The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2017 Update on Outcomes and Quality

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The Society of Thoracic Surgeons Congenital Heart Surgery Database is the largest congenital and pediatric cardiac surgical clinical data registry in the world. It is the platform for all activities of The Society of Thoracic Surgeons related to the analysis of outcomes and the improvement of quality in this subspecialty. This report summarizes current aggregate national outcomes in congenital and pediatric cardiac surgery and reviews related activities in the areas of quality measurement, performance improvement, and transparency.

The reported data about aggregate national outcomes are exemplified by an analysis of 10 benchmark operations performed from January 2012 to December 2015. This analysis documents the overall aggregate operative mortality (interquartile range among all participating programs) for the following procedural groups: off-bypass coarctation repair, 1.3% (0.0% to 1.8%); ventricular septal defect repair, 0.6% (0.0% to 0.9%); tetralogy of Fallot repair, 1.1% (0.0% to 1.4%); complete atrioventricular canal repair, 3.0% (0.0% to 4.7%); arterial switch operation, 2.7% (0.0% to 4.1%); arterial switch operation and ventricular septal defect repair, 5.3% (0.0% to 6.7%); Glenn/hemi-Fontan, 2.5% (0.0% to 4.5%); Fontan operation, 1.2% (0.0% to 1.2%); truncus arteriosus repair, 9.4% (0.0% to 16.7%); and Norwood procedure, 15.7% (8.9% to 25.0%).

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The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS CHSD) was founded in 1994 to provide assessment of programmatic and aggregate outcomes to participants and to support quality improvement and patient safety in pediatric and congenital cardiothoracic surgery [1–3]. STS CHSD is now

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the largest congenital and pediatric cardiac surgical clinical data registry in the world, containing data about approximately 394,980 operations as of September 9, 2016. These data are the foundation for assessment of performance by benchmarking and comparison of individual programmatic outcomes to national aggregate data, development and subsequent application of sophisticated risk adjustment models [4–7], quality improvement initiatives, research, voluntary public reporting [8–11], development of reimbursement strategies, and governmental and regulatory collaborations. This article is the second in a series of annual reports summarizing current national aggregate congenital and pediatric cardiac surgical outcomes and detailing quality measurement and performance improvement activities based on STS CHSD during the past year [12, 13].

Overview of STS CHSD

Collection of detailed clinical data and feedback of risk-adjusted nationally benchmarked results to participating cardiac surgical programs are the primary functions of STS CHSD [14]. An STS CHSD participant is typically a hospital cardiac surgery program, a practice group of cardiothoracic surgeons, or uncommonly, an individual surgeon. Data are submitted to the STS data warehouse and analytical center at the Duke Clinical Research Institute. Duke Clinical Research Institute harvests the data two times each year, and Feedback Reports are disseminated every 6 months to each STS CHSD participant. These Feedback Reports facilitate internal quality assessment and serve as a platform for quality improvement by presenting data about the risk factors and outcomes of the individual participant compared with national benchmark data.

The spectrum of individual congenital cardiac malformations is broad, and the variety of types of cardiac disease affecting individuals early in life is large. Consequently, to collect relevant data, a database must account for nearly 200 individual diagnoses and a roughly comparable number of distinct types of therapeutic interventions, which are often performed concomitantly as elements of a multicomponent operation. To maintain clinical relevance with evolving surgical practice, data elements undergo periodic revision to clarify existing variables, harmonize definitions with related national and international databases, add new variables of interest, and remove irrelevant ones. These revisions are performed on a 3-year cycle.

As of 2016, STS CHSD included 120 participants comprising 392 surgeons from 39 states in the United States and from 3 other countries: Canada (4 Canadian participants from 4 Canadian provinces), Israel, and Turkey [15]. The 6 current participants in STS CHSD not located in the United States are:

- British Columbia Children's Hospital, Vancouver, British Columbia, Canada
- Montreal Children's Hospital, Montreal, Quebec, Canada
- Stollery Children's Hospital, Edmonton, Alberta, Canada
- The Hospital for Sick Children, Toronto, Ontario, Canada
- Anadolu Medical Center Hospital, Gebze, Turkey
- Wolfson Medical Center, Holon, Israel

Data from 3 of the 4 Canadian hospitals in the list above are included in the national aggregate data presented in this report. When reporting national aggregate data, STS CHSD includes only data from participants located in the United States and Canada. Thus, the aggregate data in this report are from operations performed at 117 participants, 114 located in the United States and 3 located in Canada. (One Canadian hospital in the list above actively participates in STS CHSD, but its data were not included in the 2016 STS CHSD Spring Harvest Feedback Report [14] and are not included in the national aggregate data presented in this report.)

