Variation in Outcomes for Benchmark Operations: An Analysis of The Society of Thoracic Surgeons Congenital Heart Surgery Database

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Background. **We evaluated outcomes for common operations in The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSDB) to provide contemporary benchmarks and examine variation between centers.**

Methods. **Patients undergoing surgery from 2005 to 2009 were included. Centers with greater than 10% missing data were excluded. Discharge mortality and postoperative length of stay (PLOS) among patients discharged alive were calculated for 8 benchmark operations of varying complexity. Power for analyzing between-center variation in outcome was determined for each operation. Variation was evaluated using funnel plots and Bayesian hierarchical modeling.**

Results. **Eighteen thousand three hundred seventy-five index operations at 74 centers were included in the analysis of 8 benchmark operations. Overall discharge mortality was: ventricular septal defect (VSD) repair = 0.6% (range, 0% to 5.1%), tetralogy of Fallot (TOF) repair = 1.1% (range, 0% to 16.7%), complete atrioventricular canal repair (AVC) = 2.2% (range, 0% to 20%), arterial switch operation (ASO) = 2.9% (range, 0% to 50%), ASO + VSD = 7.0% (range, 0% to 100%), Fontan operation = 1.3% (range, 0% to 9.1%), truncus arteriosus repair = 10.9% (0% to 100%), and Norwood procedure = 19.3% (range, 0% to 100%). Funnel plots revealed that the number of centers characterized as outliers were VSD = 0, TOF = 0, AVC = 1, ASO = 3, ASO + VSD = 1, Fontan operation = 0, truncus arteriosus repair = 4, and Norwood procedure = 11. Power calculations showed that statistically meaningful comparisons of mortality rates between centers could be made only for the Norwood procedure, for which the Bayesian-estimated range (95% probability interval) after risk-adjustment was 7.0% (3.7% to 10.3%) to 41.6% (30.6% to 57.2%). Between-center variation in PLOS was analyzed for all operations and was larger for more complex operations.**

Conclusions. **This analysis documents contemporary benchmarks for common pediatric cardiac surgical operations and the range of outcomes among centers. Variation was most prominent for the more complex operations. These data may aid in quality assessment and quality improvement initiatives.**

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The Congenital Heart Surgery Database of the Society of Thoracic Surgeons (STS-CHSDB) is the largest database in North America tracking the outcomes of pediatric and congenital cardiac surgery [1–3]. As of January 1, 2011, participants in the STS-CHSDB included 96 of the estimated 122 congenital cardiac surgical programs in the United States [4]. One of the major goals of the STS-CHDB is to facilitate the improvement of quality in pediatric cardiac surgical programs in North America.

The purpose of this analysis is to document current outcomes for common operations in the STS-CHSDB to provide contemporary benchmarks and examine variation in outcomes between centers. In this article, the terms *centers* and *participants* are used synonymously to denote pediatric and congenital cardiac surgical programs that participate in the STS-CHSDB. The approach of using benchmark operations to assess the quality of care of pediatric cardiac surgical operations has been

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Table 1. Benchmark Operation Included in This Analysis

Procedure Type	Abbreviation	STS-CHSDB Primary Procedure Codes
1. VSD repair	VSD	110 = VSD repair, Patch
2. TOF repair	TOF	350 = TOF repair, No ventriculotomy 360 = TOF repair, Ventriculotomy, Nontransanular patch 370 = TOF repair, Ventriculotomy, Transanular patch
3. Complete atrioventricular canal repair	AVC	170 = AVC (AVSD) repair, Complete (CAVSD)
4. Arterial switch	ASO	1110 = Arterial switch operation (ASO)
5. Arterial switch + VSD repair	ASO + VSD	1120 = Arterial switch operation (ASO) and VSD repair
6. Fontan operation	Fontan	970 = Fontan, TCPC, Lateral tunnel, Fenestrated 980 = Fontan, TCPC, Lateral tunnel, Nonfenestrated 1000 = Fontan, TCPC, External conduit, Fenestrated 1010 = Fontan, TCPC, External conduit, Nonfenestrated
7. Truncus arteriosus repair	Truncus	230 = Truncus arteriosus repair
8. Norwood procedure	Norwood	870 = Norwood procedure

