The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2018 Update on Outcomes and Quality

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The Society of Thoracic Surgeons Congenital Heart Surgery Database is a comprehensive registry of clinical outcomes that captures almost all pediatric cardiac surgical operations in the United States. 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 article 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 operation groups performed from January 2013 through December 2016. 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 1.4%%); ventricular septal defect repair, 0.6% (0.0% to 0.9%); tetralogy of Fallot repair, 1.1% (0.0% to 2.0%); complete atrioventricular canal repair, 2.7% (0.0% to 4.4%); arterial switch operation, 2.2% (0.0% to 2.9%); arterial switch operation and ventricular septal defect repair, 5.1% (0.0% to 8.3%); Glenn/HemiFontan, 2.1% (0.0% to 3.1%); Fontan operation, 1.1% (0.0% to 0.0%); truncus arteriosus repair, 10.1% (0.0% to 15.4%); and Norwood procedure, 15.8% (9.0% 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 the largest congenital and pediatric cardiac surgical clinical data registry in the world, containing data for approximately 435,373 operations as of October 1, 2017. These data are the foundation for assessment of performance (by benchmarking and evaluation of individual programmatic outcomes within the context of national aggregate data), development and subsequent application of sophisticated risk adjustment models [4–7], quality improvement initiatives, research, voluntary public reporting [8–13], development of reimbursement strategies, and governmental and regulatory collaborations. This article is the third annual report summarizing current national aggregate congenital and pediatric cardiac surgical outcomes [14–16].

Overview of STS CHSD

Collection of detailed clinical data and feedback of risk-adjusted nationally benchmarked results to participating

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cardiac surgical programs are the primary functions of STS CHSD [17]. A participant in STS CHSD 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 (DCRI). The Duke Clinical Research Institute develops Feedback Reports two times each year based on the most recently completed 48-month period of data collection, and these Feedback Reports are distributed every 6 months to each STS CHSD participant. These Feedback Reports facilitate internal quality assessment and serve as a platform for quality improvement. These Feedback Reports present data about risk-stratified and risk-adjusted outcomes of the individual participant within the context of multiinstitutional aggregate benchmarks obtained by pooling data from all participants located in the United States or Canada.

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, STS CHSD must account for nearly 200 individual diagnoses and a roughly comparable number of distinct types of therapeutic interventions, which are not infrequently performed in various combinations as elements of a multiple component 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 or rarely used data elements. These revisions are performed on a 3-year cycle.

As of 2017, STS CHSD included 119 participants comprising 394 surgeons from 40 states in the United States and from Canada (3 provinces), Colombia, and Turkey [18]. When reporting multiinstitutional 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 116 participants, 113 located in the United States and 3 located in Canada.

Of the 435,373 cumulative worldwide operations included in STS CHSD as of October 1, 2016, 422,931 were submitted by participants located in the United States [18]. The 113 participants located in the United States represent 133 hospitals [18]. 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 1 hospital; however, in some instances, 1 STS database participant is linked to more than 1 hospital or 1 hospital is linked to more than 1 STS database participant. Therefore, minor differences exist between the number of STS database participants and the number of hospitals submitting data to the STS databases.

The Report of the 2015 STS Congenital Heart Surgery Practice Survey, undertaken by the STS Workforce on Congenital Heart Surgery, estimated that pediatric cardiac operations are performed in 125 hospitals in the United States and in 8 hospitals in Canada [19]. Therefore, more than 95% of hospitals that perform pediatric cardiac operations in the United States participate in STS CHSD; and, the patient-level penetration is estimated to be an even higher percentage, 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.

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, 2013, through December 31, 2016, inclusive, and presented in the 2017 Spring Harvest Feedback Report [17]. The outcomes in this report are based on the data elements specified in the current versions of the data collection instrument (versions 3.0, 3.22, and 3.3, which went live on January 1, 2010, January 1, 2014, and January 1, 2016, 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 2013 through December 2016), with the end points of Operative Mortality and postoperative length of stay (PLOS) [20-22]. 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 [21, 22]. 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, whereas the mortality for STAT Mortality Category 3 is higher than for STAT Mortality 2. The explanation for this observation is uncertain, although the STS CHSD 2016 and 2017 Update on Outcomes and Quality [15, 16] also reported this same observation. In the future, we may choose to stratify mortality outcomes by the STAT Mortality Categories [21, 22] and PLOS outcomes by the STAT Morbidity Categories [23].