Of the 394,980 cumulative worldwide operations included in STS CHSD as of September 9, 2016, 383,558 were submitted by participants located in the United States [15]. The 114 participants located in the United States represent 121 hospitals [15]. (An STS database participant is a "practice group of cardiothoracic surgeons" or, uncommonly, an individual cardiothoracic surgeon. In most instances, an STS database participant is a hospital cardiac or thoracic surgery program. In most situations, one STS database participant is linked to one hospital; however, in some instances, one STS database participant is linked to more than one hospital or one hospital is linked to more than one STS database participant. Therefore, the number of STS database participants and the number of hospitals is slightly different.)

The 2015 STS Congenital Heart Surgery Practice Survey Report, undertaken by the STS Workforce on Congenital Heart Surgery, estimates that 125 hospitals in the United States and 8 hospitals in Canada perform pediatric cardiac operations [16]. Therefore, more than 95% of hospitals that perform pediatric heart operations in the United States participate in STS CHSD, and the patient-level penetration is even higher, because virtually all high-volume pediatric cardiac surgical programs in the United States participate in STS CHSD. These data suggest that nearly all pediatric cardiac operations performed in the United States are captured in STS CHSD.

Assessing Outcomes With STS CHSD

To perform meaningful multiinstitutional analyses of outcomes, any database should strive to incorporate the following seven essential elements [13, 17–19]:

1. use of a common language and nomenclature [20, 21];
2. an established uniform core data set for collection of information [14];
3. incorporation of a mechanism to evaluate and account for case complexity [22–24];
4. availability of a mechanism to ensure and verify the completeness and accuracy of the data collected [25];

5. collaboration between medical and surgical subspecialties [26];
6. incorporation of strategies for quality assessment and quality improvement; and
7. standardization of protocols for life-long follow-up.

STS CHSD has made important advances in the first six of these elements; however, STS CHSD has not yet developed strategies for longitudinal follow-up beyond discharge from the hospital and 30 days after the operation. Details regarding these advances within STS CHSD have been previously summarized and reported [13].

Measuring Quality With STS CHSD

STS CHSD is increasingly used to document variation in outcomes [27, 28] and measure quality [19, 29]. STS has collaborated with the Congenital Heart Surgeons' Society to develop and endorse metrics to assess the quality of care delivered to patients with pediatric and congenital cardiac disease [29]. Best practices can be identified by studying structure and processes of care at "high performing centers," and quality improvement initiatives can be initiated in "low performing centers." The vast amount of accumulated data may ultimately be used for strategies to identify these best practices by studying structure and processes of care at "high performing centers," creating the opportunity for quality improvement initiatives to be implemented across all sites or specifically in "low performing centers."

The STS CHSD: Aggregate Outcomes

The aggregate outcomes summarized in this section are based on data collected in STS CHSD for all operations performed from January 1, 2012, to December 31, 2015, inclusive, and presented in the STS CHSD 2016 Spring Harvest Feedback Report [14]. The outcomes in this report are based on the data elements specified in the current versions of the data collection instrument (versions 3.0 and 3.22, which went live on January 1, 2010, and January 1, 2014, respectively), and are presented using only data from centers located in the United States or Canada.

Table 1 reports aggregate outcomes of risk-stratified operations in STS CHSD during the last 4 years (January 2012 to December 2015), with the end points of operative mortality and postoperative length of stay (PLOS) [28]. Although the aggregate data in Table 1 are not risk-adjusted, these unadjusted outcomes data are risk-stratified by the STS–European Association for Cardio-Thoracic Surgery (STAT) Mortality Categories [23, 24]. The Appendix provides the latest version of the STAT Mortality Categories that was used to create Table 1. In Table 1, it is interesting to note that the PLOS for STAT Mortality Category 2 is longer than the PLOS for STAT Mortality Category 3 and that the mortality for STAT Mortality Category 3 is higher than the mortality for STAT Mortality Category 2. The explanation for this observation is uncertain, although the STS CHSD 2016 Update on Outcomes and Quality [13] also reported this same observation.

Table 2 reports unadjusted aggregate outcomes for current benchmark operations in STS CHSD, also during the last 4 years (January 2012 to December 2015), and also with the end points of operative mortality and PLOS. Data about the following 10 benchmark operations are included in Table 2:

1. Ventricular septal defect repair
2. Tetralogy of Fallot repair
3. Complete atrioventricular canal repair (complete atrioventricular septal defect repair)
4. Arterial switch
5. Arterial switch + ventricular septal defect repair
6. Glenn/hemi-Fontan
7. Fontan operation
8. Truncus arteriosus repair
9. Norwood procedure
10. Off-bypass coarctation repair (only includes cases with Op Type = no cardiopulmonary bypass cardiovascular)

Table 2 of this report was developed based on Table 2 from a previous publication, "Richard E. Clark Paper: Variation in Outcomes for Benchmark Operations: An Analysis of the Society of Thoracic Surgeons Congenital Heart Surgery Database" [27] and includes 10 benchmark operations rather than the eight listed as benchmark operations in the previous publication [27]. The inclusionary and exclusionary criteria used for Table 2 of this report are different from those described in the previous publication [27] because in Table 2 of this report, the relevant inclusion factors are only the procedure codes listed in Table 3.