The study population includes patients who underwent operations with 1 of the primary procedures listed in Table 1 and met the following inclusionary and exclusionary criteria:

1. Age < 18 years.
2. Surgical dates: January 1, 2005–December 31, 2009 inclusive.
3. Operation types: "CPB" or "No CPB Cardiovascular".
4. The operation was the index operation of the admission (ie, the first operation of a given admission in which operation type was "CPB" or "No CPB Cardiovascular").
5. STS participant had at least 90% complete data for discharge mortality, PLOS, preoperative risk factors, and noncardiac abnormalities.
6. Fontan operation: exclude patients ≥ 7 years of age.
7. Truncus: exclude any operation that includes a secondary procedure of "240 = Valvuloplasty, Truncal valve" or "250 = Valve replacement, Truncal valve".
8. From included participants, patients with missing discharge mortality status or PLOS were excluded from analysis.
9. For certain analyses, we restricted inclusion to participants with a certain number of cases, as discussed in the text.

ASO = arterial switch operation; AVC = atrioventricular canal repair; AVSD = atrioventricular septal defect; CAVSD = complete atrioventricular septal defect; CPB = cardiopulmonary bypass; PLOS = postoperative length of stay; STS-CHSDB = Society of Thoracic Surgeons Congenital Heart Surgery Database; TCPC = total cavopulmonary connection; TOF = tetralogy of Fallot; VSD = ventricular septal defect.

previously described by Jaroslav F. Stark, MD and colleagues [5]. The goal of this current analysis is to describe discharge mortality and postoperative length of stay (PLOS) for 8 common potential benchmark operations of varying complexity and to examine between-participant variation in these end points. A related goal is to assess the feasibility of comparing institutions with these end points.

Material and Methods

Study Population

The study population included patients who underwent operations with one of the primary procedures listed in Table 1 and who met the inclusionary and exclusionary criteria also listed in Table 1. Patients undergoing arterial switch operation (ASO) are in a separate cohort from those undergoing ASO + ventricular septal defect (VSD) repair because the outcomes of these 2 groups are quite different [6]. Furthermore the presence or absence of a VSD is a nonmodifiable variable that is an intrinsic characteristic of the patient. In the Fontan cohort, patients undergoing "Fontan revision or conversion (redo Fontan)" were excluded. Patients 7 years or older undergoing Fontan operations were excluded because it was felt to be less likely that the patient was undergoing a primary Fontan operation.

Analytic Methods

OUTCOME VARIABLES. Outcome variables in this analysis are mortality before discharge from the hospital (discharge mortality) and PLOS among patients discharged alive. In this article, the word *mortality* is used to represent discharge mortality [7, 8]. Previous publications from the STS-CHSDB have used PLOS as one measure of operative morbidity [7–9]. In these previous analyses, prolonged PLOS was regarded as a very general proxy measure of morbidity [9].

RAW DATA SUMMARY. For each type of procedure, the overall and participant-specific discharge mortality rates and the overall and participant-specific average PLOS were calculated. Participant-specific results were summarized by the median (50th percentile), range (minimum and maximum), and interquartile range (25th and 75th percentiles).

FUNNEL PLOTS. Participant-specific unadjusted mortality rates were depicted graphically in relation to the participant's number of eligible cases (ie, the participant's sample size). Lines depicting exact 95% binomial prediction limits were overlaid to make a funnel plot [10]. For each participant, the probability of observing a mortality rate that falls outside the plotted prediction limits is less than 5% if the participant's true mortality rate is equal to the overall aggregate mortality rate of all STS participants in the analysis.