Table 2 reports unadjusted aggregate outcomes for current benchmark operation groups in STS CHSD, also during the last 4 years (January 2013 through December 2016) and also with the end points of Operative Mortality and PLOS [20]. Data about the following 10 benchmark operation groups are included in Table 2:

1. Ventricular septal defect (VSD) repair
2. Tetralogy of Fallot (TOF) repair
3. Complete atrioventricular canal repair (complete atrioventricular septal defect repair [CAVSD repair])
4. Arterial switch
5. Arterial switch + VSD repair
6. Glenn/HemiFontan
7. Fontan operation

Table 1. *The 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 2013 through December 2016)[a]*

	STAT Category				
Variable	1	2	3	4	5
STS overall (all participants)					
Sample size, No.					
Participants	116	116	116	116	110
Operations	29,099	35,866	10,943	20,271	3,974
Participant-specific sample size					
Average	250.9	309.2	94.3	174.8	36.1
Range	3.0–1,226.0	5.0–1,284.0	2.0–488.0	3.0–815.0	1.0–171.0
Operative Mortality,[a] %					
Aggregate mortality rate	0.4	1.6	2.5	6.6	15.3
Participant-specific mortality rate					
Median	0.3	1.5	2.2	6.6	15.4
Range	0.0–2.8	0.0–5.9	0.0–14.3	0.0–19.6	0.0–100.0
Interquartile range	0.0–0.7	0.8–2.4	0.7–3.9	4.5–9.1	9.1–21.7
PLOS, d					
Aggregate average PLOS per patient	6.9	19.4	14.6	25.0	42.9
Participant-specific average PLOS					
Median	6.6	18.6	14.3	24.6	40.5
Range	3.1–13.6	7.2–58.8	5.7–55.3	11.3–49.3	0.0–144.7
Interquartile range	5.6–7.7	15.1–27.3	12.0–17.1	20.4–28.1	31.0–50.3
Among sites with ≥10 operations[b]					
Sample size					
Participants, No.	114	115	109	114	82
Operations, No.	29,087	35,861	10,906	20,262	3,840
Participant-specific sample size					
Average	255.1	311.8	100.1	177.71	46.8
Range	12.0–1,226.0	37.0–1,284.0	12.0–488.0	14.0–815.0	10.0–171.0
Operative Mortality,[a] %					
Aggregate mortality rate	0.4	1.6	2.5	6.6	15.1
Participant-specific mortality rate					
Median	0.3	1.5	2.3	6.6	15.5
Range	0.0–2.8	0.0–5.9	0.0–13.3	0.0–19.6	0.0–53.8
Interquartile range	0.0–0.7	0.9–2.4	1.0–3.9	4.5–8.9	11.1–20.4
PLOS, d					
Aggregate average PLOS per patient	6.9	19.4	14.6	25.0	43.1
Participant-specific average PLOS					
Median	6.6	18.6	14.3	24.7	43.7
Range	3.1–13.6	7.8–58.8	5.7–41.0	11.5–49.3	10.5–72.8
Interquartile range	5.6–7.7	15.2–27.6	12.2–16.9	20.7–28.1	35.5–51.8

[a] Rates of mortality depicted are observed (unadjusted) mortality rates. (Although the aggregate data 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 [21, 22]). [b] More than 9 operations in a given category in the analytic window of time.

PLOS = postoperative length of stay; STS = The Society of Thoracic Surgeons.

8. Truncus arteriosus repair
9. Norwood procedure
10. Off-bypass coarctation repair (only includes cases with Operation Type (Op Type) = No CPB Cardiovascular).

For Table 2 of this report, the relevant inclusion factors are the procedure codes listed in Table 3. Inclusion is not based on the intersection of diagnostic and procedural codes, as was the case in an earlier report on "Benchmark Operations" [24].