Operative mortality is defined in all STS databases 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 acute care facilities); and (2) all deaths, regardless of cause, occurring after discharge from the hospital, but before the end of the 30th postoperative day [30, 31].

Beginning with the Spring 2014 STS CHSD Feedback Report, the STS CHSD Task Force now uses the field "Mortality Status at Database Discharge" rather than the field "Mortality Status at Hospital Discharge" when calculating operative mortality. This field ("Mortality Status at Database Discharge") is now used in combination with the field "Status at 30 Days After Surgery" to arrive at a determination of operative mortality. Similarly, beginning with the Spring 2014 STS CHSD Feedback Report, the STS CHSD Task Force now uses the field "Date of Database Discharge" rather than the field "Date of Hospital Discharge" when calculating length of stay. This change in reporting was implemented to ensure accurate reporting of outcomes for patients who are transferred not only to another acute care facility but also to a chronic care facility after undergoing an operation at a participating center. The definitions of the fields "Mortality Status at Database Discharge" and

Table 1. Society of Thoracic Surgeons Congenital Heart Surgery Database Aggregate Outcomes of Risk Stratified Operations: Operative Mortality and Postoperative Length of Stay, Last 4 Years (January 2012 to December 2015)[a]

	STAT Mortality Category				
Variable	1	2	3	4	5
STS overall (all participants)					
Sample size					
Number of participants	117	117	117	117	111
Number of operations	28,896	35,519	10,629	19,038	3,753
Average participant-specific sample size	247.0	303.6	90.8	162.7	33.8
Range of participant-specific sample sizes	(16.0–1247.0)	(20.0–1304.0)	(4.0–500.0)	(4.0–730.0)	(1.0–147.0)
Operative mortality[a]					
Aggregate mortality rate,[a] %	0.5	1.7	2.6	6.9	16.1
Median participant-specific mortality rate,[a] %	0.4	1.6	2.1	6.8	14.9
Range of participant-specific mortality rates,[a] %	(0.0–5.0)	(0.0–13.3)	(0.0–18.2)	(0.0–20.7)	(0.0–100.0)
Interquartile range of participant-specific mortality rates,[a] %	(0.0–0.8)	(0.9–2.2)	(0.7–3.9)	(4.8–9.4)	(10.2–25.0)
Postoperative length of stay (PLOS)					
Aggregate average PLOS per patient, days	6.8	19.7	14.5	24.5	42.4
Median participant-specific average PLOS, days	6.7	18.9	13.7	24.0	40.9
Range of participant-specific average PLOS, days	(3.5–20.2)	(8.3–55.9)	(5.2–42.8)	(10.5–51.3)	(0.0–102.0)
Interquartile range of participant-specific average PLOS, days	(5.5–7.7)	(15.5–27.4)	(12.0–16.9)	(19.6–27.6)	(31.6–51.3)
Among sites with N $\geq$ 10 operations[b]					
Sample size					
Number of participants	117	117	110	116	83
Number of operations	28,896	35,519	10,589	19,034	3,630
Average participant-specific sample size	247.0	303.6	96.3	164.1	43.7
Range of participant-specific sample sizes	(16.0–1247.0)	(20.0–1304.0)	(10.0–500.0)	(11.0–730.0)	(10.0–147.0)
Operative mortality[a]					
Aggregate mortality rate,[a] %	0.5	1.7	2.6	6.9	15.9
Median participant-specific mortality rate,[a] %	0.4	1.6	2.2	6.8	15.4
Range of participant-specific mortality rates,[a] %	(0.0–5.0)	(0.0–13.3)	(0.0–18.2)	(0.0–20.7)	(0.0–54.5)
Interquartile range of participant-specific mortality rates,[a] %	(0.0–0.8)	(0.9–2.2)	(1.0–4.2)	(4.8–9.4)	(12.0–23.8)
Postoperative length of stay (PLOS)					
Aggregate average PLOS per patient, days	6.8	19.7	14.5	24.5	42.3
Median participant-specific average PLOS, days	6.7	18.9	13.8	24.1	41.7
Range of participant-specific average PLOS, days	(3.5–20.2)	(8.3–55.9)	(5.6–41.6)	(10.5–51.3)	(11.3–80.1)
Interquartile range of participant-specific average PLOS, days	(5.5–7.7)	(15.5–27.4)	(12.1–16.8)	(19.7–27.7)	(34.2–51.3)

[a] Rates of mortality depicted are observed (unadjusted) mortality rates. (Although the aggregate data in Table 1 are not risk adjusted, these unadjusted outcomes data are risk stratified by the Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery [STAT]) Mortality Categories [23, 24].) [b] More than 9 operations in a given category in the analytic window of time.

STS = The Society of Thoracic Surgeons.

"Date of Database Discharge" are previously published [30, 32] and are summarized in Table 4 of the previously published STS CHSD 2016 Update on Outcomes and Quality [13].

