NATIONAL QUALITY FORUM

Measure Evaluation 4.1
December 2009

This form contains the measure information submitted by stewards. Blank fields indicate no information was provided. Attachments also may have been submitted and are provided to reviewers. The subcriteria and most of the footnotes from the evaluation criteria are provided in Word comments within the form and will appear if your cursor is over the highlighted area. Hyperlinks to the evaluation criteria and ratings are provided in each section.

TAP/Workgroup (if utilized)**:** Complete all yellow highlighted areas of the form. Evaluate the extent to which each subcriterion is met. Based on your evaluation, summarize the strengths and weaknesses in each section.

Note: *If there is no TAP or workgroup, the SC also evaluates the subcriteria (yellow highlighted areas).*

Steering Committee: Complete all pink highlighted areas of the form. Review the workgroup/TAP assessment of the subcriteria, noting any areas of disagreement; then evaluate the extent to which each major criterion is met; and finally, indicate your recommendation for the endorsement. Provide the rationale for your ratings.

Evaluation ratings of the extent to which the criteria are met
C = Completely (unquestionably demonstrated to meet the criterion)
P = Partially (demonstrated to partially meet the criterion)
M = Minimally (addressed BUT demonstrated to only minimally meet the criterion)
N = Not at all (NOT addressed; OR incorrectly addressed; OR demonstrated to NOT meet the criterion)
NA = Not applicable (only an option for a few subcriteria as indicated)

(for NQF staff use) **NQF Review #:** PCS-008-09 **NQF Project:** Surgery Endorsement Maintenance 2010
MEASURE DESCRIPTIVE INFORMATION
De.1 **Measure Title:** Surgical Volume for Pediatric and Congenital Heart Surgery: Total Programmatic Volume and Programmatic Volume Stratified by the Five STS-EACTS Mortality Levels
De.2 **Brief description of measure:** Surgical volume for pediatric and congenital heart surgery: total programmatic volume and programmatic volume stratified by the five STS-EACTS Mortality Levels, a multi-institutional validated complexity stratification tool
1.1-2 **Type of Measure:** Structure De.3 **If included in a composite or paired with another measure, please identify composite or paired measure** N/A
De.4 **National Priority Partners Priority Area:** Safety De.5 **IOM Quality Domain**: Safety De.6 **Consumer Care Need:** Getting better

CONDITIONS FOR CONSIDERATION BY NQF	
Four conditions must be met before proposed measures may be considered and evaluated for suitability as voluntary consensus standards:	**NQF Staff**
A. The measure is in the public domain or an intellectual property (measure steward agreement) is signed. *Public domain only applies to governmental organizations. All non-government organizations must sign a measure steward agreement even if measures are made publicly and freely available.* A.1 **Do you attest that the measure steward holds intellectual property rights to the measure and the right to use aspects of the measure owned by another entity (e.g., risk model, code set)?** Yes A.2 **Indicate if Proprietary Measure** (*as defined in measure steward agreement*)**:** A.3 **Measure Steward Agreement:** Agreement will be signed and submitted prior to or at the time of measure submission A.4 **Measure Steward Agreement attached:** Society of Thoracic Surgeons_2010-634141161804340024.pdf	**A** **Y**☐ **N**☐

B. The measure owner/steward verifies there is an identified responsible entity and process to maintain and update the measure on a schedule that is commensurate with the rate of clinical innovation, but at least every 3 years. Yes, information provided in contact section	**B** Y☐ N☐
C. The intended use of the measure includes both public reporting and quality improvement. ►**Purpose:** Public Reporting, Quality Improvement (Internal to the specific organization), Quality Improvement with Benchmarking (external benchmarking to multiple organizations)	**C** Y☐ N☐
D. The requested measure submission information is complete. Generally, measures should be fully developed and tested so that all the evaluation criteria have been addressed and information needed to evaluate the measure is provided. Measures that have not been tested are only potentially eligible for a time-limited endorsement and in that case, measure owners must verify that testing will be completed within 12 months of endorsement. D.1**Testing:** No, testing will be completed within 12 months D.2 **Have NQF-endorsed measures been reviewed to identify if there are similar or related measures?** Yes	**D** Y☐ N☐
(for NQF staff use**)** **Have all conditions for consideration been met?** **Staff Notes to Steward** (*if submission returned*)**:**	**Met** Y☐ N☐
Staff Notes to Reviewers (*issues or questions regarding any criteria*)**:**	
Staff Reviewer Name(s):	

TAP/Workgroup Reviewer Name:	
Steering Committee Reviewer Name:	
1. IMPORTANCE TO MEASURE AND REPORT	
Extent to which the specific measure focus is important to making significant gains in health care quality (safety, timeliness, effectiveness, efficiency, equity, patient-centeredness) and improving health outcomes for a specific high impact aspect of healthcare where there is variation in or overall poor performance. ***Measures must be judged to be important to measure and report*** *in order to be evaluated against the remaining criteria.* (evaluation criteria) **1a. High Impact**	**Eval Rating**
(for NQF staff use) **Specific NPP goal**:	
1a.1 **Demonstrated High Impact Aspect of Healthcare:** High resource use 1a.2 1a.3 **Summary of Evidence of High Impact:** Congenital heart disease is a common birth defect that affects approximately 1 in 125 live births [1]. Pediatric and congenital heart surgery is a subspecialty of high resource utilization that has the potential to repair or palliate the majority of patients with pediatric and congenital cardiac disease. 1a.4 **Citations for Evidence of High Impact:** 1. Tchervenkov CI, Jacobs JP, Bernier P-L, Stellin G, Kurosawa H, Mavroudis C, Jonas RA, Cicek SM, Al-Halees Z, J. Elliott MJ, Jatene MB, Kinsley RH, Kreutzer C, Leon-Wyss J, Liu J, Maruszewski B, Nunn GR, Ramirez-Marroquin S, Sandoval N, Sano S, Sarris GE, Sharma R, Shoeb A, Spray TL, Ungerleider RM, Yangni-Angate H, Ziemer G. The improvement of care for paediatric and congenital cardiac disease across the World: a challenge for the World Society for Pediatric and Congenital Heart Surgery. In: 2008 Supplement to Cardiology in the Young: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 63–69, December 9, 2008.	**1a** C☐ P☐ M☐ N☐
1b. Opportunity for Improvement	**1b** C☐ P☐
1b.1 **Benefits (improvements in quality) envisioned by use of this measure:** The incidence of mortality	

Comment [KP1]: 1a. The measure focus addresses:
•a specific national health goal/priority identified by NQF's National Priorities Partners; OR
•a demonstrated high impact aspect of healthcare (e.g., affects large numbers, leading cause of morbidity/mortality, high resource use (current and/or future), severity of illness, and patient/societal consequences of poor quality).

Comment [KP2]: 1b. Demonstration of quality problems and opportunity for improvement, i.e., data demonstrating considerable variation, or overall poor performance, in the quality of care across providers and/or population groups (disparities in care).

stratified by complexity varies between centers, as demonstrated in the STS Congenital Heart Surgery Database.

Over the past decade, mortality after pediatric cardiac surgery has been declining and currently stands at 4%. Nevertheless, operative mortality remains a significant indicator of programmatic quality. Because case mix varies between programs, operative mortality must be stratified by case mix [1, 2, 3, 4, 5]. In addition, in order to track a variety of outcomes represented in other proposed Quality Indicators, one must have a firm grasp on the volume of pediatric and congenital cardiac surgery performed at a center over both 1 year and 4 year time intervals, stratified by complexity, as required by this measure (Surgical Volume for Pediatric and Congenital Heart Surgery, Stratified by the five STS-EACTS Mortality Levels)

Tracking this structure measure is necessary in order to track other outcome measures that use this structure measure as a denominator. Furthermore, the very act of tracking this structure measure should in and of itself lead to improvements in quality.

References:

1. Jacobs ML, Jacobs JP, Jenkins KJ, Gauvreau K, Clarke DR, Lacour-Gayet FL. Stratification of complexity: The Risk Adjustment for Congenital Heart Surgery-1 Method and The Aristotle Complexity Score – past, present, and future. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 163–168, December 9, 2008.
2. Clarke DR, Lacour-Gayet F, Jacobs JP, Jacobs ML, Maruszewski B, Pizarro C, Edwards FH, Mavroudis C. The assessment of complexity in congenital cardiac surgery based on objective data. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 169–176, December 9, 2008.
3. O´Brien SM, Jacobs JP, Clarke DR, Maruszewski B, Jacobs ML, Walters HL 3rd, Tchervenkov CI, Welke KF, Tobota Z, Stellin G, Mavroudis C, Hamilton JR, Gaynor JW, Pozzi M, Lacour-Gayet FG. Accuracy of the Aristotle Basic Complexity Score for classifying the mortality and morbidity potential of congenital heart surgery operations. The Annals of Thoracic Surgery, 84(6):2027-37, PMID: 18036930, December 2007.
4. O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009.
5. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha EA, Maruszewski B, Clarke DR, Tchervenkov CI, Gaynor JW, Spray, TL, Stellin G, O´Brien SM, Elliott MJ, Mavroudis C. Stratification of Complexity Improves Utility and Accuracy of Outcomes Analysis in a Multi-institutional Congenital Heart Surgery Database – Application of the RACHS-1 and Aristotle Systems in the STS Congenital Heart Surgery Database. Pediatric Cardiology, accepted for publication, in press.

1b.2 Summary of data demonstrating performance gap (variation or overall poor performance) across providers:

Data is currently being collected in the STS Congenital Heart Surgery Database. Data will be provided within 24 months after endorsement is received. We know that 82 out of 122 pediatric heart surgery centers in the USA participate in the STS Congenital Heart Surgery Database.

1b.3 Citations for data on performance gap:

Jacobs JP, Jacobs ML, Mavroudis C, Lacour-Gayet FG, Tchervenkov CI. Executive Summary: The Society of Thoracic Surgeons Congenital Heart Surgery Database - Tenth Harvest – (January 1, 2005 – December 31, 2008). The Society of Thoracic Surgeons (STS) and Duke Clinical Research Institute (DCRI), Duke University Medical Center, Durham, North Carolina, United States, Spring 2009 Harvest.

1b.4 Summary of Data on disparities by population group:

No formal testing of disparities has been done. Disparities and trends could be tested for many of these metrics using the STS Database.

