Associations Between Unplanned Cardiac Reinterventions and Outcomes After Pediatric Cardiac Operations

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Background. **After pediatric heart operations, we sought to determine the incidence of unplanned cardiac reinterventions during the same hospitalization, assess risk factors for these reinterventions, and explore associations between reinterventions and outcomes. We hypothesized that younger patients undergoing more complex operations would be at greater risk for unplanned cardiac reinterventions and that operative mortality and postoperative length of stay (PLOS) would be greater in patients who undergo reintervention than in those who do not.**

Methods. **Patients aged 18 years or younger in The Society of Thoracic Surgeons Congenital Heart Surgery Database (January 2010 to June 2015) were included. We used multivariable regression to evaluate risk factors for unplanned cardiac reintervention (operation or therapeutic catheterization) and associations of reintervention with operative mortality and PLOS.**

Results. **Of 84,404 patients (117 centers), 21% were neonates and 36% infants. An unplanned cardiac reintervention was performed in 5.4% of patients, including 11.8% of neonates, 5.2% of infants, and 2.8% of children. Independent risk factors for unplanned reintervention included presence of noncardiac anomalies/genetic syndromes, nonwhite race, younger age, lower weight among neonates and infants, prior cardiothoracic operations, preoperative mechanical ventilation, other Society of Thoracic Surgeons preoperative risk factors, and higher Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery Mortality Category (adjusted $p < 0.001$ for all). Unplanned reintervention was a risk factor for operative mortality (adjusted odds ratio, 5.3; 95% confidence interval, 4.8 to 5.8; $p < 0.001$) and longer PLOS (adjusted relative risk, 2.3; 95% confidence interval, 2.2 to 2.4; $p < 0.001$).**

Conclusions. **Unplanned cardiac reinterventions are not rare, particularly in neonates, and are independently associated with operative mortality and increased PLOS. Patients at greater risk may be identified preoperatively, presenting opportunities for quality improvement.**

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Mortality rates for pediatric patients undergoing cardiac operations vary across institutions, indicating the potential for quality improvement through identification and mitigation of risk factors [1]. The presence of one or more important residual or uncorrected anatomic defects resulting in an unplanned cardiac reintervention may be a modifiable risk factor for adverse outcomes.

The need to consider an unplanned cardiac reintervention may be driven by one or more factors, including an important residual anatomic defect, an incomplete preoperative diagnosis, or a failed therapeutic plan [2]. A single-center study reported 11% of neonates underwent an early unplanned cardiac reintervention, the occurrence of which was a strong, independent risk factor for death [3]. A recent report from the United Kingdom's National Congenital Heart Disease Audit database found that 3.5% of patients underwent early reoperations, of whom 15.8% died [4].

We sought to further explore this issue in children who undergo cardiac operations by using clinical registry data to determine the epidemiology of and risk factors for

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unplanned cardiac reinterventions during the same hospitalization as the index operation. We also sought to identify associations between unplanned cardiac reinterventions and adverse outcomes.

Patients and Methods

This study was approved by the Duke University Institutional Review Board with waiver of informed consent.

Data Source

The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSD) was used for this study [1]. Perioperative and outcomes data are collected on all patients undergoing heart operations at participating centers using standard definitions (STS-CHSD Data Specifications, versions 3.0 and 3.22, available at http://www.sts.org/node/518).

Study Population

The potential study population was derived from 126,037 index operations performed with or without cardiopulmonary bypass (CPB) in patients aged younger than 18 years that were performed at 122 STS-CHSD centers from January 1, 2010, through June 30, 2015. We excluded operations for patients whose demographic information was not collected using data collection form version 3.0 or 3.22 (n = 9,068), isolated closure of patent ductus arteriosus with weight less than 2.5 kg or organ procurements (n = 6,491), and operations not classifiable into an STS–European Association for Cardiothoracic Surgery (STS-EACTS) Mortality Category (n = 2,858) [5]. We excluded 19,454 operations that were performed at centers with more than 15% missing data during an individual study year for operative mortality, postoperative length of stay (PLOS), preoperative factors, noncardiac anomalies, syndromes, chromosomal anomalies, prematurity in neonates and infants, and previous cardiovascular operations. Also excluded were individual operations with missing data for operative mortality (n = 89), PLOS (n = 100), sex or ambiguous sex (n = 82), weight if a neonate (n = 38), and unplanned cardiac reoperation or interventional catheterization variables (n = 3,122). Neonates and infants with weight-for-age z score of less than –7 or more than 5 (n = 331) were also excluded because such weights are likely erroneous. The final cohort for analysis included 84,404 patients from 117 centers.

Exposure Variables

Unplanned cardiac reinterventions are recorded in the STS-CHSD using existing complication codes:

- Complication code 22: unplanned cardiac reoperation during the postoperative or postprocedural time period, exclusive of reoperation for bleeding. According to CHSD specifications, delayed sternal closure, extracorporeal membrane oxygenation decannulation, ventricular assist device decannulation, and removal of Broviac catheter are not counted as unplanned reoperations.
- Complication code 24: unplanned interventional cardiovascular catheterization procedure during the postoperative or postprocedural time period. Diagnostic cardiac catheterization without a therapeutic intervention was not considered an unplanned cardiac reintervention.

Code 22 or 24, or both, may be used once for each index operation, indicative of one or more of the unplanned cardiac reinterventions of the specified type.

Outcomes

The primary outcome for this study was operative mortality. Operative mortality is defined in the STS-CHSD as (1) all deaths, regardless of cause, occurring during the hospitalization in which the operation was performed, even if after 30 days (including patients transferred to other care facilities); and (2) all deaths, regardless of cause, occurring after discharge from the hospital, but before the end of the 30th postoperative day. PLOS was also analyzed.

Analysis

Index operations were divided into groups (cases and controls) based on the occurrence of at least one unplanned cardiac reintervention. For the entire cohort as well as each group, summary statistics are reported as the count (percentage) or median (25th to 75th percentiles), as appropriate.

To identify risk factors for unplanned cardiac reintervention, differences between the two groups were initially assessed using the χ^2 test for categoric variables and the Wilcoxon rank sum test for continuous variables. We then used random intercept logistic regression with backward selection. The final regression model accounted for center variability and was developed based on selected risk factors from the previously developed mortality risk model [5] by using the Tibshirani lasso method [6, 7] and backward selection with an $\alpha = 0.20$ for exclusion. All continuous variables were tested for linearity, and linear splines were used to account for nonlinear relationships. To assess the association between unplanned cardiac reintervention and adverse outcomes, we used random intercept logistic regression for operative mortality and modified Poisson regression with robust error variances [8] for PLOS. Both models were adjusted for the variables used in the risk factor models described above. Missing covariates were imputed to the mode for categoric variables, or to the population median for continuous variables. SAS/STAT 9.4 software (SAS Institute Inc, Cary, NC) was used to perform the analyses. A p value of less than 0.05 was considered statistically significant.

Results

Study Population

The final study population included 84,404 patients who underwent an index cardiac operation at 1 of 117 institutions. Preoperative characteristics and operative variables are reported in Table 1.