The STS CHSD: Transparency and Public Reporting of National Outcomes in Congenital and Pediatric Cardiac Surgery

In January 2015, STS began to publicly report outcomes of pediatric and congenital cardiac operations using the STS CHSD Mortality Risk Model (http://www.sts.org/quality-research-patient-safety/sts-public-reporting-online) [4–7], which calculates rates of risk-adjusted operative mortality for pediatric and congenital heart operations and includes adjustment for procedural factors and patient-level factors. The STS CHSD Mortality Risk Model adjusts for the variables listed in Table 4. This model, which includes procedural factors and individual patient factors, is the most comprehensive and most sophisticated risk model for congenital and pediatric heart operations in use at the present time [6]. Assessment of model fit and discrimination in the development sample and the validation sample revealed overall C statistics of 0.875 and 0.858, respectively. Coefficients for variables in the model are reestimated every 6 months to ensure that the model remains well calibrated for its intended use in STS CHSD Feedback Reports.

Table 2. Society of Thoracic Surgeons Congenital Heart Surgery Database Aggregate Outcomes of Benchmark Operations: Operative Mortality and Postoperative Length of Stay, Last 4 Years (January 2012 to December 2015)[a]

Variable	Off-Bypass Coarctation	VSD	TOF	AVC	ASO	ASO+VSD	Glenn/ Hemi-Fontan	Fontan	Truncus	Norwood
STS overall (all participants)										
Sample size										
Number of participants	113	117	116	117	112	101	115	111	93	104
Number of operations	3,964	7,250	4,648	3,169	1,888	785	4,839	4,279	631	2,810
Average participant-specific sample size	35.1	62.0	40.1	27.1	16.9	7.8	42.1	38.5	6.8	27.0
Range of participant-specific sample sizes	(1.0–132.0)	(2.0–231.0)	(1.0–165.0)	(1.0–156.0)	(1.0–73.0)	(1.0–40.0)	(1.0–177.0)	(1.0–195.0)	(1.0–22.0)	(1.0–118.0)
Operative mortality[a]										
Aggregate mortality rate,[a] %	1.3	0.6	1.1	3.0	2.7	5.3	2.5	1.2	9.4	15.7
Median participant-specific mortality rate,[a] %	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	14.6
Range of participant-specific mortality rates,[a] %	(0.0–15.0)	(0.0–20.0)	(0.0–20.0)	(0.0–33.3)	(0.0–33.3)	(0.0–100.0)	(0.0–25.0)	(0.0–18.2)	(0.0–100.0)	(0.0–100.0)
Interquartile range of participant-specific mortality rates,[a] %	(0.0–1.8)	(0.0–0.9)	(0.0–1.4)	(0.0–4.7)	(0.0–4.1)	(0.0–6.7)	(0.0–4.5)	(0.0–1.2)	(0.0–16.7)	(8.9–25.0)
Postoperative length of stay (PLOS)										
Aggregate average PLOS per patient, days	12.2	8.4	11.5	16.7	16.4	18.6	14.4	13.3	32.0	43.6
Median participant-specific average PLOS, days	11.2	7.8	10.7	16.1	15.9	17.0	13.1	13.6	29.5	41.8
Range of participant-specific average PLOS, days	(3.2–34.7)	(3.6–37.4)	(5.0–41.8)	(5.0–94.5)	(4.3–59.0)	(0.0–55.0)	(4.4–25.9)	(4.9–52.0)	(5.5–171.0)	(0.0–198.0)
Interquartile range of participant-specific average PLOS, days	(7.7–13.7)	(6.4–9.7)	(8.4–12.8)	(11.5–20.8)	(13.1–22.1)	(13.7–21.7)	(10.0–17.4)	(11.4–15.8)	(21.0–39.6)	(32.0–52.9)
Among sites with N $\geq$ 10 operations[b]										
Sample size										
Number of participants	93	108	102	88	69	30	95	88	23	73
Number of operations	3,864	7,199	4,572	3,029	1,690	502	4,753	4,173	331	2,673
Average participant-specific sample size	41.5	66.7	44.8	34.4	24.5	16.7	50.0	47.4	14.4	36.6
Range of participant-specific sample sizes	(10.0–132.0)	(10.0–231.0)	(10.0–165.0)	(10.0–156.0)	(10.0–73.0)	(10.0–40.0)	(10.0–177.0)	(10.0–195.0)	(10.0–22.0)	(11.0–118.0)
Operative mortality[a]										
Aggregate mortality rate,[a] %	1.3	0.6	1.1	2.9	2.6	3.4	2.5	1.2	7.9	15.1
Median participant-specific mortality rate,[a] %	0.0	0.0	0.0	2.5	0.0	0.0	1.3	0.0	9.1	15.0
Range of participant-specific mortality rates,[a] %	(0.0–15.0)	(0.0–8.0)	(0.0–10.0)	(0.0–21.4)	(0.0–16.7)	(0.0–15.4)	(0.0–12.0)	(0.0–18.2)	(0.0–26.3)	(0.0–47.4)
Interquartile range of participant-specific mortality rates,[a] %	(0.0–2.0)	(0.0–0.9)	(0.0–1.6)	(0.0–4.9)	(0.0–5.4)	(0.0–5.9)	(0.0–4.7)	(0.0–1.7)	(0.0–10.5)	(11.7–21.4)