M☐ N☐

Comment [k3]: 1 Examples of data on opportunity for improvement include, but are not limited to: prior studies, epidemiologic data, measure data from pilot testing or implementation. If data are not available, the measure focus is systematically assessed (e.g., expert panel rating) and judged to be a quality problem.

The incidence of mortality stratified by complexity varies between centers, as demonstrated in the STS Congenital Heart Surgery Database

1b.5 Citations for data on Disparities:
Jacobs JP, Jacobs ML, Mavroudis C, Lacour-Gayet FG, Tchervenkov CI. Executive Summary: The Society of Thoracic Surgeons Congenital Heart Surgery Database - Tenth Harvest – (January 1, 2005 – December 31, 2008). The Society of Thoracic Surgeons (STS) and Duke Clinical Research Institute (DCRI), Duke University Medical Center, Durham, North Carolina, United States, Spring 2009 Harvest.

1c. Outcome or Evidence to Support Measure Focus

1c.1 Relationship to Outcomes (*For non-outcome measures, briefly describe the relationship to desired outcome. For outcomes, describe why it is relevant to the target population*)**:** Please see section 1c.4

1c.2-3. Type of Evidence: Systematic synthesis of research

1c.4 Summary of Evidence (*as described in the criteria; for outcomes, summarize any evidence that healthcare services/care processes influence the outcome*)**:**
The relationship between the volume of pediatric and congenital cardiac surgery performed at a center and quality of care is unclear and controversial at best [1, 2, 3, 4, 5, 6, 7]. Nevertheless, in order to track a variety of outcomes represented in other proposed Quality Indicators, one must have a firm grasp on the volume of pediatric and congenital cardiac surgery performed at a center over both 1 year and 4 year time intervals. The very act of tracking this structure measure is necessary in order to track other outcome measures that use this structure measure as a denominator. Furthermore, the very act of tracking this structure measure can, in and of itself, lead to improvements in quality.

In addition to capturing total programmatic volume, it should also be stratified by complexity [8, 9, 10, 11, 13]. The selection of the proper tool for complexity stratification tool can be controversial. Suitable multi-institutional validated complexity stratification tools include the 5 functional RACHS-1 classifications, the 4 Aristotle Basic Complexity Score Levels, and the five STS-EACTS Mortality Levels. When comparing RACHS-1 and Aristotle, the Aristotle methodology allows classification of more operations while the RACHS-1 system discriminates better at the higher end of complexity.

The discrimination of any complexity stratification tool as a predictor of mortality can be quantified by calculating the c statistic, which is equivalent to the area under the receiver operating characteristic curve, as determined by univariable logistic regression [14]. The c statistic represents the probability that a randomly selected patient who had the outcome of interest (i.e. discharge mortality) had a higher predicted risk of the outcome compared to a randomly selected patient who did not experience the outcome. The c statistic generally ranges from 0.5 to 1.0 with 0.5 representing no discrimination (i.e. a coin flip) and 1.0 representing perfect discrimination.The model for risk-adjustment in the STS Adult Cardiac Surgery Database for predicting 30-day mortality after surgery to place coronary arterial bypass grafts, contains 28 clinical variables and has a C-statistic of 0.78 [14].

The Table below documents the c-statistic for the previously mentioned complexity stratification tools [13].

Method of Modeling Procedures	Model without patient covariates	Model with patient covariates
STS-EACTS Congenital Heart Surgery Mortality Categories (2009)	C = 0.778	C = 0.812
RACHS-1 Categories	C = 0.745	C = 0.802
Aristotle Basic Complexity Score	C = 0.687	C = 0.795

**STS recommends that only the STS-EACTS Congenital Heart Surgery Mortality Categories (2009) are used for complexity stratification of volume. The rationale for this is two-fold:
1. The C-statistic for the STS-EACTS Congenital Heart Surgery Mortality Categories (2009) is higher than those of the RACHS-1 Categories and the Aristotle Basic Complexity Score.
2. The publications provided below document that 84% of pediatric and congenital cardiac operations can be assessed by the RACHS-1 Categories, 96% by the Aristotle Basic Complexity Score, and 99% by the STS-EACTS Congenital Heart Surgery Mortality Categories (2009) [11,13,14].

Please note that the following publication was previously provided:
O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota

1c
C☐
P☐
M☐
N☐

Comment [k4]: 1c. The measure focus is:
•an outcome (e.g., morbidity, mortality, function, health-related quality of life) that is relevant to, or associated with, a national health goal/priority, the condition, population, and/or care being addressed;
OR
•if an intermediate outcome, process, structure, etc., there is **evidence** that supports the specific measure focus as follows:
oIntermediate outcome – evidence that the measured intermediate outcome (e.g., blood pressure, Hba1c) leads to improved health/avoidance of harm or cost/benefit.
oProcess – evidence that the measured clinical or administrative process leads to improved health/avoidance of harm and
if the measure focus is on one step in a multi-step care process, it measures the step that has the greatest effect on improving the specified desired outcome(s).
oStructure – evidence that the measured structure supports the consistent delivery of effective processes or access that lead to improved health/avoidance of harm or cost/benefit.
oPatient experience – evidence that an association exists between the measure of patient experience of health care and the outcomes, values and preferences of individuals/ the public.
oAccess – evidence that an association exists between access to a health service and the outcomes of, or experience with, care.
oEfficiency – demonstration of an association between the measured resource use and level of performance with respect to one or more of the other five IOM aims of quality.

Comment [k5]: 4 Clinical care processes typically include multiple steps: assess → identify problem/potential problem → choose/plan intervention (with patient input) → provide intervention → evaluate impact on health status. If the measure focus is one step in such a multi-step process, the step with the greatest effect on the desired outcome should be selected as the focus of measurement. For example, although assessment of immunization status and recommending immunization are necessary steps, they are not sufficient to achieve the desired impact on health status – patients must be vaccinated to achieve immunity. This does not preclude consideration of measures of preventive screening interventions where there is a strong link with desired outcomes (e.g., mammography) or measures for multiple care processes that affect a single outcome.

Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009.

1c.5 **Rating of strength/quality of evidence (***also provide narrative description of the rating and by whom***):** N/A

1c.6 **Method for rating evidence:** N/A

1c.7 **Summary of Controversy/Contradictory Evidence:** The selection of the proper tool for complexity stratification tool can be controversial. Suitable multi-institutional validated complexity stratification tools include the five functional RACHS-1 classifications, the four Aristotle Basic Complexity Score Levels, and the five STS-EACTS Mortality Levels [1, 2, 3, 4, 5]. When comparing RACHS-1 and Aristotle, the Aristotle methodology allows classification of more operations while the RACHS-1 system discriminates better at the higher end of complexity [5].

The discrimination of any complexity stratification tool as a predictor of mortality can be quantified by calculating the c statistic, as described in the previous section. The c-statistic represents the probability that a randomly selected patient who had the outcome of interest (i.e. discharge mortality) had a higher predicted risk of the outcome compared to a randomly selected patient who did not experience the outcome. The c-statistic generally ranges from 0.5 to 1.0 with 0.5 representing no discrimination (i.e. a coin flip) and 1.0 representing perfect discrimination. The model for risk-adjustment in the STS Adult Cardiac Surgery Database for predicting 30-day mortality after surgery to place coronary arterial bypass grafts, contains 28 clinical variables and has a C-statistic of 0.78 [5].

Table 1 displays c-statistics for the previously mentioned complexity stratification tools [4]:

Table 1: Method of Modeling Procedures	Model without patient covariates	Model with patient covariates
STS-EACTS Congenital Heart Surgery Mortality Categories (2009)	C = 0.778	C = 0.812
RACHS-1 Categories	C = 0.745	C = 0.802
Aristotle Basic Complexity Score	C = 0.687	C = 0.795

**STS recommends that only the STS-EACTS Congenital Heart Surgery Mortality Categories (2009) are used for complexity stratification of volume. The rationale for this was provided in a previous section.

References

1. Jacobs ML, Jacobs JP, Jenkins KJ, Gauvreau K, Clarke DR, Lacour-Gayet FL. Stratification of complexity: The Risk Adjustment for Congenital Heart Surgery-1 Method and The Aristotle Complexity Score – past, present, and future. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 163–168, December 9, 2008.

2. Clarke DR, Lacour-Gayet F, Jacobs JP, Jacobs ML, Maruszewski B, Pizarro C, Edwards FH, Mavroudis C. The assessment of complexity in congenital cardiac surgery based on objective data. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 169–176, December 9, 2008.

3. O´Brien SM, Jacobs JP, Clarke DR, Maruszewski B, Jacobs ML, Walters HL 3rd, Tchervenkov CI, Welke KF, Tobota Z, Stellin G, Mavroudis C, Hamilton JR, Gaynor JW, Pozzi M, Lacour-Gayet FG. Accuracy of the Aristotle Basic Complexity Score for classifying the mortality and morbidity potential of congenital heart surgery operations. The Annals of Thoracic Surgery, 84(6):2027-37, PMID: 18036930, December 2007.

4. O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular

Comment [k6]: 3 The strength of the body of evidence for the specific measure focus should be systematically assessed and rated (e.g., USPSTF grading system http://www.ahrq.gov/clinic/uspstf07/methods/benefit.htm). If the USPSTF grading system was not used, the grading system is explained including how it relates to the USPSTF grades or why it does not. However, evidence is not limited to quantitative studies and the best type of evidence depends upon the question being studied (e.g., randomized controlled trials appropriate for studying drug efficacy are not well suited for complex system changes). When qualitative studies are used, appropriate qualitative research criteria are used to judge the strength of the evidence.

Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009

5. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha EA, Maruszewski B, Clarke DR, Tchervenkov CI, Gaynor JW, Spray, TL, Stellin G, O´Brien SM, Elliott MJ, Mavroudis C. Stratification of Complexity Improves Utility and Accuracy of Outcomes Analysis in a Multi-institutional Congenital Heart Surgery Database – Application of the RACHS-1 and Aristotle Systems in the STS Congenital Heart Surgery Database. Pediatric Cardiology, accepted for publication, in press.

1c.8 Citations for Evidence (*other than guidelines***):**

1. Welke KF, O'Brien SM, Peterson ED, Ungerleider RM, Jacobs ML, Jacobs JP. The Complex Relationship between Pediatric Cardiac Surgical Case Volumes and Mortality Rates in a National Clinical Database. The Journal of Thoracic and Cardiovascular Surgery,. 2009 May;137(5):1133-40. Epub 2009 Mar 17, PMID: 19379979, May, 2009.