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

Table 2. The Society of Thoracic Surgeons Congenital Heart Surgery Database Aggregate Outcomes of Benchmark Operation Groups: Operative Mortality and Postoperative Length of Stay, Last 4 Years (January 2013 through December 2016)[a]

Variable	Off-Bypass Coarctation	VSD	TOF	AVC	ASO	ASO+VSD	Glenn/HemiFontan	Fontan	Truncus	Norwood
STS overall (all participants)										
Sample size, No.										
Participants	113	115	115	115	109	100	113	112	98	104
Operations	3,949	7,322	4,735	3,219	1,879	782	4,5389	4,252	621	2,783
Participant-specific sample size										
Average	34.9	63.7	41.2	28.0	17.2	7.8	40.2	38.0	6.3	26.8
Range	1.0–144.0	1.0–234.0	1.0–164.0	1.0–133.0	1.0–72.0	1.0–38.0	1.0–174.0	1.0–205.0	1.0–24.0	1.0–113.0
Operative Mortality,[a] %										
Aggregate mortality rate	1.3	0.6	1.1	2.7	2.2	5.1	2.1	1.1	10.1	15.8
Participant-specific mortality rate										
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7
Range	0.0–16.7	0.0–7.1	0.0–16.7	0.0–33.3	0.0–33.3	0.0–100.0	0.0–33.3	0.0–20.0	0.0–100.0	0.0–100.0
Interquartile range	0.0–1.4	0.0–0.9	0.0–2.0	0.0–4.4	0.0–2.9	0.0–8.3	0.0–3.1	0.0–0.0	0.0–15.4	9.0–25.0
PLOS, d										
Aggregate average PLOS per patient	12.5	8.5	11.9	16.9	16.8	19.1	14.3	13.6	33.5	45.7
Participant-specific average PLOS										
Median	11.3	8.3	11.5	16.6	16.8	16.4	13.3	13.6	28.7	43.7
Range	3.4–33.2	3.4–42.3	5.0–35.5	5.0–68.9	5.7–76.0	0.0–73.0	4.1–38.7	5.5–34.3	8.0–171.0	1.0–144.7
Interquartile range	7.7–15.4	6.4–9.9	9.3–13.4	11.5–22.2	13.2–20.0	13.0–23.1	10.2–16.2	11.2–16.0	21.5–42.0	33.0–54.5
Among sites with N ≥10[b]										
Sample size, No.										
Participants	93	110	101	91	68	36	95	87	22	74
Operations	3,852	7,303	4,652	3,099	1,666	545	4,466	4,126	306	2,660
Participant-specific sample size										
Average	41.4	66.4	46.1	34.1	24.5	15.1	47.0	47.4	13.9	35.9
Range	10.0–144.0	10.0–234.0	10.0–164.0	10.0–133.0	10.0–72.0	10.0–38.0	10.0–174.0	10.0–205.0	10.0–24.0	10.0–113.0
Operative Mortality,[a] %										
Aggregate mortality rate	1.3	0.6	1.1	2.6	1.9	4.1	2.1	1.0	9.9	15.6
Participant-specific mortality rate										
Median	0.0	0.0	0.0	1.5	0.0	0.0	1.3	0.0	8.0	15.0
Range	0.0–12.5	0.0–7.1	0.0–8.0	0.0–16.7	0.0–11.1	0.0–33.3	0.0–18.2	0.0–16.7	0.0–27.3	0.0–54.5
Interquartile range	0.0–1.7	0.0–0.9	0.0–2.0	0.0–4.5	0.0–2.9	0.0–8.3	0.0–3.6	0.0–1.6	6.3–15.4	10.9–21.4
PLOS, d										
Aggregate average PLOS per patient	12.6	8.4	11.8	16.5	16.4	18.6	14.3	13.5	31.4	45.9
Participant-specific average PLOS										
Median	12.2	8.3	11.5	16.6	16.7	17.4	13.8	13.5	25.6	45.4
Range	3.4–33.2	3.4–26.2	5.0–28.0	6.3–49.0	5.7–34.8	10.7–33.4	4.1–26.0	5.5–27.2	17.2–78.1	11.5–83.9
Interquartile range	9.1–16.2	6.4–9.7	9.5–13.0	11.5–20.4	13.4–19.0	14.5–20.3	10.6–17.1	11.3–15.4	23.0–40.1	34.6–54.9

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

ASO = atrial switch operation;   AVC = atrioventricular canal repair;   PLOS = postoperative length of stay;   STS = The Society of Thoracic Surgeons;   TOF = tetralogy of Fallot repair;   VSD = ventricular septal defect repair.