(*Continued*)

Table 2. Continued

Variable	Off-Bypass Coarctation	VSD	TOF	AVC	ASO	ASO+VSD	Glenn/ Hemi-Fontan	Fontan	Truncus	Norwood
Postoperative length of Stay (PLOS)										
Aggregate average PLOS per patient, days	12.3	8.3	11.4	16.6	15.9	17.6	14.4	13.3	30.0	43.7
Median participant-specific average PLOS, days	11.6	7.8	10.5	16.1	15.3	17.1	13.1	13.7	29.5	42.9
Range of participant-specific average PLOS, days	(3.2–33.5)	(3.6–19.1)	(5.8–31.4)	(6.8–50.5)	(6.0–40.8)	(9.4–31.2)	(4.4–25.9)	(4.9–19.8)	(16.5–67.0)	(11.5–82.2)
Interquartile range of participant-specific average PLOS, days	(8.9–13.7)	(6.4–9.6)	(8.6–12.6)	(11.6–20.0)	(13.3–18.7)	(14.6–20.4)	(10.6–17.4)	(11.7–15.3)	(23.4–34.5)	(34.9–52.5)

[a] Rates of mortality depicted in Table 2 are observed (unadjusted) mortality rates. [b] More than 9 operations in a given category in the analytic window of time.

ASO = arterial switch operation; AVC = atrioventricular canal repair; STS = The Society of Thoracic Surgeons; TOF = tetralogy of Fallot repair; VSD = ventricular septal defect.

The data in STS CHSD include the observed operative mortality of all participants. The STS CHSD Mortality Risk Model estimates the expected operative mortality of all participants. Then, the observed-to-expected (O/E) operative mortality ratio and associated 95% confidence intervals can be calculated for each program, along with the rates of risk-adjusted operative mortality and associated 95% confidence intervals for each program.

For all STS CHSD participants who consent to participate in voluntary public reporting, STS Public Reporting Online reports the following:

- the overall observed and expected operative mortality rates for each STS CHSD participant during a 4-year period for patients of all ages;
- the observed and expected operative mortality rates for each STS CHSD participant during a 4-year period for patients of all ages, reported separately for each of the five STAT Mortality Categories;
- the O/E operative mortality ratio and associated 95% confidence intervals that correspond to each of the above-mentioned patient groups; and
- the adjusted mortality rate and associated 95% confidence intervals that correspond to each of the above-mentioned patient groups.

Detailed descriptions of the multiple outcomes publicly reported by STS CHSD have been previously published [13, 33]. When publicly reporting outcomes for centers participating in STS CHSD voluntary public reporting, STS reports the data with varying levels of granularity, ranging from point estimates with confidence intervals for statistically sophisticated users to star ratings (based on the work of Professor Judith Hibbard [10, 34–38]) that assist patients and families in correctly interpreting complex data. In STS CHSD, the overall star rating of a given STS CHSD participant is based on their overall risk-adjusted O/E operative morality ratio for all cardiovascular surgical patients, using the latest version of the STS CHSD Mortality Risk Model (Table 4). Centers are classified into three categories by their overall O/E risk-adjusted operative morality ratio:

- One star = higher than expected operative mortality (the 95% confidence interval for their risk-adjusted O/E mortality ratio was entirely above the number 1)
- Two stars = same as expected operative mortality (the 95% confidence interval for their risk-adjusted O/E mortality ratio overlapped with the number 1)
- Three stars = lower than expected operative mortality (the 95% confidence interval for their risk-adjusted O/E mortality ratio was entirely below the number 1)

The star rating designations are determined using the 95% confidence intervals of a center's overall risk-adjusted O/E operative morality ratio for all index cardiovascular surgical operations. Table 5 documents the distribution of star ratings for the Fall 2014, Spring 2015, Fall 2015, Spring 2016, and Fall 2016 STS CHSD Feedback Reports. The star ratings were first publicly reported in August 2015 based on the Spring 2015 STS CHSD

Table 3. Ten Benchmark Operations[a]

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, Nontransannular patch
		370 = TOF repair, Ventriculotomy, Transannular 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. Glenn/Hemi-Fontan	Glenn/Hemi-Fontan	1670 = Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)
		1680 = Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)
		1690 = Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)
		1700 = Hemi-Fontan
		2130 = Superior Cavopulmonary anastomosis(es) + PA reconstruction
7. 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
		2780 = Fontan, TCPC, Intra/extracardiac conduit, Fenestrated[a]
		2790 = Fontan, TCPC, Intra/extracardiac conduit, Nonfenestrated[a]
		3310 = Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Fenestrated[b]
		3320 = Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Nonfenestrated[b]
8. Truncus arteriosus repair	Truncus	230 = Truncus arteriosus repair
9. Norwood procedure	Norwood	870 = Norwood procedure
10. Off-Bypass Coarctation—only include cases with Op Type = No CPB Cardiovascular	Coarctation	1210 = Coarctation repair, End to end
		1220 = Coarctation repair, End to end, Extended
		1230 = Coarctation repair, Subclavian flap
		1240 = Coarctation repair, Patch aortoplasty
		1250 = Coarctation repair, Interposition graft
		1280 = Aortic arch repair

[a] Only available in data version 3.22 and 3.3. [b] Only available in data version 3.3.