2. Bradley SM. Good Things in Small Packages: Meeting Challenge in the Low-volume Program. Jacobs JP, Wernovsky G, Cooper DS, Gaynor JW, Anderson RH (editors). 2009 Supplement to Cardiology in the Young: Annual Heart Week in Florida Supplement Number 7 - Innovation Associated With The Treatment Of Patients With Congenital and Pediatric Cardiac Disease, Cardiology in the Young, Volume 19, accepted for publication, in press.

3. Jenkins KJ, Newburger JW, Lock JE, et al. In-hospital mortality for surgical repair of congenital heart defects: preliminary observations of variation by hospital caseload. Pediatrics. 1995;95:323-30.

4. Hannan EL, Racz M, Kavey RE, Quagebeur JM, Williams R. Pediatric cardiac surgery: the effect of hospital and surgeon volume on in-hospital mortality. Pediatrics. 1998;101:963-9.

5. Sollano JA, Gelijns AC, Moskowitz AJ, et al. Volume-outcome relationships in cardiovascular operations: New York State, 1990-1995. J Thorac Cardiovasc Surg. 1999;117:419-28.

6. Chang RK, Klitzner TS. Can regionalization decrease the number of deaths for children who undergo cardiac surgery? A theoretical analysis. Pediatrics. 2002; 109:173-81.

7. Quintessenza JA, Jacobs JP, Morell VO. Issues in Regionalization of Pediatric Cardiovascular Care. Progress in Pediatric Cardiology 18 (2003) 49–53. Elsevier Science Ireland Ltd. 2003.

8. Jacobs JP, Lacour-Gayet FG, Jacobs ML, Clarke DR, Tchervenkov CI, Gaynor JW, Spray TL, Maruszewski B, Stellin G, Gould J, Dokholyan RS, Peterson ED, Elliott MJ, Mavroudis C. Initial application in the STS congenital database of complexity adjustment to evaluate surgical case mix and results. Ann Thorac Surg. 2005 May;79(5):1635-49.

9. Jacobs JP, Jacobs ML, Maruszewski B, Lacour-Gayet FG, Clarke DR, Tchervenkov CI, Gaynor JW, Spray TL, Stellin G, Elliott MJ, Ebels T, Mavroudis C. Current status of the European Association for Cardio-Thoracic Surgery and the Society of Thoracic Surgeons Congenital Heart Surgery Database. Ann Thorac Surg 80(6):2278-83, 2005.

10. Lacour-Gayet F., Jacobs J.P., Clarke D.R., Maruszewski B., Jacobs M.L., O'Brien S.M., Mavroudis C. Evaluation of the quality of care in congenital heart surgery: contribution of the Aristotle complexity score. Adv Pediatr. 2007;54:67-83.

11. O'Brien S.M., Jacobs J.P., Clarke D.R., Maruszewski B., Jacobs M.L., Walters H.L., Tchervenkov C.I., Welke K.F., Tobota Z., Stellin G., Mavroudis C., Hamilton J.R., Gaynor J.W., Pozzi M., Lacour-Gayet F.G. Accuracy of the Aristotle basic complexity score for classifying the mortality potential of congenital heart surgery operations. Ann Thorac Surg. 2007 Dec;84(6):2027-37.

12. Jacobs ML, Jacobs JP. Jenkins KJ, Gauvreau K, Clarke DR, Lacour-Gayet F. Stratification of complexity: The Risk Adjustment for Congenital Heart Surgery-1Method and The Aristotle Complexity Score – past, present, and future. Cardiol Young. 2008 Dec;18 Suppl 2:163-8.

13. O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B,

Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009.

14. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha EA, Maruszewski B, Clarke DR, Tchervenkov CI, Gaynor JW, Spray, TL, Stellin G, O´Brien SM, Elliott MJ, Mavroudis C. Stratification of Complexity Improves Utility and Accuracy of Outcomes Analysis in a Multi-institutional Congenital Heart Surgery Database – Application of the RACHS-1 and Aristotle Systems in the STS Congenital Heart Surgery Database. Pediatric Cardiology, accepted for publication, in press.

1c.9 **Quote the Specific guideline recommendation (***including guideline number and/or page number***):**
N/A

1c.10 **Clinical Practice Guideline Citation:** At the current time no uniform practice guidelines are in place for pediatric and congenital cardiac surgery. Clinical care rationale mainly depends on the consensus of a panel of experts in the field. In lieu of guideline support for the measures, published consensus opinion and supporting clinical data from the STS Congenital Heart Surgery Database will be used.

1c.11 **National Guideline Clearinghouse or other URL:** N/A

1c.12 **Rating of strength of recommendation (***also provide narrative description of the rating and by whom***):**
N/A

1c.13 **Method for rating strength of recommendation** (*If different from USPSTF system, also describe rating and how it relates to USPSTF)***:**
N/A

1c.14 **Rationale for using this guideline over others:**
N/A

TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Importance to Measure and Report*?	**1**
Steering Committee: Was the threshold criterion, *Importance to Measure and Report*, met? **Rationale:**	**1** **Y☐** **N☐**
2. SCIENTIFIC ACCEPTABILITY OF MEASURE PROPERTIES	
Extent to which the measure, as specified, produces consistent (reliable) and credible (valid) results about the quality of care when implemented. (evaluation criteria)	**Eval Rating**
2a. MEASURE SPECIFICATIONS	
S.1 **Do you have a web page where current detailed measure specifications can be obtained?** S.2 **If yes, provide web page URL:** **2a. Precisely Specified**	
2a.1 **Numerator Statement (***Brief, text description of the numerator - what is being measured about the target population, e.g. target condition, event, or outcome***):** 1) Total number of pediatric and congenital cardiac surgery operations and 2) number of pediatric and congenital cardiac surgery operations in each of the strata of complexity specified by the five STS-EACTS Mortality Levels, a multi-institutional validated complexity stratification tool 2a.2 **Numerator Time Window (***The time period in which cases are eligible for inclusion in the numerator***):** 12 months 2a.3 **Numerator Details (***All information required to collect/calculate the numerator, including all codes,*	**2a-specs** **C☐** **P☐** **M☐** **N☐**

Comment [k7]: USPSTF grading system **http://www.ahrq.gov/clinic/uspstf/grades.htm**: **A -** The USPSTF recommends the service. There is high certainty that the net benefit is substantial. **B -** The USPSTF recommends the service. There is high certainty that the net benefit is moderate or there is moderate certainty that the net benefit is moderate to substantial. **C -** The USPSTF recommends against routinely providing the service. There may be considerations that support providing the service in an individual patient. There is at least moderate certainty that the net benefit is small. Offer or provide this service only if other considerations support the offering or providing the service in an individual patient. **D -** The USPSTF recommends against the service. There is moderate or high certainty that the service has no net benefit or that the harms outweigh the benefits. **I -** The USPSTF concludes that the current evidence is insufficient to assess the balance of benefits and harms of the service. Evidence is lacking, of poor quality, or conflicting, and the balance of benefits and harms cannot be determined.

Comment [KP8]: 2a. The measure is well defined and precisely specified so that it can be implemented consistently within and across organizations and allow for comparability. The required data elements are of high quality as defined by NQF's Health Information Technology Expert Panel (HITEP) .

logic, and definitions):
Cardiac operations are defined as operations that are of operation types of "CPB" or "No CPB Cardiovascular". (CPB is cardiopulmonary bypass.) [1]. Pediatric heart surgery is heart surgery on patients <18 years of age to treat congenital or acquired cardiac disease. Congenital heart surgery is heart surgery on patients of any age to treat congenital cardiac disease.

The following are STS procedure codes for pediatric and congenital cardiac operations per the STS Congenital Heart Surgery Database Version 3.0 Data Specifications (http://www.sts.org/sites/default/files/documents/pdf/CongenitalDataSpecificationsV3_0_20090904.pdf). Analysis should include any index operation performed with any of the following component procedures on a patient with pediatric and/or congenital cardiac disease:

10, 20, 30, 40, 2110, 50, 60, 70, 80, 85, 100, 110, 120, 130, 140, 150, 170, 180, 190, 2300, 2250, 2230, 210, 220, 230, 240, 2290, 250, 2220, 260, 270, 2120, 280, 2200, 290, 300, 310, 330, 340, 350, 360, 370, 380, 390, 400, 420, 430, 440, 450, 460, 2280, 465, 470, 480, 490, 500, 510, 520, 530, 540, 550, 570, 590, 2270, 600, 630, 640, 650, 610, 620, 1774, 1772, 580, 660, 2240, 2310, 2320, 670, 680, 690, 700, 715, 720, 730, 735, 740, 750, 760, 770, 780, 2100, 790, 800, 810, 820, 830, 2260, 840, 850, 860, 870, 880, 2160, 2170, 2180, 2140, 2150, 890, 900, 910, 920, 930, 940, 950, 960, 970, 980, 1000, 1010, 1025, 1030, 2340, 1035, 1050, 1060, 1070, 1080, 1090, 1110, 1120, 1123, 1125, 1130, 1140, 1145, 1150, 1160, 2190, 2210, 1180, 1200, 1210, 1220, 1230, 1240, 1250, 1260, 1275, 1280, 1285, 1290, 1291, 1300, 1310, 1320, 1330, 1340, 1360, 1365, 1370, 1380, 1390, 1410, 1450, 1460, 2350, 1470, 1480, 1490, 1500, 1590, 1600, 1610, 1630, 2095, 1640, 1650, 1660, 1670, 1680, 1690, 1700, 2330, 2130, 1720, 1730, 1740, 1760, 1780, 1790, 1802, 1804, 1830, 1860

As demonstrated in the previously provided publication [2], the five STS-EACTS Mortality Levels constitute an objective and empirically based tool for complexity stratification. In addition, it represents an improvement over existing consensus-based tools.

References:
1.Jacobs JP, Mavroudis C, Jacobs ML, Maruszewski B, Tchervenkov CI, Lacour-Gayet FG, Clarke DR, Yeh T, Walters HL 3rd, Kurosawa H, Stellin G, Ebels T, Elliott MJ. 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. The Annals of Thoracic Surgery, 81(5):1937-41, May 2006.
There are currently three validated systems of Complexity Stratification in use to categorize operations for pediatric and congenital heart disease on the basis of complexity. Each of these is used in some registry databases, and data is currently stratified using each of the three systems in the most recent outcome reports of the Society of Thoracic Surgery Congenital Heart Surgery database. The three systems are: 1. the RACHS-1 (Risk Adjustment in Congenital Heart Surgery) System with 5 functional levels; 2. The Aristotle Basic Complexity Score with 4 levels; and 3. STS-EACTS Mortality Levels (5 levels).