Table 3. Ten Benchmark Operation Groups[a]

Procedure Type	Abbreviation	STS-CHSDB Primary Procedure Codes
1. Ventricular septal defect repair	VSD	110 = VSD repair, Patch
2. Tetralogy of Fallot repair	TOF	350 = TOF repair, No ventriculotomy
		360 = TOF repair, Ventriculotomy, Nontransanular patch
		370 = TOF repair, Ventriculotomy, Transannular patch
3. Complete atrioventricular canal repair	AVC	170 = AVC (AVSD) repair, Complete (CAVSD)
4. Arterial switch operation	ASO	1110 = ASO
5. Arterial switch operation + VSD repair	ASO + VSD	1120 = ASO and VSD repair
6. Glenn/HemiFontan	Glenn/HemiFontan	1670 = Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)
		1680 = Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)
		1690 = Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)
		1700 = HemiFontan
		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[b]
		2790 = Fontan, TCPC, Intra/extracardiac conduit, Nonfenestrated[b]
		3310 = Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Fenestrated[c]
		3320 = Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Nonfenestrated[c]
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] Listed are the 10 current benchmark operation groups, together with The Society for 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 Operation Groups 6 and 10 are not included in the initial publication of these benchmark operation [24] and are new. Also, please note that operations are classified into the various benchmark operation groups according to the assigned primary procedure for that operation). [b] Only available in data version 3.22 and 3.3. [c] Only available in data version 3.3.

ASO = atrial switch operation; AVC = atrioventricular canal repair; CAVC = complete atrioventricular canal repair; CPB = cardiopulmonary bypass; Op Type = Operation Type; PA = pulmonary artery; TCPC = total cavopulmonary connection; TOF = tetralogy of Fallot repair; VSD = ventricular septal defect repair.

from the hospital but before the end of the 30th postoperative day [25, 26].

Beginning with the Spring 2014 STS CHSD Feedback Report, the STS CHSD Task Force has used the field "Mortality Status at Database Discharge" rather than the field "Mortality Status at Hospital Discharge" when calculating Operative Mortality. (In the definition above, the phrase "the hospitalization in which the operation was performed," is deemed to end at the time of Database Discharge, in accordance with the established definition

of that term [25, 27].) 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 has used the field "Date of Database Discharge" rather than the field "Date of Hospital Discharge" when calculating length of stay. These changes in reporting were implemented to ensure accurate reporting of outcomes for

Table 4. The Distribution of Star Ratings in The Society of Thoracic Surgeons Congenital Heart Surgery Database Feedback Reports[a]

STS CHSD Feedback Report	Participants, No.	Percentage of All Programs	Percentage 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
Spring 2017			
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
Fall 2017			
No star rating assigned	15	12.71	XX
1 star	17	14.41	16.50
2 stars	75	63.56	72.82
3 stars	11	9.32	10.68
Total	118	100	100

[a] The distribution of star ratings is documented for the Fall 2014, Spring 2015, Fall 2015, Spring 2016, Fall 2016, Spring 2017, and Fall 2017 Society of Thoracic Surgeons Congenital Heart Surgery Database (STS CHSD) Feedback Reports. The star ratings were first publicly reported in August 2015 based on the Spring 2015 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 because they are associated with more than one participant identification number).

patients who are transferred to another acute care facility or a chronic care facility after undergoing an operation at a participating center. The definitions of the fields "Mortality Status at Database Discharge" and "Date of Database Discharge" were previously published [25, 27] and summarized in Table 4 of the previously published STS CHSD 2016 Update on Outcomes and Quality [15].

Beginning with Fall 2017 STS CHSD Feedback Report, reporting of Operative Mortality is based on the "episode of care" and uses a mortality calculation based on episode of care. In most instances, an episode of care

Table 5. Public Reporting With The Society of Thoracic Surgeons Congenital Heart Surgery Database