Table 3 lists the 10 current benchmark operations, together with the Society of Thoracic Surgeons Congenital Heart Surgery Database (STS CHSD) procedural codes (version 3.0, version 3.22, and version 3.3) that qualify for inclusion in each of the Benchmark Operation groups. (Please note that Benchmark Operations 6 and 10 are not included in the initial publication of these benchmark operations [27] and were added to the list of benchmark operations after the publication of the initial list of benchmark operations in reference 27. Also, please note that operations are classified into the various benchmark procedure groups according to the assigned primary procedure for that operation.)

AVC = atrioventricular canal repair; CPB = cardiopulmonary bypass; PA = pulmonary artery; TCPC = total cavopulmonary connection; TOF = tetralogy of Fallot; VSD = ventricular septal defect.

Feedback Report. These publicly reported star ratings were updated in August 2016 based on the Spring 2016 STS CHSD Feedback Report. The next update to the publicly reported star ratings will be in August 2017 based on the Spring 2017 STS CHSD Feedback Report. The final appearance of these publicly reported data can be viewed at http://www.sts.org/quality-research-patient-safety/sts-public-reporting-online.

The data that are publicly reported and provided in STS CHSD Feedback Reports (ie, point estimates with confidence intervals) can be used to determine the star rating of an individual program simply by examining the 95% confidence interval of a center's overall risk-adjusted O/E operative morality ratio for all cardiovascular surgical patients and comparing this O/E operative morality ratio to unity (the number 1). By providing the star rating, this statistical analysis becomes more accessible and understandable for many patients and families [10, 13, 34–38].

Round 1 of voluntary public reporting from STS CHSD was published in January 2015, based on the STS CHSD 2014 Fall Harvest and Feedback Report (which was based on data from operations performed in the 4-year analytic window of July 1, 2010, to June 30. 2014). Round 1 publicly reported only point estimates with confidence intervals

Table 4. The STS Congenital Heart Surgery Database Mortality Risk Model: List of Included Variables for Which the Model Adjusts

Variable
Age[a]
Primary procedure[b]
Weight (neonates and infants)
Prior cardiothoracic operation
Any noncardiac congenital anatomic abnormality[c]
Any chromosomal abnormality or syndrome[d]
Prematurity (neonates and infants)
Preoperative factors
• Preoperative/preprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS)
• Shock, persistent at time of operation
• Mechanical ventilation to treat cardiorespiratory failure
• Renal failure requiring dialysis and/or renal dysfunction
• Preoperative neurologic deficit
• Any other preoperative factor[e]

[a] Modeled as a piecewise linear function with separate intercepts and slopes for each Society of Thoracic Surgeons-defined age group (neonate, infant, child, adult). [b] The model adjusts for each combination of primary procedure and age group. Coefficients obtained via shrinkage estimation with The Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STS-EACTS [STAT]) Mortality Category [6] as an auxiliary variable. [c] Except "Other noncardiac congenital abnormality" with code value = 990). [d] Except "Other chromosomal abnormality" with code value = 310 and except "Other syndromic abnormality" with code value = 510). [e] Defined as any of the other specified preoperative factors contained in the list of preoperative factors in the data collection form of the STS Congenital Heart Surgery Database, exclusive of 777 = "Other preoperative factors."

CPS = cardiopulmonary support; ECMO =extracorporeal membrane oxygenation; IABP = intraaortic balloon pump; VAD = ventricular assist device.

and did not publicly report star ratings. In round 1, 25 of 109 participating programs in STS CHSD in the United States at that time (23% of United States participants in STS CHSD) consented to participate and were enrolled in public reporting. However, only 19 of the 25 participants in the STS CHSD who were enrolled in public reporting in round 1 actually publicly reported their data at that time because 6 participants who consented to publicly report had incomplete data and, therefore, ultimately could not publicly report.

Round 2 of voluntary public reporting from STS CHSD was published in August 2015, based on the STS CHSD 2015 Spring Harvest and Feedback Report. Round 2 was the first time that STS CHSD publicly reported star ratings along with the previously reported point estimates with confidence intervals. In round 2, 38 of 110 participating programs in STS CHSD in the United States at that time (35% of United States participants in STS CHSD) consented to participate and were enrolled in public reporting. However, only 33 of the 38 participants in the STS CHSD who were enrolled in public reporting in round 2 actually publicly reported their data at that time. Based on the data from operations performed in the 4-year analytic window of January 1, 2011, to December 31, 2014, the STS CHSD 2015 Spring Harvest and Feedback Report documented 11 one star programs, 79 two star programs, 6 three star programs, and 20 programs that had no star rating because of incomplete data. (Three participants appear twice in this listing because they are associated with more than one participant identification number.)