2. O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009.

2a.4 Denominator Statement (*Brief, text description of the denominator - target population being measured***):**
N/A

2a.5 Target population gender: Female, Male
2a.6 Target population age range: Pediatric heart surgery: patients <18 years of age. Congenital heart surgery: patients of any age to treat congenital cardiac disease

2a.7 Denominator Time Window (*The time period in which cases are eligible for inclusion in the denominator***):**
N/A

2a.8 Denominator Details (*All information required to collect/calculate the denominator - the target population being measured - including all codes, logic, and definitions***):**
N/A

2a.9 Denominator Exclusions (*Brief text description of exclusions from the target population***):** Measure Exclusions:

Any operation that is not a pediatric or congenital cardiac operation. Cardiac operations are defined as operations that are of operation types of "CPB" or "No CPB Cardiovascular" (CPB is cardiopulmonary bypass.) [1].

Any operation that is a pediatric or congenital open heart surgery (operation types of "CPB" or "No CPB Cardiovascular") that cannot be classified into a level of complexity by the five STS-EACTS Mortality Levels.

1. Jacobs JP, Mavroudis C, Jacobs ML, Maruszewski B, Tchervenkov CI, Lacour-Gayet FG, Clarke DR, Yeh T, Walters HL 3rd, Kurosawa H, Stellin G, Ebels T, Elliott MJ. 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. The Annals of Thoracic Surgery, 81(5):1937-41, May 2006.

2a.10 Denominator Exclusion Details (*All information required to collect exclusions to the denominator, including all codes, logic, and definitions***):**
N/A

2a.11 Stratification Details/Variables (*All information required to stratify the measure including the stratification variables, all codes, logic, and definitions***):**
The second component of this measure captures volume stratified by the five STS-EACTS Mortality Levels, a multi-institutional validated complexity stratification tool. Please see information provided in numerator details section above

2a.12-13 Risk Adjustment Type: No risk adjustment necessary

2a.14 Risk Adjustment Methodology/Variables (*List risk adjustment variables and describe conceptual models, statistical models, or other aspects of model or method***):**
N/A

2a.15-17 Detailed risk model available Web page URL or attachment:

2a.18-19 Type of Score: Count
2a.20 Interpretation of Score: Better quality = Higher score
2a.21 Calculation Algorithm (*Describe the calculation of the measure as a flowchart or series of steps***):**
N/A

2a.22 Describe the method for discriminating performance *(e.g., significance testing)*:
N/A

2a.23 Sampling (Survey) Methodology *If measure is based on a sample (or survey), provide instructions for obtaining the sample, conducting the survey and guidance on minimum sample size (response rate)*:
N/A

2a.24 Data Source (*Check the source(s) for which the measure is specified and tested)*
Electronic Clinical Data : Registry

2a.25 Data source/data collection instrument (*Identify the specific data source/data collection instrument, e.g. name of database, clinical registry, collection instrument, etc.***):**
The Society of Thoracic Surgeons Congenital Heart Surgery Database, Version 3.0

2a.26-28 Data source/data collection instrument reference web page URL or attachment: URL Data Collection Form -
http://www.sts.org/sites/default/files/documents/pdf/ndb/CongenitalDataCollectionForm3_0_Annotated_20090916.pdf

2a.29-31 Data dictionary/code table web page URL or attachment: URL
http://www.sts.org/sites/default/files/documents/pdf/CongenitalDataSpecificationsV3_0_20090904.pdf

2a.32-35 Level of Measurement/Analysis (*Check the level(s) for which the measure is specified and tested)*

Comment [k9]: 11 Risk factors that influence outcomes should not be specified as exclusions.
12 Patient preference is not a clinical exception to eligibility and can be influenced by provider interventions.

Clinician : Group/Practice, Facility, Population : County or City, Population : National, Population : Regional, Population : State

2a.36-37 **Care Settings (***Check the setting(s) for which the measure is specified and tested)*
Hospital/Acute Care Facility

2a.38-41 **Clinical Services** (*Healthcare services being measured, check all that apply*)
Clinicians: Physicians (MD/DO)

TESTING/ANALYSIS

2b. Reliability testing

2b.1 **Data/sample** *(description of data/sample and size)*: "Reliability is the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials. Without the agreement of independent observers able to replicate research procedures, or the ability to use research tools and procedures that yield consistent measurements, researchers would be unable to satisfactorily draw conclusions, formulate theories, or make claims about the generalizability of their research." [http://writing.colostate.edu/guides/research/relval/]

The reliability of the STS-EACTS Congenital Heart Surgery Mortality Categories (2009) is documented in detail in the following manuscript:

O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009.

Accuracy and Completeness of the STS Congenital Heart Surgery Database data

The audit process assures the accuracy and completeness of STS Congenital data through a combination of two strategies:

1. Intrinsic data verification – designed to rectify inconsistencies of data and missing elements of data)
2. Site visits with "Source Data Verification" – in other words, verification of the data at the primary source of the data

This process of verification of data has demonstrated that the STS Congenital Heart Surgery Database is very complete and accurate, as documented in the STS Congenital Heart Surgery Database Report Overview, as well as in the following peer-reviewed publication:

Clarke DR, Breen LS, Jacobs ML, Franklin RCG, Tobota Z, Maruszewski B, Jacobs JP. Verification of data in congenital cardiac surgery. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 177–187, December 9, 2008.

2b.2 **Analytic Method** *(type of reliability & rationale, method for testing)*:

2b.3 **Testing Results** *(reliability statistics, assessment of adequacy in the context of norms for the test conducted)*:

2b
C☐
P☐
M☐
N☐

2c. Validity testing

2c.1 **Data/sample** *(description of data/sample and size)*: "Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. While reliability is concerned with the accuracy of the actual measuring instrument or procedure, validity is

2c
C☐
P☐
M☐
N☐

Comment [KP10]: 2b. Reliability testing demonstrates the measure results are repeatable, producing the same results a high proportion of the time when assessed in the same population in the same time period.

Comment [k11]: 8 Examples of reliability testing include, but are not limited to: inter-rater/abstractor or intra-rater/abstractor studies; internal consistency for multi-item scales; test-retest for survey items. Reliability testing may address the data items or final measure score.

Comment [KP12]: 2c. Validity testing demonstrates that the measure reflects the quality of care provided, adequately distinguishing good and poor quality. If face validity is the only validity addressed, it is systematically assessed.

concerned with the study´s success at measuring what the researchers set out to measure.

Researchers should be concerned with both external and internal validity. External validity refers to the extent to which the results of a study are generalizable or transferable.

Internal validity refers to (1) the rigor with which the study was conducted (e.g., the study´s design, the care taken to conduct measurements, and decisions concerning what was and wasn´t measured) and (2) the extent to which the designers of a study have taken into account alternative explanations for any causal relationships they explore (Huitt, 1998). In studies that do not explore causal relationships, only the first of these definitions should be considered when assessing internal validity.

Scholars discuss several types of internal validity:

- Face Validity
- Criterion Related Validity
- Construct Validity
- Content Validity"

[http://writing.colostate.edu/guides/research/relval/]

This measure has been developed by a multi-institutional, multi-subspecialty panels of experts made up of international leaders in the medical and surgical care of patients with pediatric and congenital heart disease. This process is described in detail in the following publications:

1. Jacobs JP. (Editor). 2008 Supplement to Cardiology in the Young: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Cardiology in the Young, Volume 18, Supplement S2, pages 1 –530, December 9, 2008.

2. Jacobs JP. Introduction – Databases and the assessment of complications associated with the treatment of patients with congenital cardiac disease. In: 2008 Supplement to Cardiology in the Young: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 1-37, December 9, 2008.

3. Jacobs JP, Jacobs ML, Mavroudis C, Backer CL, Lacour-Gayet FG, Tchervenkov CI, Franklin RCG, Béland MJ, Jenkins KJ, Walters III H, Bacha EA, Maruszewski B, Kurosawa H, Clarke DR, Gaynor JW, Spray TL, Stellin G, Ebels T, Krogmann ON, Aiello VD, Colan SD, Weinberg P, Giroud JM, Everett A, Wernovsky G, Martin J. Elliott MJ, Edwards FH. Nomenclature and databases for the surgical treatment of congenital cardiac disease – an updated primer and an analysis of opportunities for improvement. In: 2008 Supplement to Cardiology in the Young: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 38-62, December 9, 2008.

Mortality and morbidity related to pediatric and congenital heart surgery are defined in detail in the following publications:

1. Jacobs JP, Mavroudis C, Jacobs ML, Maruszewski B, Tchervenkov CI, Lacour-Gayet FG, Clarke DR, Yeh T, Walters HL 3rd, Kurosawa H, Stellin G, Ebels T, Elliott MJ. 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. The Annals of Thoracic Surgery, 81(5):1937-41, May 2006.

2. Jacobs JP, Jacobs ML, Mavroudis C, Maruszewski B, Tchervenkov CI, Lacour-Gayet FG, Clarke DR, Yeh T, Walters HL 3rd, Kurosawa H, Stellin G, Ebels T, Elliott MJ, Vener DF, Barach P, Benavidez OJ, Bacha EA.. 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. The Annals of Thoracic Surgery; 84:1416-1421, October 2007.

Due to the process used to develop these measures, we believe they have exceptional face validity. These metrics have external validity because they are clearly generalizable or transferable, as documented in the publications mentioned above. When used in the STS Congenital Heart Surgery Database, these metrics have internal validity due to (1) the rigor of the analyses conducted and (2) the extent to which the STS Congenital Heart Surgery Database Task Force has recognized and considered alternative explanations for any causal relationships reported, as documented in the STS Congenital Heart Surgery Database Feedback Report and Report Overview, which has been sent to the National Quality Forum in a separate e-mail. Finally, as these outcome metrics encompass a broad and comprehensive range of outcomes that are all directly related to pediatric cardiac surgery performance, we believe they have strong content and construct validity.