STS CHSD Public Reporting Cycle and Date the Data Were Publicly Reported On sts.org	Feedback Report and 4-Year Analytic Window	Participants in STS CHSD Who Consented to Participate and Were Enrolled in Public Reporting No.	Percentage of Participating Programs in the United States Enrolled in Public Reporting % (n/N)	Participants in STS CHSD With Data on STS Public Reporting Website No.	Star Rating, No.			
					1	2	3	None
Round 1	STS CHSD 2014 Fall Harvest and Feedback Report	25	23% (25/109)	19				
January 2015	July 1, 2010, through June 30, 2014							
Entire STS CHSD					11	72	6	24
Publicly reporting sites					[a]	[a]	[a]	[a]
Round 2[b]	STS CHSD 2015 Spring Harvest and Feedback Report	38	35% (38/110)	33				
August 2015	January 1, 2011 through December 31, 2014							
Entire STS CHSD					11	79	6	20
Publicly reporting sites					0	27	5	N/A
Round 3[c]	STS CHSD 2016 Spring Harvest and Feedback Report	70	61% (70/115)	61				
August 2016	January 1, 2012 through December 31, 2015							
Entire STS CHSD					14	84	8	12
Publicly reporting sites					3	49	8	N/A
Round 4[c]	STS CHSD 2017 Spring Harvest and Feedback Report	78	69% (78/113)	70				
August 2017	January 1, 2013, through December 31, 2016							
Entire STS CHSD					18	74	11	13
Publicly reporting sites					6	54	10	N/A

[a] Round 1 publicly reported only point estimates with confidence intervals, and did not publicly report star ratings. Round 2 was the first time that STS CHSD publicly reported star ratings along with the previously reported point estimates with confidence intervals. Round 3 and 4 again included publicly reported star ratings along with the previously reported point estimates with confidence intervals.   [b] Three participants appear twice in the Spring 2015 Harvest because they are associated with more than one participant identification number. Also, in the Spring 2015 Harvest, 3 Canadian participants were included in the overall aggregate data but did not publicly report.   [c] Two participants appear twice in the Spring 2016 Harvest because they are associated with more than one participant identification number. Also, in the Spring 2016 Harvest and the Spring 2017 harvest, 3 Canadian participants were included in the overall aggregate data but did not publicly report.

N/A = not applicable because sites with no star rating cannot publicly report;   STS CHSD = Society of Thoracic Surgeons Congenital Heart Surgery Database.

encompasses a single hospital admission. Less commonly, an episode of care may encompass a string of two or more consecutive hospital admissions, when a given patient is readmitted to the same database participant center after discharge to another acute care facility or to a chronic care facility, but without having been discharged to home (or residing in the chronic care facility for 183 consecutive postoperative days). An episode of care can have only one Index Operation and only one Date of Database Discharge, even though it may include multiple dates of admission, multiple operations, and multiple dates of hospital discharge. Episode of care–based Operative Mortality is determined by (1) status (alive/dead) at Date of Database Discharge, and (2) status (alive/dead) at 30 days after the last cardiovascular surgical operation of the episode of care.

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 surgery[12, 13] (http://publicreporting.sts.org/) using the STS CHSD Mortality Risk Model [4–7], which calculates rates of risk-adjusted Operative Mortality for pediatric and congenital heart surgery and includes adjustment for both procedural factors and patient-level factors. The STS CHSD Mortality Risk Model adjusts for the variables listed in Table 4 of the previously published STS CHSD 2017 Update on Outcomes and Quality [16]; these variables include both procedural factors and individual patient factors [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. Data in the STS CHSD includes the observed Operative Mortality of all participants with adequate completeness of data. The STS CHSD Mortality Risk Model estimates the expected Operative Mortality of all participants with adequate completeness of data. 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 number of index cardiac operations eligible for inclusion in the analysis of mortality, for each STS CHSD participant during a 4-year period, for patients of all ages;
- the number of index cardiac operations eligible for inclusion in the analysis of mortality, for each STS CHSD participant over a 4-year period, for patients of all ages, reported separately for each of the five STAT Mortality Categories;

- the number of index cardiac operations associated with Operative Mortality for each of the above-mentioned patient groups;
- the observed and expected Operative Mortality rates that correspond to each of the above-mentioned patient groups;
- the O/E Operative Mortality ratio and associated 95% confidence intervals that correspond to each of the above-mentioned patient groups;
- the adjusted mortality rate (AMR) 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 [12, 13, 15]. 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 more statistically sophisticated users to star ratings that can help patients and families correctly interpret complex data [15]. In STS CHSD, the overall star rating of a given STS CHSD Participant is based on the overall risk-adjusted O/E Operative Mortality ratio for all index cardiovascular operations, as follows:

- 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 Mortality ratio for all index cardiovascular surgical operations. Table 4 documents the distribution of star ratings for the Fall 2014, Spring 2015, Fall 2015, Spring 2016, Fall 2016, Spring 2017, and Fall 2017 STS CHSD Feedback Reports. Table 5 documents the history of public reporting with STS CHSD. Public reporting with STS CHSD began in January 2015, with the public reporting of point estimates with confidence intervals, but without publicly reporting star ratings. In January 2015, 23% (25 of 109) of participants in STS CHSD located in the United States consented to publicly report.