In round 2 of voluntary public reporting from STS CHSD, public reporting was provided by 0 of 11 one star

Table 5. The Distribution of Star Ratings for the Fall 2014, Spring 2015, Fall 2015, and Spring 2015 Society of Thoracic Surgeons Congenital Heart Surgery Database Feedback Reports[a]

STS CHSD Feedback Report	Participants, No.	Percentage of All Programs	Percentage of Programs With Star Rating
Fall 2014			
No star rating assigned	24	21.2	XXX
1 star	11	9.7	12.4
2 stars	72	63.7	80.9
3 stars	6	5.3	6.7
Total	113	100	100
Spring 2015			
No star rating assigned	20	17.2	XXX
1 star	11	9.5	11.4
2 stars	79	68.1	82.3
3 stars	6	5.2	6.3
Total	116	100	100
Fall 2015			
No star rating assigned	19	16.2	XXX
1 star	12	10.3	12.2
2 stars	76	65.0	77.6
3 stars	10	8.6	10.2
Total	117	100	100
Spring 2016			
No star rating assigned	12	10.3	XXX
1 star	14	12.0	13.3
2 stars	83	70.9	79.1
3 stars	8	6.8	7.6
Total	117	100	100
Fall 2016			
No star rating assigned	13	11.21	XX
1 star	18	15.52	17.48
2 stars	74	63.79	71.84
3 stars	11	9.48	10.68
Total	116	100	100

[a] The star ratings were first publicly reported in August 2015 based on the Spring 2015 Society of Thoracic Surgeons Congenital Heart Surgery Database (STS CHSD) Feedback Report. The next update to the publicly reported star ratings will be in August 2017 based on the Spring 2017 STS CHSD Feedback Report. (In the Fall 2014, Spring 2015, Fall 2015, Spring 2016, and Fall 2016 STS CHSD Feedback Reports, 1, 3, 2, 2, and 1 participant(s), respectively, appear twice in this table because they are associated with more than one participant identification number.)

programs, 27 of 79 two star programs, and 5 of 6 three star programs. One of the reasons cited by programs for not participating in public reporting was that collection of incomplete or inaccurate data related to the risk factors listed in Table 4 could lead to inaccurate estimation of expected mortality. The submission of complete and accurate data about risk factors is of critical importance to facilitate meaningful calculation of the O/E mortality ratio on which the publicly reported star rating is based [39].

Round 3 of voluntary public reporting from STS CHSD was published in August 2016, based on the STS CHSD 2016 Spring Harvest and Feedback Report. Round 3 again included publicly reported star ratings along with the previously reported point estimates with confidence intervals. Of 114 programs participating in STS CHSD in the United States at that time (61% of United States participants in STS CHSD), 70 consented to participate and were enrolled in public reporting. However, only 61 of 70 STS CHSD participants that were enrolled in public reporting in round 3 actually publicly reported their data at that time. From the data from operations performed in the 4-year analytic window of January 1, 2012, to December 31, 2015, the STS CHSD 2016 Spring Harvest and Feedback Report documented 14 one star programs, 83 two star programs, 8 three star programs, and 12 programs that had no star rating because of incomplete data. (Two participants appear twice in this listing because they are associated with more than one participant identification number.) In round 3 of voluntary public reporting from STS CHSD, 3 of 14 one star programs publicly reported, 49 of 83 two star programs publicly reported, and 8 of 8 three star programs publicly reported.

Round 4 of voluntary public reporting from STS CHSD will be published in August 2017, based on the STS CHSD 2017 Spring Harvest and Feedback Report using data from operations performed in the 4-year analytic window of January 1, 2013, to December 31, 2016.

Upcoming Activities Involving STS CHSD

In 2015, STS CHSD completed its latest periodic revision of data specifications, and this upgraded version of STS CHSD was implemented on January 1, 2016. In 2016, the STS CHSD Task Force and STS Quality Measurement Task Force began to collaborate on an initiative to refine risk adjustment for chromosomal abnormalities, syndromes, and noncardiac congenital anatomic abnormalities and then enhance the STS CHSD Mortality Risk Model with this additional information. Upon completion of this project, STS CHSD Task Force plans to collaborate with STS Quality Measurement Task Force to study the relationship between volume (programmatic volume and surgeon volume) and outcome using this enhanced STS CHSD Mortality Risk Model.