As stated above, extensive testing has also been performed within the STS Congenital Heart Surgery Database that confirms the validity and reliability of the three multi-institutional validated complexity stratification tools (the five functional RACHS-1 classifications, the four Aristotle Basic Complexity Score Levels, or the five STS-EACTS Congenital Heart Surgery Mortality Categories [2009]). This testing is summarized in the following manuscripts:

1. O´Brien SM, Jacobs JP, Clarke DR, Maruszewski B, Jacobs ML, Walters HL 3rd, Tchervenkov CI, Welke KF, Tobota Z, Stellin G, Mavroudis C, Hamilton JR, Gaynor JW, Pozzi M, Lacour-Gayet FG. Accuracy of the Aristotle Basic Complexity Score for classifying the mortality and morbidity potential of congenital heart surgery operations. The Annals of Thoracic Surgery, 84(6):2027-37, PMID: 18036930, December 2007.

2. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha E, Maruszewski B, Clarke DR, Tchervenkov CI, Gaynor JW, Spray TL, Stellin G, O´Brien SM, Elliott MJ, Mavroudis C. Stratification of complexity improves the utility and accuracy of outcomes analysis in a Multi-Institutional Congenital Heart Surgery Database: Application of the Risk Adjustment in Congenital Heart Surgery (RACHS-1) and Aristotle Systems in the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database. Pediatric Cardiology, 2009, DOI 10.1007/s00246-009-9496-0.

3. O´Brien SM, Clarke DR, Jacobs JP, Jacobs ML, Lacour-Gayet FG, Pizarro C, Welke KF, Maruszewski B, Tobota Z, Miller WJ, Hamilton L, Peterson ED, Mavroudis C, Edwards FH. An empirically based tool for analyzing mortality associated with congenital heart surgery. The Journal of Thoracic and Cardiovascular Surgery, 2009 Nov;138(5):1139-53.PMID: 19837218, November 2009.

The third manuscript in the list above describes the development of the "STS–EACTS Congenital Heart Surgery Mortality Categories (2009)" using data from 77,294 operations entered into the European Association for Cardiothoracic Surgery (EACTS) Congenital Heart Surgery Database (33,360 operations) and the STS Congenital Heart Surgery Database (43,934 patients) between 2002 and 2007. This manuscript clearly states that: "Model performance was subsequently assessed in an independent validation sample (n = 27,700) and compared with 2 existing methods: Risk Adjustment for Congenital Heart Surgery (RACHS-1) categories and Aristotle Basis Complexity scores." This peer-reviewed and published validity testing using "an independent validation sample (n = 27,700 operations)" generated the c-statistics shown in Table 1 below and should satisfy the requirements for validity and reliability testing for our outcome metrics. The technical details of this validity and reliability testing is described in reference number 3 above. This publication is also provided as STS Attachment 1 (of 2) - O´Brien et al, JTCVS, Nov 2009.

Table 1: Method of Modeling Procedures	Model without patient covariates	Model with patient covariates
STS-EACTS Congenital Heart Surgery Mortality Categories (2009)	C = 0.778	C = 0.812
RACHS-1 Categories	C = 0.745	C = 0.802
Aristotle Basic Complexity Score	C = 0.687	C = 0.795

2c.2 Analytic Method *(type of validity & rationale, method for testing)***:**

2c.3 Testing Results *(statistical results, assessment of adequacy in the context of norms for the test conducted)***:**

Comment [k13]: 9 Examples of validity testing include, but are not limited to: determining if measure scores adequately distinguish between providers known to have good or poor quality assessed by another valid method; correlation of measure scores with another valid indicator of quality for the specific topic; ability of measure scores to predict scores on some other related valid measure; content validity for multi-item scales/tests. Face validity is a subjective assessment by experts of whether the measure reflects the quality of care (e.g., whether the proportion of patients with BP < 140/90 is a marker of quality). If face validity is the only validity addressed, it is systematically assessed (e.g., ratings by relevant stakeholders) and the measure is judged to represent quality care for the specific topic and that the measure focus is the most important aspect of quality for the specific topic.

2d. Exclusions Justified

2d.1 Summary of Evidence supporting exclusion(s):

STS excludes any operation that is not a pediatric or congenital Cardiac Operation. Cardiac operations are defined as operations that are of operation types of "CPB" or "No CPB Cardiovascular" (CPB is cardiopulmonary bypass.) [1]. In addition, STS exclude sany operation that is a pediatric or congenital open heart surgery (operation types of "CPB" or "No CPB Cardiovascular") that cannot be classified into a level of complexity by the five STS-EACTS Mortality Levels.

This measure is designed to track total surgical volume and volume stratified by the five STS-EACTS Mortality Levels, which is a multi-institutional validated complexity stratification tool. Published methodology is available that describes the proper techniques for gathering this information based on the consensus of a panel of experts.

Furthermore, it is important to understand that the Society of Thoracic Surgeons advocates utilization of a systematic multi-institutional clinical database (registry) for the analysis of cardiac surgical outcomes and the assessment of quality. Evidence from three recent investigations suggests that the validity of coding of lesions seen in the congenitally malformed heart via the International Classification of Diseases as used in Administrative Databases is likely to be poor[2, 3, 4]. First, in a series of 373 infants with congenital cardiac defects at Children's Hospital of Wisconsin, investigators report that only 52% of the cardiac diagnoses in the medical records had a corresponding code from the International Classification of Diseases in the hospital discharge database [2]. Second, the Hennepin County Medical Center discharge database in Minnesota identified all infants born during 2001 with a code for congenital cardiac disease using the International Classification of Diseases. A review of these 66 medical records by physicians was able to confirm only 41% of the codes contained in the administrative database from the International Classification of Diseases [3]. Third, the Metropolitan Atlanta Congenital Defect Program of the Birth Defect Branch of the Centers for Disease Control and Prevention of the federal government of the United States of America carried out surveillance of infants and fetuses with cardiac defects delivered to mothers residing in Atlanta during the years 1988 through 2003 [4]. These records were reviewed and classified using both administrative coding and the clinical nomenclature used in the Society of Thoracic Surgeons Congenital Heart Surgery Database. This study concluded that analyses based on the codes available in the International Classification of Diseases are likely to "have substantial misclassification" of congenital cardiac disease.

Several potential reasons can explain the poor diagnostic accuracy of Administrative Databases and codes from the International Classification of Diseases:
1) accidental miscoding
2) coding performed by medical records clerks who have never seen the actual patient
3) contradictory or poorly described information in the medical record
4) lack of diagnostic specificity for congenital cardiac disease in the codes of the of International Classification of Diseases
5) inadequately trained medical coders

2d.2 Citations for Evidence:

1. Jacobs JP, Mavroudis C, Jacobs ML, Maruszewski B, Tchervenkov CI, Lacour-Gayet FG, Clarke DR, Yeh T, Walters HL 3rd, Kurosawa H, Stellin G, Ebels T, Elliott MJ. 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. The Annals of Thoracic Surgery, 81(5):1937-41, May 2006.

2. Cronk CE, Malloy ME, Pelech AN, et al. Completeness of state administrative databases for surveillance of congenital heart disease. Birth Defects Res A Clin Mol Teratol 2003; 67: 597-603.

3. Frohnert BK, Lussky RC, Alms MA, Mendelsohn NJ, Symonik DM, Falken MC. Validity of hospital discharge data for identifying infants with cardiac defects. J Perinatol 2005; 25: 737-742.

4. Strickland MJ, Riehle-Colarusso TJ, Jacobs JP, Reller MD, Mahle WT, Botto LD, Tolbert PE, Jacobs ML, Lacour-Gayet FG, Tchervenkov CI, Mavroudis C, Correa A. The importance of nomenclature for congenital cardiac disease: implications for research and evaluation. In: 2008 Supplement to Cardiology in the Young:

2d
C☐
P☐
M☐
N☐
NA ☐

Comment [KP14]: 2d. Clinically necessary measure exclusions are identified and must be:
•supported by evidence of sufficient frequency of occurrence so that results are distorted without the exclusion;
AND
•a clinically appropriate exception (e.g., contraindication) to eligibility for the measure focus;
AND
•precisely defined and specified:
–if there is substantial variability in exclusions across providers, the measure is specified so that exclusions are computable and the effect on the measure is transparent (i.e., impact clearly delineated, such as number of cases excluded, exclusion rates by type of exclusion);
if patient preference (e.g., informed decision-making) is a basis for exclusion, there must be evidence that it strongly impacts performance on the measure and the measure must be specified so that the information about patient preference and the effect on the measure is transparent (e.g., numerator category computed separately, denominator exclusion category computed separately).

Comment [k15]: 10 Examples of evidence that an exclusion distorts measure results include, but are not limited to: frequency of occurrence, sensitivity analyses with and without the exclusion, and variability of exclusions across providers.

Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 92–100, December 9, 2008.

2d.3 **Data/sample** *(description of data/sample and size)*:

2d.4 **Analytic Method** *(type analysis & rationale)*:

2d.5 **Testing Results** *(e.g., frequency, variability, sensitivity analyses)*:

2e. Risk Adjustment for Outcomes/ Resource Use Measures

2e.1 **Data/sample** *(description of data/sample and size)*: None

2e.2 **Analytic Method** *(type of risk adjustment, analysis, & rationale)*:

2e.3 **Testing Results** *(risk model performance metrics)*:

2e.4 **If outcome or resource use measure is not risk adjusted, provide rationale:**

2e
C☐ P☐ M☐ N☐ NA☐

2f. Identification of Meaningful Differences in Performance

2f.1 **Data/sample from Testing or Current Use** *(description of data/sample and size)*: The STS Congenital Heart Surgery Database

2f.2 **Methods to identify statistically significant and practically/meaningfully differences in performance** *(type of analysis & rationale)*:
Outliers can be identified with 95% confidence intervals based on the sample size, with complexity stratification for one and four-year time intervals. Data will be available when the STS Congenital Heart Surgery Database National Report is published in May 2010.

2f.3 **Provide Measure Scores from Testing or Current Use** *(description of scores, e.g., distribution by quartile, mean, median, SD, etc.; identification of statistically significant and meaningfully differences in performance)*:
Currently being collected in the STS Congenital Heart Surgery Database. We do not have this data. We know that 82 out of 122 pediatric heart surgery centers in the USA participate in the STS Congenital Heart Surgery Database.

