CI, 1.1-22.8]; \( P = .04 \)).

**DISCUSSION**

A significant increase in the rate of cardiothoracic SSI at St. Louis Children’s Hospital was identified on the basis of historical surveillance data. If a patient had more than 1 cardiothoracic surgical procedure performed concurrently or had an infection present preoperatively, these factors could plausibly increase the risk of SSI because these variables reflect the patient’s underlying severity of illness and/or immune function and could increase surgical complexity. Procedure time did not vary between case and control patients, and therefore surgical duration could not explain the increased SSI risk associated with multiple procedures. Concurrent infections also increase the microbial burden and have been shown to increase the SSI risk in other studies.\(^5\) The increased risk of infection associated with surgery performed on a Monday is difficult to explain. No obvious difference in the complexity of cases was noted on any particular day of the week. Unfortunately, this finding remains difficult to explain.

Several risk factors associated with SSI in adults were not relevant to this article.\(^9,10\) For example, administration of antibiotic prophylaxis within 60 minutes of incision time was not significant. However, during the study period, the rate of compliance with timing guidelines for antibiotic prophylaxis was low for case and control patients. Similarly, intraoperative hyperglycemia was also not associated with increased risk of SSI, but both groups had similarly elevated glucose levels, making it difficult to discern any significance.

This study represents a single center’s experience with a limited number of cases. A small number of patients underwent each cardiac procedure, which meant that they could not be matched by procedure type. Similarly, sample size prevented us from matching patients by age or weight. However, age and weight were strongly correlated with ASA score. When we controlled for age, weight, or ASA score in the multivariate models, results were similar. Finally, the ASA score is not a pediatric patient-specific score. Lack of a standardized pediatric preoperative risk score limits risk stratification in children.\(^6\)

On the basis of this study, it appears prudent to avoid performing surgery for patients with underlying infections in the immediate preoperative period. Further studies of pediatric SSI that involve multiple centers’ experience and increased numbers of patients would be ideal. Establishing standardized interhospital comparisons would better enable benchmarking among institutions.

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