The star ratings were first publicly reported in August 2015 based on the Spring 2015 STS CHSD Feedback Report. These publicly reported star ratings were updated in August 2016 based on the Spring 2016 STS CHSD Feedback Report and were again updated in August 2017 based on the Spring 2017 STS CHSD Feedback Report. In each instance, star ratings are based on the latest version of the STS CHSD Mortality Risk Model, which is updated every 6 months. As of August 2017, 69% (78 of 113) of participants in STS CHSD located in the United States

have consented to publicly report. The final appearance of these publicly reported data can be viewed at http://publicreporting.sts.org/chsd.

The "expected Operative Mortality rates" and "O/E Operative Mortality ratios" reported by STS CHSD are computed using *indirect standardization*, which allows assessment of a center's observed outcomes in relation to what would be expected for their specific case-mix. Because the calculations of expected outcomes using indirect standardization are estimated only for the patients that a center actually treated, results only apply to their particular case-mix. The results derived using indirect standardization cannot be used to directly compare 2 hospitals unless their case-mix has been demonstrated to be similar, and it cannot be assumed that a center achieving better than expected results in a generally low-risk population could do the same in a population of higher-risk patients.

Based on the data that are publicly reported or provided in STS CHSD Feedback Reports (ie, point estimates with confidence intervals), it is possible 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 Mortality ratio for all index cardiovascular operations and comparing this 95% confidence interval to unity (the number 1). The star rating is provided by STS with the intent of making this statistical analysis more understandable to many patients and families [15].

Summary

In the monthly STS National Database series on outcomes analysis, quality improvement, and patient safety, this report is the third annual article that focuses specifically on outcomes and quality in STS CHSD [13]. This article, the STS CHSD 2018 Update on Outcomes and Quality, provides a summary of current national aggregate outcomes of congenital and pediatric cardiac surgery. As part of this monthly series, *The Annals of Thoracic Surgery* will publish another article derived from STS CHSD 6 months after the publication of this article, with this additional article summarizing all research-related reports published from STS CHSD during the past 12 months, along with an update on funded research grants and grant proposals from STS CHSD [28, 29]. 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 has been previously published [18] and is available at http://www.sts.org/registries-research-center/sts-research-center/access-publications.

With information about nearly all pediatric cardiac operations performed in the United States, STS CHSD contains a highly representative sample of national aggregate data that is useful for multiple purposes. The data that are collected by STS CHSD and the analytical methods used by STS CHSD, including risk adjustment, are constantly reevaluated to ensure that they are statistically accurate and clinically meaningful. The current national aggregate congenital and pediatric cardiac

surgical outcomes from STS CHSD and described in this report 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 [30].