2f
C☐ P☐ M☐ N☐

2g. Comparability of Multiple Data Sources/Methods

2g.1 **Data/sample** *(description of data/sample and size)*: Clinical data abstraction is the only method utilized

2g.2 **Analytic Method** *(type of analysis & rationale)*:

2g.3 **Testing Results** *(e.g., correlation statistics, comparison of rankings)*:

2g
C☐ P☐ M☐ N☐ NA☐

2h. Disparities in Care

2h.**1 If measure is stratified, provide stratified results** *(scores by stratified categories/cohorts)*:

2h.2 **If disparities have been reported/identified, but measure is not specified to detect disparities, provide follow-up plans:**

2h
C☐ P☐ M☐ N☐ NA

Comment [KP16]: 2e. For outcome measures and other measures (e.g., resource use) when indicated:
•an evidence-based risk-adjustment strategy (e.g., risk models, risk stratification) is specified and is based on patient clinical factors that influence the measured outcome (but not disparities in care) and are present at start of care;[Error! Bookmark not defined.] OR rationale/data support no risk adjustment.

Comment [k17]: 13 Risk models should not obscure disparities in care for populations by including factors that are associated with differences/inequalities in care such as race, socioeconomic status, gender (e.g., poorer treatment outcomes of African American men with prostate cancer, inequalities in treatment for CVD risk factors between men and women). It is preferable to stratify measures by race and socioeconomic status rather than adjusting out differences.

Comment [KP18]: 2f. Data analysis demonstrates that methods for scoring and analysis of the specified measure allow for identification of statistically significant and practically/clinically meaningful differences in performance.

Comment [k19]: 14 With large enough sample sizes, small differences that are statistically significant may or may not be practically or clinically meaningful. The substantive question may be, for example, whether a statistically significant difference of one percentage point in the percentage of patients who received smoking cessation counseling (e.g., 74% v. 75%) is clinically meaningful; or whether a statistically significant difference of $25 in cost for an episode of care (e.g., $5,000 v. $5,025) is practically meaningful. Measures with overall poor performance may not demonstrate much variability across providers.

Comment [KP20]: 2g. If multiple data sources/methods are allowed, there is demonstration they produce comparable results.

Comment [KP21]: 2h. If disparities in care have been identified, measure specifications, scoring, and analysis allow for identification of disparities through stratification of results (e.g., by race, ethnicity, socioeconomic status, gender);OR rationale/data justifies why stratification is not necessary or not feasible.

	☐
TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Scientific Acceptability of Measure Properties*?	**2**
Steering Committee: Overall, to what extent was the criterion, *Scientific Acceptability of Measure Properties*, met? **Rationale:**	***2*** **C☐** **P☐** **M☐** **N☐**
3. USABILITY	
Extent to which intended audiences (e.g., consumers, purchasers, providers, policy makers) can understand the results of the measure and are likely to find them useful for decision making. (evaluation criteria)	**Eval Rating**
3a. Meaningful, Understandable, and Useful Information 3a.1 **Current Use:** In use 3a.2 **Use in a public reporting initiative (disclosure of performance results to the public at large)** (*If used in a public reporting initiative, provide name of initiative(s), locations, Web page URL(s). If not publicly reported, state the plans to achieve public reporting within 3 years*)**:** 3a.3 **If used in other programs/initiatives (***If used in quality improvement or other programs/initiatives, name of initiative(s), locations, Web page URL(s). If not used for QI, state the plans to achieve use for QI within 3 years***):** **Testing of Interpretability** (*Testing that demonstrates the results are understood by the potential users for public reporting and quality improvement*) 3a.4 **Data/sample** *(description of data/sample and size)***:** Post-operative mortality and morbidity data are currently being collected voluntarily by The Society of Thoracic Surgeons Congenital Cardiac Surgery Database. All of the outcome metrics are used by clinicians as performance feedback and are tracked in the STS Database. No focused consumer testing has been done to date on any of these metrics. No public reporting has been done on any of these metrics to date. Pediatric and congenital heart surgery is very different from adult heart surgery. Separate metrics are necessary. 3a.5 **Methods** *(e.g., focus group, survey, QI project)***:** 3a.6 **Results** *(qualitative and/or quantitative results and conclusions)***:**	**3a** **C☐** **P☐** **M☐** **N☐**
3b/3c. Relation to other NQF-endorsed measures 3b.1 **NQF # and Title of similar or related measures:**	
(for NQF staff use) **Notes on similar/related endorsed or submitted measures:**	
3b. Harmonization If this measure is related to measure(s) already endorsed by NQF (e.g., same topic, but different target population/setting/data source or different topic but same target population): 3b.2 **Are the measure specifications harmonized? If not, why?** This measure has been harmonized with PCS-007-09 Surgical Volume for Pediatric and Congenital Heart Surgery at the request of the NQF Surgery Steering Committee. It has not been harmonized with # 0340. It is STS´s understanding that the NQF Surgery Steering Committee is in agreement that harmonization with #340 is not necessary.	**3b** **C☐** **P☐** **M☐** **N☐** **NA☐**

Comment [KP22]: 3a. Demonstration that information produced by the measure is meaningful, understandable, and useful to the intended audience(s) for both public reporting (e.g., focus group, cognitive testing) and informing quality improvement (e.g., quality improvement initiatives). An important outcome that may not have an identified improvement strategy still can be useful for informing quality improvement by identifying the need for and stimulating new approaches to improvement.

Comment [KP23]: 3b. The measure specifications are harmonized with other measures, and are applicable to multiple levels and settings.

Comment [k24]: 16 Measure harmonization refers to the standardization of specifications for similar measures on the same topic (e.g., ***influenza immunization*** of patients in hospitals or nursing homes), or related measures for the same target population (e.g., eye exam and HbA1c for ***patients with diabetes***), or definitions applicable to many measures (e.g., age designation for children) so that they are uniform or compatible, unless differences are dictated by the evidence. The dimensions of harmonization can include numerator, denominator, exclusions, and data source and collection instructions. The extent of harmonization depends on the relationship of the measures, the evidence for the specific measure focus, and differences in data sources.

(Provided in original STS submission in 2009):
NQF # 0340 and NQF # 0339 are both suboptimal. The limitations of each of these measures will be reviewed below:

NQF # 0340
Title: Pediatric Heart Surgery Volume (PDI 7)
Status: Endorsed
Endorsed on: MAY 15, 2008
Steward(s): Agency for Healthcare Research and Quality
Description: Raw volume compared to annual thresholds (100 procedures)

The relationship between the volume of pediatric and congenital cardiac surgery performed at a center and quality of care is unclear and controversial at best [1, 2, 3, 4, 5, 6, 7]. Evidence simply does not exist to support an annual volume threshold of 100 procedures.

Nevertheless, in order to track a variety of outcomes represented in other proposed Quality Indicators, one must have a firm grasp on the volume of pediatric and congenital cardiac surgery performed at a center over both 1 year and 4 year time intervals. The very act of tracking this structure measure is necessary in order to track other outcome measures that use this structure measure as a denominator. Furthermore, very act of tracking this structure measure should in and of itself lead to improvements in quality.

The operations counted towards this metric must clearly be defined as pediatric or congenital Cardiac Operation. Cardiac operations are defined as operations that are of operation types of "CPB" or "No CPB Cardiovascular". (CPB is cardiopulmonary bypass.) [8]. Published methodology is available that describes the proper techniques for gathering this information based on the consensus of a panel of experts.

NQF # 0339
Title: Pediatric Heart Surgery Mortality (PDI 6) (risk adjusted)
Status: Endorsed
Endorsed on: MAY 15, 2008
Steward(s): Agency for Healthcare Research and Quality
Description: Number of in-hospital deaths in patients undergoing surgery for congenital heart disease per 1000 patients.

Furthermore, it is important to understand that the Society of Thoracic Surgeons advocates utilization of a systematic multi-institutional clinical database (registry) for the analysis of cardiac surgical outcomes and the assessment of quality. Evidence from three recent investigations suggests that the validity of coding of lesions seen in the congenitally malformed heart via the International Classification of Diseases as used in Administrative Databases is likely to be poor[9, 10, 11]. First, in a series of 373 infants with congenital cardiac defects at Children's Hospital of Wisconsin, investigators report that only 52% of the cardiac diagnoses in the medical records had a corresponding code from the International Classification of Diseases in the hospital discharge database [9]. Second, the Hennepin County Medical Center discharge database in Minnesota identified all infants born during 2001 with a code for congenital cardiac disease using the International Classification of Diseases. A review of these 66 medical records by physicians was able to confirm only 41% of the codes contained in the administrative database from the International Classification of Diseases [10]. Third, the Metropolitan Atlanta Congenital Defect Program of the Birth Defect Branch of the Centers for Disease Control and Prevention of the federal government of the United States of America carried out surveillance of infants and fetuses with cardiac defects delivered to mothers residing in Atlanta during the years 1988 through 2003 [11]. These records were reviewed and classified using both administrative coding and the clinical nomenclature used in the Society of Thoracic Surgeons Congenital Heart Surgery Database. This study concluded that analyses based on the codes available in the International Classification of Diseases are likely to "have substantial misclassification" of congenital cardiac disease.

Several potential reasons can explain the poor diagnostic accuracy of Administrative Databases and codes from the International Classification of Diseases:

1) accidental miscoding
2) coding performed by medical records clerks who have never seen the actual patient
3) contradictory or poorly described information in the medical record
4) lack of diagnostic specificity for congenital cardiac disease in the codes of the of International Classification of Diseases
5) inadequately trained medical coders

References:

1. Welke KF, O'Brien SM, Peterson ED, Ungerleider RM, Jacobs ML, Jacobs JP. The Complex Relationship between Pediatric Cardiac Surgical Case Volumes and Mortality Rates in a National Clinical Database. The Journal of Thoracic and Cardiovascular Surgery,. 2009 May;137(5):1133-40. Epub 2009 Mar 17, PMID: 19379979, May, 2009.

2. Bradley SM. Good Things in Small Packages: Meeting Challenge in the Low-volume Program. Jacobs JP, Wernovsky G, Cooper DS, Gaynor JW, Anderson RH (editors). 2009 Supplement to Cardiology in the Young: Annual Heart Week in Florida Supplement Number 7 - Innovation Associated With The Treatment Of Patients With Congenital and Pediatric Cardiac Disease, Cardiology in the Young, Volume 19, accepted for publication, in press.

