# Mortality Trends in Pediatric and Congenital Heart Surgery: An Analysis of The Society of Thoracic Surgeons Congenital Heart Surgery Database

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*Background.* **Previous analyses of The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database have demonstrated a reduction over time of risk-adjusted operative mortality after coronary artery bypass grafting. The STS Congenital Heart Surgery Database (STS CHSD) was queried to assess multiinstitutional trends over time in discharge mortality and postoperative length of stay (PLOS).**

*Methods.* **Since 2009, operations in the STS CHSD have been classified according to STAT (The Society of Thoracic Surgeons—European Association for Cardio-Thoracic Surgery) Congenital Heart Surgery Mortality Categories. The five STAT Mortality Categories were chosen to be optimal with respect to minimizing variation within categories and maximizing variation between categories. For this study, all index cardiac operations from 1998 to 2014, inclusive, were grouped by STAT Mortality Category (exclusions: patent ductus arteriosus ligation in patients weighing less than or equal to 2.5 kg and operations that could not be assigned to a STAT Mortality Category). End points were discharge mortality and PLOS in survivors for the entire period and for 4-year epochs. The Cochran-Armitage trend test was used to test the null hypothesis that the mortality was the same across epochs, by STAT Mortality Category.**

*Results.* **The analysis encompassed 202,895 index operations at 118 centers. The number of centers participating in STS CHSD increased in each epoch. Overall discharge mortality was 3.4% (6,959 of 202,895) for 1998 to 2014 and 3.1% (2,308 of 75,337) for 2011 to 2014. Statistically significant improvement in discharge mortality was seen in STAT Mortality Categories 2, 3, 4, and 5 ($p$ values for STAT Mortality Categories 1 through 5 are 0.060, <0.001, 0.015, <0.001, and <0.001, respectively). PLOS in survivors was relatively unchanged over the same time intervals. Sensitivity analyses reveal that the finding of declining risk-stratified rates of discharge mortality over time is not simply attributable to the addition of more centers to the cohort over time.**

*Conclusions.* **This 16-year analysis of STS CHSD reveals declining discharge mortality over time, especially for more complex operations.**

**(Ann Thorac Surg 2016;■:■–■)**


The Society of Thoracic Surgeons (STS) National Database was established in 1989 as an initiative to enhance the quality and safety of cardiothoracic surgery and to provide an accurate and valid basis for measuring performance in our specialty. The STS National Database has three components, each focusing on a different area of cardiothoracic surgery—Adult Cardiac Surgery,

Accepted for publication Jan 11, 2016.

Presented at the Sixty-second Annual Meeting of the Southern Thoracic Surgical Association, Orlando, FL, Nov 4–7, 2015.

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0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2016.01.071

General Thoracic Surgery, and Congenital Heart Surgery [1]. The STS Congenital Heart Surgery Database (CHSD) was founded in 1994 to support quality improvement and patient safety in pediatric and congenital cardiothoracic surgery [2].

Previous analyses of the STS Adult Cardiac Surgery Database have demonstrated a reduction over time of risk-adjusted operative mortality after coronary artery bypass grafting [3]. The purpose of this analysis is to describe congenital and pediatric cardiac surgical trends in multi-institutional outcomes achieved at centers participating in the STS CHSD.

## Patients and Methods

### *Data Source*

The STS CHSD was used for this study. STS CHSD is an audited comprehensive database of patients who have undergone congenital and pediatric cardiac surgical operations at centers in the United States and Canada. STS CHSD is a voluntary registry that contains preoperative, operative, and outcomes data for all patients undergoing congenital and pediatric cardiovascular operations at participating centers. STS CHSD uses the following age groupings: neonates (0 to 30 days), infants (31 days to 1 year), children (>1 year to <18 years), and adults (≥18 years).

The Report of the 2010 STS Congenital Heart Surgery Practice and Manpower Survey, undertaken by the STS Workforce on Congenital Heart Surgery, estimated that 125 hospitals in the United States and 8 hospitals in Canada perform pediatric and congenital heart operations [4]. In 2014, the STS CHSD included 114 congenital heart surgery programs representing 119 of the 125 hospitals (95.2% penetration by hospital) in the United States and 3 of the 8 centers in Canada.

Coding for this database is accomplished by clinicians and support staff using the International Pediatric and Congenital Cardiac Code [5, 6] and is entered into the contemporary version of the STS CHSD data collection form [7]. The definitions of all terms and codes from the STS CHSD used in this report have been standardized and published [7]. Evaluation of data quality in the STS CHSD includes intrinsic verification of data (eg, identification and correction of missing/out of range values and inconsistencies across fields), along with a formal process of audits at approximately 10% of all participating centers each year conducted by a panel of independent quality-assurance personnel and pediatric cardiac surgeons [8]. Audit of the STS CHSD has documented the following rates of completeness and accuracy for the specified fields of data [9]:

- Primary diagnosis (completeness, 100%; accuracy, 96.2%)
- Primary procedure (completeness, 100%; accuracy, 98.7%)
- Mortality status at hospital discharge (completeness, 100%; accuracy, 98.8%)

### *Accounting for Case Mix*

Owing to the large number of different types of pediatric and congenital cardiac operations (ie, more than 200 individual procedure types, most often performed in various combinations), it is useful to stratify individual operations into groups or categories that are relatively homogeneous with respect to complexity or risk. This methodology, called complexity stratification (or risk stratification), has been used by STS CHSD since 2002. Risk stratification is a method of analysis in which the data are divided into relatively homogeneous groups (called strata). The data are analyzed and reported within each stratum. STS CHSD has used three methods of risk stratification [10–12]:

1. The Society of Thoracic Surgeons—European Association for Cardio-Thoracic Surgery (STAT) Congenital Heart Surgery Mortality Categories (STAT Mortality Categories)
2. Aristotle Basic Complexity Levels
3. Risk Adjustment for Congenital Heart Surgery-1 Categories

STS CHSD initially used the Aristotle Basic Complexity Levels and the Risk Adjustment for Congenital Heart Surgery-1 Categories to stratify procedures according to degree of complexity and risk. With the increasing availability of multiinstitutional clinical data, the empirically based STAT Mortality Score and STAT Mortality Categories were introduced in the STS CHSD in 2010. The STAT Mortality Categories [11, 12] are a tool for stratification based on the procedure-specific estimate of the risk of discharge mortality, which was developed from an analysis of 77,294 operations entered into the European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Database (33,360 operations) and the STS CHSD (43,934 operations). Procedure-specific mortality rate estimates were calculated using a Bayesian model that adjusted for small denominators. Operations were sorted by increasing risk and grouped into five categories (the STAT Mortality Categories) that were designed to be optimal with respect to minimizing variation within categories and maximizing variation between categories. STAT Mortality Category 1 is associated with the lowest risk for mortality and STAT Mortality Category 5 is associated with the highest risk for mortality.

### *Study Population*

For this study, all index cardiac operations in STS CHSD from January 1998 through June 2014, inclusive, were eligible for inclusion. Index operations are defined as the first cardiac operation of a hospitalization. Patients weighing less than or equal to 2.5 kg undergoing isolated closure of a patent arterial duct were excluded. Operations that could not be assigned a STAT Mortality Category were also excluded. All remaining eligible index cardiac operations were grouped by STAT Mortality Category. The final study cohort included 202,895 index cardiac operations performed in 118 centers.