References

1. The Society of Thoracic Surgeons. STS National Database. Available at http://www.sts.org/registries-research-center/sts-national-database. Accessed December 12, 2017.
2. The Society of Thoracic Surgeons. STS Congenital Heart Surgery Database. Available at http://www.sts.org/registries-research-center/sts-national-database/congenital-heart-surgery-database. Accessed December 12, 2017.
3. Mavroudis C (chairman) and Congenital Database Subcommittee: Backer CL, Bove E, Burke RP, et al. Data analyses of The Society of Thoracic Surgeons National Congenital Cardiac Surgery Database, 1994–1997, Summit Medical, Minnetonka, MN, September 1998.
4. Jacobs JP, O'Brien SM, Pasquali SK, et al. The importance of patient-specific preoperative factors: an analysis of the Society of Thoracic Surgeons Congenital Heart Surgery Database. Ann Thorac Surg 2014;98:1653–9.
5. O'Brien SM, Jacobs JP, Pasquali SK, et al. The Society of Thoracic Surgeons Congenital Heart Surgery Database Mortality Risk Model: part 1-statistical methodology. Ann Thorac Surg 2015;100:1054–62.
6. Jacobs JP, O'Brien SM, Pasquali SK, et al. The Society of Thoracic Surgeons Congenital Heart Surgery Database Mortality Risk Model: part 2-clinical application. Ann Thorac Surg 2015;100:1063–70.
7. Pasquali SK, Jacobs ML, O'Brien SM, et al. Impact of patient characteristics on hospital-level outcomes assessment in congenital heart surgery. Ann Thorac Surg 2015;100:1071–7.
8. Jacobs JP, Cerfolio RJ, Sade RM. The ethics of transparency: publication of cardiothoracic surgical outcomes in the lay press. Ann Thorac Surg 2009;87:679–86.
9. Shahian DM, Edwards FH, Jacobs JP, et al. Public reporting of cardiac surgery performance: part 1-history, rationale, consequences. Ann Thorac Surg 2011;92(3 Suppl):S2–11.
10. Shahian DM, Edwards FH, Jacobs JP, et al. Public reporting of cardiac surgery performance: part 2-implementation. Ann Thorac Surg 2011;92(3 Suppl):S12–23.
11. Shahian DM, Grover FL, Prager RL, et al. The Society of Thoracic Surgeons voluntary public reporting initiative: the first 4 years. Ann Surg 2015;262:526–35.
12. Jacobs JP, Jacobs ML. Transparency and public reporting of pediatric and congenital heart surgery outcomes in North America. World J Pediatr Congenit Heart Surg 2016;7:49–53.
13. Jacobs JP. The Society of Thoracic Surgeons Congenital Heart Surgery Database public reporting initiative. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu 2017;20:43–8.
14. Jacobs JP, Shahian DM, Prager RL, et al. Introduction to the STS National Database series: outcomes analysis, quality improvement, and patient safety. Ann Thorac Surg 2015;100:1992–2000.
15. Jacobs JP, Mayer JE, Jr, Mavroudis C, et al. The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2016 update on outcomes and quality. Ann Thorac Surg 2016;101:850–62.
16. Jacobs JP, Mayer JE, Jr, Mavroudis C, et al. The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2017 update on outcomes and quality. Ann Thorac Surg 2017;103:699–709.
17. Jacobs JP, Jacobs ML, Mavroudis C, Tchervenkov CI, Pasquali SK. Executive summary: The Society of Thoracic Surgeons Congenital Heart Surgery Database – twenty-sixth harvest – (January 1, 2013 – December 31, 2016). The Society of Thoracic Surgeons (STS) and Duke Clinical Research

Institute (DCRI), Duke University Medical Center, Durham, North Carolina, United States, Spring 2017 Harvest.

18. Jacobs JP, Shahian DM, D'Agostino RS, et al. The Society of Thoracic Surgeons National Database 2017 annual report. Ann Thorac Surg 2017;104:1774–81.

19. Morales DL, Khan MS, Turek JW, et al. Report of the 2015 Society of Thoracic Surgeons Congenital Heart Surgery Practice Survey. Ann Thorac Surg 2017;103:622–8.

20. Jacobs JP, O'Brien SM, Pasquali SK, et al. Variation in outcomes for risk-stratified pediatric cardiac surgical operations: an analysis of the STS Congenital Heart Surgery Database. Ann Thorac Surg 2012;94:564–72.

21. O'Brien SM, Clarke DR, Jacobs JP, et al. An empirically based tool for analyzing mortality associated with congenital heart surgery. J Thorac Cardiovasc Surg 2009;138:1139–53.

22. Jacobs JP, Jacobs ML, Maruszewski B, et al. Initial application in the EACTS and STS Congenital Heart Surgery Databases of an empirically derived methodology of complexity adjustment to evaluate surgical case mix and results. Eur J Cardiothorac Surg 2012;42:775–80.

23. Jacobs ML, O'Brien SM, Jacobs JP, et al. An empirically based tool for analyzing morbidity associated with operations for congenital heart disease. J Thorac Cardiovasc Surg 2013;145:1046–57.e1.