3. Jenkins KJ, Newburger JW, Lock JE, et al. In-hospital mortality for surgical repair of congenital heart defects: preliminary observations of variation by hospital caseload. Pediatrics. 1995;95:323-30.

4. Hannan EL, Racz M, Kavey RE, Quagebeur JM, Williams R. Pediatric cardiac surgery: the effect of hospital and surgeon volume on in-hospital mortality. Pediatrics. 1998;101:963-9.

5. Sollano JA, Gelijns AC, Moskowitz AJ, et al. Volume-outcome relationships in cardiovascular operations: New York State, 1990-1995. J Thorac Cardiovasc Surg. 1999;117:419-28.

6.Chang RK, Klitzner TS. Can regionalization decrease the number of deaths for children who undergo cardiac surgery? A theoretical analysis. Pediatrics. 2002; 109:173-81.

7. Quintessenza JA, Jacobs JP, Morell VO. Issues in Regionalization of Pediatric Cardiovascular Care. Progress in Pediatric Cardiology 18 (2003) 49–53. Elsevier Science Ireland Ltd. 2003.

8. Jacobs JP, Mavroudis C, Jacobs ML, Maruszewski B, Tchervenkov CI, Lacour-Gayet FG, Clarke DR, Yeh T, Walters HL 3rd, Kurosawa H, Stellin G, Ebels T, Elliott MJ. 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. The Annals of Thoracic Surgery, 81(5):1937-41, May 2006.

9. Cronk CE, Malloy ME, Pelech AN, et al. Completeness of state administrative databases for surveillance of congenital heart disease. Birth Defects Res A Clin Mol Teratol 2003; 67: 597-603.

10. Frohnert BK, Lussky RC, Alms MA, Mendelsohn NJ, Symonik DM, Falken MC. Validity of hospital discharge data for identifying infants with cardiac defects. J Perinatol 2005; 25: 737-742.

11. Strickland MJ, Riehle-Colarusso TJ, Jacobs JP, Reller MD, Mahle WT, Botto LD, Tolbert PE, Jacobs ML, Lacour-Gayet FG, Tchervenkov CI, Mavroudis C, Correa A. The importance of nomenclature for congenital cardiac disease: implications for research and evaluation. In: 2008 Supplement to Cardiology in the Young: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young, Volume 18, Issue S2 (Suppl. 2), pp 92–100, December 9, 2008.

3c. Distinctive or Additive Value — **3c**

3c.1 Describe the distinctive, improved, or additive value this measure provides to existing NQF-endorsed measures:

Please see above

C ☐ **P** ☐ **M** ☐

Comment [KP25]: 3c. Review of existing endorsed measures and measure sets demonstrates that the measure provides a distinctive or additive value to existing NQF-endorsed measures (e.g., provides a more complete picture of quality for a particular condition or aspect of healthcare, is a more valid or efficient way to measure).

5.1 **If this measure is similar to measure(s) already endorsed by NQF (i.e., on the same topic and the same target population), Describe why it is a more valid or efficient way to measure quality:** Please see above	**N☐ NA ☐**
TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Usability*?	**3**
Steering Committee: Overall, to what extent was the criterion, *Usability*, met? **Rationale:**	**3** **C☐** **P☐** **M☐** **N☐**
4. FEASIBILITY	
Extent to which the required data are readily available, retrievable without undue burden, and can be implemented for performance measurement. (evaluation criteria)	**Eval Rating**
4a. Data Generated as a Byproduct of Care Processes 4a.1-2 **How are the data elements that are needed to compute measure scores generated?** Data generated as byproduct of care processes during care delivery (Data are generated and used by healthcare personnel during the provision of care, e.g., blood pressure, lab value, medical condition), Coding/abstraction performed by someone other than person obtaining original information (E.g., DRG, ICD-9 codes on claims, chart abstraction for quality measure or registry)	**4a** **C☐** **P☐** **M☐** **N☐**
4b. Electronic Sources 4b.1 **Are all the data elements available electronically?** (*elements that are needed to compute measure scores are in defined, computer-readable fields, e.g., electronic health record, electronic claims*) Yes 4b.2 **If not, specify the near-term path to achieve electronic capture by most providers.**	**4b** **C☐** **P☐** **M☐** **N☐**
4c. Exclusions 4c.1 **Do the specified exclusions require additional data sources beyond what is required for the numerator and denominator specifications?** No 4c.2 **If yes, provide justification.**	**4c** **C☐** **P☐** **M☐** **N☐** **NA ☐**
4d. Susceptibility to Inaccuracies, Errors, or Unintended Consequences 4d.1 **Identify susceptibility to inaccuracies, errors, or unintended consequences of the measure and describe how these potential problems could be audited. If audited, provide results.** Inaccuracies and Errors: This measure may be susceptible to human error (i.e., recording the measure inaccurately or not recording the measure at all) Unintended Consequences: One should be cautious in drawing conclusions from the observation of these measures, especially in circumstances where there is a declining morbidity and mortality. 1,2 1. Welke KF, Karamlou T, Ungerleider RM, Diggs BS. Mortality is not a valid indicator of quality differences between pediatric cardiac surgery programs. Ann Thoracic Surgery. (in press) 2. O'Brien SM, Gauvreau K. Statistical issues in the analysis and interpretation of outcomes for congenital cardiac surgery. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD	**4d** **C☐** **P☐** **M☐** **N☐**

Comment [KP26]: 4a. For clinical measures, required data elements are routinely generated concurrent with and as a byproduct of care processes during care delivery. (e.g., BP recorded in the electronic record, not abstracted from the record later by other personnel; patient self-assessment tools, e.g., depression scale; lab values, meds, etc.)

Comment [KP27]: 4b. The required data elements are available in electronic sources. If the required data are not in existing electronic sources, a credible, near-term path to electronic collection by most providers is specified and clinical data elements are specified for transition to the electronic health record.

Comment [KP28]: 4c. Exclusions should not require additional data sources beyond what is required for scoring the measure (e.g., numerator and denominator) unless justified as supporting measure validity.

Comment [KP29]: 4d. Susceptibility to inaccuracies, errors, or unintended consequences and the ability to audit the data items to detect such problems are identified.

(editor). Cardiology in the Young. 2008;18(Suppl.2):145–151.

naccuracies and Errors:
Each participant is responsible for the quality and accuracy of the data they submit to the database. Each participant agrees to the following quality control measures in the participation agreement:

i) "Participant hereby warrants that all data submitted for inclusion in the CHS Database will be accurate and complete, and acknowledges that such data may be subject to independent audit. Participant will use its best efforts to address any data or related deficiencies identified by the independent data warehouse service provider, and agrees to cooperate with and assist STS and its designees in connection with the performance of any independent audit.

ii) Participant warrants that it will take all reasonable steps to avoid the submission of duplicative data for inclusion in the CHS Database, including but not limited to apprising the Director of the STS National Database and the independent data warehouse service provider about any other Participation Agreements in which an individual cardiothoracic surgeon named above or on Schedule A attached hereto (as amended from time to time) is also named."

In addition, the Data warehouse and analysis center at Duke Clinical Research Institute, performs a series of internal quality controls on the submitted data and issues an annual data quality report

Unintended Consequences:
The Society of Thoracic Surgeons Database audit process is used. In addition, outliers can be identified with 95% confidence intervals based on the sample size with complexity stratification for one and four-year time intervals

4e. Data Collection Strategy/Implementation

4e.1 Describe what you have learned/modified as a result of testing and/or operational use of the measure regarding data collection, availability of data/missing data, timing/frequency of data collection, patient confidentiality, time/cost of data collection, other feasibility/ implementation issues:
Lessons Learned:
•The STS CHS database collects gender, race/ethnicity, age and geographic location information, so disparities and trends can be studied for populations at risk.
•Data elements required for the measure can be captured and the measure is actionable by the physician.
•There are no data availability issues.
•Cost to collect the data includes staff training and the use of specific software. However there are no additional costs over what a provider would pay to be a part of the STS CHS Database or other registry that collects this information.
•This measure can be used in a variety of care settings and at different levels of analysis (i.e. physician, hospital, etc.)
•Formal reliability testing was not done. Instead, the participant is bound by the participation agreement and his/her participation can be monitored by observing the data submitted on an annual basis.
•There are no confidentiality concerns. The data is de-identified, and the sites must be HIPAA compliant and obtain IRB approval for use of the database.
•The STS Congenital Quality Measures Sub-Committee meets at the STS Annual Meeting. The Subcommittee will review each STS congenital cardiac surgery measure on a yearly basis. Changes or updates to the measure will be at the recommendation of the committee.
• The STS has a yearly meeting (The Advances in Quality and Outcomes Conference) devoted to the Database for the clinicians and data coordinators.
•The audit process has demonstrated that data is very complete and accurate.1

1. Clarke DR, Breen LS, Jacobs ML, Franklin RCG, Tobota Z, Maruszewski B, Jacobs JP. Verification of data in congenital cardiac surgery. In: 2008 Cardiology in the Young Supplement: Databases and The Assessment of Complications associated with The Treatment of Patients with Congenital Cardiac Disease, Prepared by: The

4e
C☐
P☐
M☐
N☐

Comment [KP30]: 4e. Demonstration that the data collection strategy (e.g., source, timing, frequency, sampling, patient confidentiality, etc.) can be implemented (e.g., already in operational use, or testing demonstrates that it is ready to put into operational use).

Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, Jeffrey P. Jacobs, MD (editor). Cardiology in the Young. 2008;18(Suppl. 2):177–187. 4e.2 **Costs to implement the measure** (*costs of data collection, fees associated with proprietary measures*)**:** 4e.3 **Evidence for costs:** 4e.4 **Business case documentation:**	
TAP/Workgroup: What are the strengths and weaknesses in relation to the subcriteria for *Feasibility*?	**4**
Steering Committee: Overall, to what extent was the criterion, *Feasibility*, met? **Rationale:**	**4** **C☐** **P☐** **M☐** **N☐**
RECOMMENDATION	
(for NQF staff use) **Check if measure is untested and only eligible for time-limited endorsement.**	**Time-limited ☐**
Steering Committee: Do you recommend for endorsement? **Comments:**	**Y☐** **N☐** **A☐**

CONTACT INFORMATION

Co.1 **Measure Steward (Intellectual Property Owner)**
Co.1 **Organization**
The Society of Thoracic Surgeons, 633 N. Saint Clair St, Floor 23, Chicago, Illinois, 60611

Co.2 **Point of Contact**
Jane, Han, MSW, jhan@sts.org, 312-202-5856-

Measure Developer If different from Measure Steward
Co.3 **Organization**
The Society of Thoracic Surgeons, 633 North Saint Clair Street, Floor 23, Chicago, Illinois, 60611

Co.4 **Point of Contact**
Jeffrey, Jacobs, M.D., FACS, FACC, FCCP, jeffjacobs@msn.com, 727-822-6666-

Co.5 **Submitter If different from Measure Steward POC**
Jane, Han, MSW, jhan@sts.org, 312-202-5856-, The Society of Thoracic Surgeons

Co.6 **Additional organizations that sponsored/participated in measure development**

ADDITIONAL INFORMATION

Workgroup/Expert Panel involved in measure development
Ad.1 **Provide a list of sponsoring organizations and workgroup/panel members' names and organizations. Describe the members' role in measure development.**
The STS Task Force to Develop NQF Indicators for Pediatric and Congenital Cardiac Surgery members collectively formulated the numerator statement and defined its parameters in addition to identifying data elements and sources of data.