Efforts are underway to develop a multidomain congenital and pediatric cardiac surgical quality metric that includes the outcomes of risk-adjusted mortality and risk-adjusted morbidity based on the occurrence of complications and PLOS [40]. One goal of this initiative is to develop risk models to help assess pediatric and congenital cardiac surgical performance using a multidomain composite metric that incorporates mortality and morbidity and adjusts for the operation performed and for patient-specific factors. Our expectation is that outcomes from this multidomain composite will also be publicly reported in combination with the public reporting of the STS CHSD Mortality Risk Model. By reporting outcomes based on both the STS CHSD Mortality Risk Model and a new multidomain composite that incorporates mortality and morbidity, the portfolio of publicly reported measures developed and reported by STS will continue to expand.

The development of this multidomain composite metric is funded through an R01 grant from the National Heart, Lung, and Blood Institute of the National Institutes of Health, “Understanding Quality and Costs in Congenital Heart Surgery” (R01-HL-122261). The period of award for this grant is April 1, 2014, through March 31, 2019. The Principal Investigator is Sara K. Pasquali, MD, MHS, and the STS Principal Investigator is Jeffrey P. Jacobs, MD. The grant includes collaboration with Children’s Hospital Association and will merge clinical data from STS CHSD with data about utilization of resources from the Pediatric Health Information Systems Database. The specific aims of this R01 grant are:

Aim 1: To develop and validate a composite quality metric in congenital heart surgery

Aim 2: To examine the relationship between our composite measure of quality and cost

Under the direction of the International Society for Nomenclature of Paediatric and Congenital Heart Disease, several members of STS CHSD are participating in the development of the codes and definitions for the component of the International Classification of Diseases Eleventh Revision dedicated to pediatric and congenital cardiac care. These new International Classification of Diseases-11 codes for pediatric and congenital cardiac care will be identical in both the International Classification of Diseases and International Paediatric and Congenital Cardiac Code, ensuring that for the first time, in the domain of pediatric and congenital cardiac care, the nomenclature used in administrative claims data will be the same as the nomenclature in clinical registries [41–45].

In collaboration with the STS Adult Cardiac Surgery Database Task Force, the STS CHSD Task Force will continue to explore the potential to automatically extract certain data elements directly from electronic health records, while requiring the same high accuracy and integrity of current data entry approaches [46, 47]. The newly created STS Patient Reported Outcomes Task Force is exploring strategies of incorporating patient-reported outcomes into the STS National Database. Although patient-reported outcomes are likely to be piloted using the STS Adult Cardiac Surgery Database or General Thoracic Surgery Database, the potential exists for extension of this initiative into STS CHSD. Finally, the STS Task Force on Quality Initiatives is exploring the possibility of offering a broad range of quality

improvement opportunities to programs that might desire these opportunities, including site visits designed to facilitate quality improvement. Although these opportunities are likely to be initially piloted using STS Adult Cardiac Surgery Database, the potential exists for extension into STS CHSD and STS General Thoracic Surgery Database.

In the future, alternative methods of risk stratification and reporting of outcomes may be considered and used by STS CHSD. For example, postoperative survival can also be displayed with variable life-adjusted display (VLAD) charts, which indicate the cumulative difference in observed minus expected survival against the cumulative number of cases performed [48, 49]. In the United Kingdom, the "National Institute of Cardiac Outcomes Research" (NICOR) uses routinely audited clinical data to report pediatric cardiac surgical outcomes with the "Partial Risk Adjustment in Surgery" (PRAiS) risk model for death within 30 days postoperatively, generating variable life-adjusted display charts for each center [49]. Another method of reporting such data that may merit additional use is the graphical reporting of outcomes using funnel plots [27, 28].

Summary

In the monthly STS National Database series of scholarly articles on outcomes analysis, quality improvement, and patient safety, this report is the second annual article that focuses specifically on outcomes and quality in STS CHSD [13]. This article, the STS CHSD 2017 Update on Outcomes and Quality, provides a summary of current national aggregate outcomes of congenital and pediatric cardiac surgery and reviews all quality measurement and improvement initiatives during the past 12 months related to STS CHSD. Six months after the publication of this article, as part of this monthly series, *The Annals* will publish another report derived from STS CHSD, with this additional article summarizing all research-related manuscripts published from STS CHSD during the past 12 months, along with an update on funded research grants and grant proposals from STS CHSD [50]. All participants in STS CHSD can access data from STS CHSD for research or quality improvement initiatives. A detailed description of how to access data from STS National Database is available at http://www.sts.org/quality-research-patient-safety/research/publications-and-research/access-data-sts-national-database.

As the largest congenital and pediatric cardiac surgical clinical data registry in the world, with data about nearly all pediatric cardiac operations performed in the United States, STS CHSD contains a truly representative sample of national aggregate data that is useful for multiple purposes. Across the globe, many other databases exist in the domain of pediatric and congenital cardiac care, spanning a variety of subspecialties, geographies, and periods of time; the size and scope of many of these complementary databases have recently been summarized and published [51, 52]. The current national aggregate congenital and pediatric cardiac surgical outcomes from STS CHSD and described in this article can serve as a platform for benchmarking performance and improving quality. These activities of outcomes analysis and quality improvement will ultimately allow congenital and pediatric cardiac surgeons to provide better care for our patients [53].

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