24. Jacobs JP, O'Brien SM, Pasquali SK, et al. Variation in outcomes for benchmark operations: an analysis of The Society

of Thoracic Surgeons Congenital Heart Surgery Database. Ann Thorac Surg 2011;92:2184–92; discussion 2191–2.

25. Jacobs JP, Mavroudis C, Jacobs ML, et al. What is operative mortality? Defining death in a surgical registry database: a report from the STS Congenital Database Task Force and the Joint EACTS-STS Congenital Database Committee. Ann Thorac Surg 2006;81:1937–41.

26. Overman D, Jacobs JP, Prager RL, et al. Report from The Society of Thoracic Surgeons National Database Work Force: clarifying the definition of operative mortality. World J Pediatr Congenit Heart Surg 2013;4:10–2.

27. Jacobs JP, Jacobs ML, Mavroudis C, et al. What is operative morbidity? Defining complications in a surgical registry database: a report from the STS Congenital Database Task Force and the Joint EACTS-STS Congenital Database Committee. Ann Thorac Surg 2007;84:1416–21.

28. Jacobs ML, Jacobs JP, Pasquali SK, et al. The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2016 update on research. Ann Thorac Surg 2016;102:688–95.

29. Jacobs ML, Jacobs JP, Hill KD, et al. The Society of Thoracic Surgeons Congenital Heart Surgery Database: 2017 update on research. Ann Thorac Surg 2017;104:731–41.

30. Jacobs JP, He X, Mayer JE, Jr, et al. Mortality trends in pediatric and congenital heart surgery: an analysis of The Society of Thoracic Surgeons Congenital Heart Surgery Database. Ann Thorac Surg 2016;102:1345–52.

INVITED COMMENTARY

CrossMark

The Congenital Heart Surgery Database (CHSD) component of The Society of Thoracic Surgeons (STS) National Database is one of the largest clinical registries in the world for congenital cardiac procedures. The CHSD patient population is unique with respect to the broad spectrum of diagnoses encountered and surgical procedures performed, as well as the complexity, severity of illnesses, and age range—from the neonate to the adult. Jacobs and colleagues [1] provide an update on outcomes and quality in this summary manuscript for 2018.

As an overview, STS risk models and performance metrics are transparent and externally validated through a variety of mechanisms. They are presented and discussed at national and international meetings, subjected to extensive peer review, published in the peer-reviewed literature, and endorsed by the National Quality Forum, nationally recognized by the health care community as best in class, evidence-based, and valid. There are no other professional society metrics in all of health care, let alone heart surgery, that have been so thoroughly scrutinized. They have been tested, retested, and tested again. Although no risk models or performance measures are perfect, those used in conjunction with the CHSD are based on the best clinical registry data, broadly representative of benchmark populations, expert surgical input, and state of the art statistical methodologies. The overarching goal of the CHSD is to use the best data and quality metrics to provide optimal, safe care for our patients, to continuously improve outcomes, and to facilitate informed choice for patients (and family) and providers.

In this current review, there are a few specific areas that deserve comment. First, the spectrum of disease is broad.

Congenital heart disease is heterogeneous with hundreds of specific diagnoses and more than 200 different types of primary procedures. Consequently, there are literally thousands of unique combinations of procedures to address the underlying problems. Persons born with congenital cardiac malformations may undergo cardiac surgical operations in the newborn period, at any time during infancy or childhood, or during adulthood. These facts support the importance of examining and reporting outcomes across the entire spectrum of patients and operations. This situation is quite different from surgery for acquired heart disease in adults, where the outcomes from a limited number of different types of surgical procedures such as coronary artery bypass grafting and valve repairs and replacements may provide a reasonable approximation of overall programmatic performance.

Second, it is important to recognize the inclusive nature of the CHSD and that the high degree of database participation, or penetrance, results in "generalizability" of the data. As of the Spring of 2017, the CHSD report included data from 116 North American congenital database participants, which represents 127 hospitals in North America, and included data pertaining to 157,357 operations. That represents 96% of hospitals with programs of pediatric and congenital heart surgery and 98% of cases of pediatric and congenital heart surgery in the United States and Canada.

Third, much recent attention has focused on the reporting of risk-adjusted mortality (observed-to-expected mortality ratio with 95% confidence interval and adjusted mortality rate) at the center level, encompassing the outcomes from the aggregate of all cardiovascular