Ad.2 **If adapted, provide name of original measure:** At the NQF Surgery Steering Committee's request, this measure has been harmonized with PCS-007-09: Surgical Volume for Pediatric and Congenital Heart Surgery.

Ad.3-5 If adapted, provide original specifications URL or attachment
Measure Developer/Steward Updates and Ongoing Maintenance **Ad.6 Year the measure was first released:** 2009 **Ad.7 Month and Year of most recent revision:** 09, 2009 **Ad.8 What is your frequency for review/update of this measure?** once a year at annual meeting **Ad.9 When is the next scheduled review/update for this measure?** 01, 2012
Ad.10 Copyright statement/disclaimers:
Ad.11 -13 Additional Information web page URL or attachment:
Date of Submission (*MM/DD/YY*)**:** 07/12/2011

The Society of Thoracic Surgeons

Congenital Heart Surgery Database

Data Collection Form Version 3.0

September 16, 2009

ADMINISTRATIVE	
Participant ID:	STS Trial Link Number:

DEMOGRAPHICS			
Patient ID (software generated)	Patient SSN: __ __ __ - __ __ - __ __ __ __		MRN:
Health Insurance Claim Number:			
Patient Last Name:	Patient First Name:		Patient MI:
Patient Region:	Postal Code:		Country:
Birth City:	Birth Region:		Birth Country:
Mother's Last Name:	Mother's First Name:	Mother's MI:	Mother's SSN: __ __ __ - __ __ - __ __ __ __
DOB: *(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __	Birth Weight (kg):		Gender: ☐ M ☐ F ☐ Ambiguous
Premature Birth: ☐ Yes ☐ No	Gestational age at birth (in weeks):		

Race (select all that apply):	Caucasian:	☐ Yes ☐ No	Black/African American:	☐ Yes ☐ No	
	Asian:	☐ Yes ☐ No	Am Indian/Alaskan Nat:	☐ Yes ☐ No	
	Native Hawaiian/Pacific Islander:	☐ Yes ☐ No	Other:	☐ Yes ☐ No	
Hispanic or Latino Ethnicity	☐ Yes ☐ No				
Date of Last Follow- Up:	*(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __				
Last follow-up NYHA Classification:	☐ NYHA 1 ☐ NYHA 2 ☐ NYHA 3 ☐ NYHA 4				
Mortality Status at Last Follow - Up:	☐ Alive ☐ Dead				
Mortality Date:	*(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __				

NONCARDIAC CONGENITAL ANATOMIC ABNORMALITIES (select all that apply)

- ☐ 5 = None
- ☐ 10 = Anal Atresia (imperforate anus)
- ☐ 20 = Congenital diaphragmatic hernia (CDH)
- ☐ 30 = Gastroschisis
- ☐ 40 = Hirschsprung's disease (Congenital aganglionic megacolon)
- ☐ 50 = Intestinal malrotation
- ☐ 60 = Omphalocele
- ☐ 70 = Tracheoesophageal fistula (TEF)

CHROMOSOMAL ABNORMALITIES (select all that apply)

- ☐ 5 = No chromosomal abnormality identified
- ☐ 10 = 11p15.5
- ☐ 20 = 11q
- ☐ 30 = 12p1.21
- ☐ 40 = 12p12.1
- ☐ 50 = 12q24
- ☐ 60 = 15q21.1
- ☐ 70 = 1q42.1
- ☐ 80 = 20p12
- ☐ 90 = 22q11 deletion
- ☐ 100 = 2p21
- ☐ 110 = 3p22
- ☐ 120 = 45X0
- ☐ 130 = 47,XXY
- ☐ 140 = 4p
- ☐ 150 = 4p16
- ☐ 160 = 5p
- ☐ 170 = 6p12
- ☐ 180 = 7q11
- ☐ 190 = 7q11.23
- ☐ 200 = 7q32
- ☐ 210 = 7q34
- ☐ 220 = 8q12
- ☐ 230 = Monosomy X
- ☐ 240 = TGFBR1 or 2
- ☐ 250 = Trisomy 08
- ☐ 260 = Trisomy 09
- ☐ 270 = Trisomy 13
- ☐ 280 = Trisomy 18
- ☐ 290 = Trisomy 21
- ☐ 310 = Other chromosomal abnormality

SYNDROMES (select all that apply)

- ☐ 5 = No syndromic abnormality identified
- ☐ 10 = Alagille syndrome (intrahepatic biliary duct agenesis)
- ☐ 20 = Apert syndrome
- ☐ 30 = Brugada syndrome (Sudden unexplained nocturnal death syndrome) (SUNDS)
- ☐ 40 = Cardiofaciocutaneous syndrome
- ☐ 50 = Carpenter syndrome
- ☐ 60 = Cat-eye syndrome
- ☐ 70 = CHARGE Association
- ☐ 80 = Cornelia de Lange syndrome
- ☐ 90 = Costello syndrome
- ☐ 100 = Cri-du-chat syndrome
- ☐ 110 = Deletion 10p syndrome
- ☐ 120 = Deletion 8p syndrome
- ☐ 130 = DiGeorge syndrome (velocardiofacial syndrome) (conotruncal anomaly face syndrome) (22q11 deletion)
- ☐ 140 = Down syndrome (Trisomy 21)
- ☐ 150 =Edwards syndrome (Trisomy 18)
- ☐ 160 = Ellis-van Creveld syndrome
- ☐ 165 = Fetal alcohol syndrome (FAS)
- ☐ 166 = Fetal drug exposure
- ☐ 170 =Goldenhar syndrome
- ☐ 180 = Heterotaxy syndrome
- ☐ 190 = Heterotaxy syndrome, Asplenia syndrome
- ☐ 200 = Heterotaxy syndrome, Polysplenia syndrome
- ☐ 210 = Holt-Oram syndrome
- ☐ 220 = Jacobsen syndrome
- ☐ 230 = Kabuki syndrome
- ☐ 240 = Kartagener syndrome (Siewert syndrome) (Primary ciliary dyskinesia)
- ☐ 250 = Klinefelter syndrome (XXY Syndrome)
- ☐ 260 = LEOPARD syndrome
- ☐ 270 = Loeys-Dietz syndrome
- ☐ 280 = Long QT syndrome (Ward Romano syndrome)
- ☐ 290 = Marfan syndrome
- ☐ 300 = Marfan-like syndrome
- ☐ 310 = Mucopolysaccharidosis type IH (Hurler syndrome)
- ☐ 320 = Mucopolysaccharidosis type IH/S (Hurler-Scheie syndrome)
- ☐ 330 = Mucopolysaccharidosis type II (Hunter syndrome)
- ☐ 340 = Mucopolysaccharidosis type IS (Scheie syndrome)
- ☐ 350 = Noonan syndrome
- ☐ 360 = Patau syndrome (Trisomy 13)
- ☐ 370 = Rethore syndrome (Trisomy 9)
- ☐ 380 = Rubella
- ☐ 390 = Rubinstein-Taybi syndrome
- ☐ 400 = Short QT syndrome
- ☐ 410 = Situs inversus
- ☐ 420 = Smith-Lemli-Opitz syndrome
- ☐ 430 = Turner syndrome (45XO)
- ☐ 440 = VACTERL syndrome (VACTER/VATER/VATERR syndrome)
- ☐ 450 = VACTERL-H syndrome (VATER association with hydrocephalus) (Briard-Evans syndrome)
- ☐ 460 = Warkany syndrome (Trisomy 8)
- ☐ 470 = Williams syndrome (Williams-Beuren syndrome)
- ☐ 480 = Wolff-Parkinson-White syndrome (WPW syndrome)
- ☐ 490 = Wolf-Hirschhorn syndrome
- ☐ 510 = Other syndromic abnormality

HOSPITALIZATION

Hospital Name:	Hospital Zip Code:	Hospital State:
Hospital National Provider Identifier:		

Payor – *(Select all that apply)*

Government Health Insurance: ☐ Yes ☐ No *(If Yes, select all that apply: ↓)*

Medicare: ☐ Yes ☐ No *(If Yes →)* Medicare Fee For Service: ☐ Yes ☐ No

Medicaid: ☐ Yes ☐ No Military Health Care: ☐ Yes ☐ No

State-Specific Plan: ☐ Yes ☐ No Indian Health Service: ☐ Yes ☐ No

Commercial Health Insurance: ☐ Yes ☐ No

Health Maintenance Organization: ☐ Yes ☐ No

Non-U.S. Insurance: ☐ Yes ☐ No

None / Self: ☐ Yes ☐ No

Admission date: *(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __	Surgery date: *(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __	
Height (Cm):	Weight (Kg):	Age at time of surgery (in days):

PREOPERATIVE FACTORS (select all that apply)

- ☐ 10 = No preoperative factors identified
- ☐ 200 = Cardio-pulmonary resuscitation
- ☐ 210 = Preoperative complete AV block
- ☐ 220 = Preoperative/Preprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS)
- ☐ 230 = Shock, Persistent at time of surgery
- ☐ 240 = Shock, Resolved at time of surgery
- ☐ 250 = Diabetes mellitus, Insulin dependent
- ☐ 260 = Diabetes mellitus, Non-insulin dependent
- ☐ 270 = Hypothyroidism
- ☐ 280 = Currently taking steroids as treatment for adrenal insufficiency
- ☐ 290 = Currently taking steroids for any reason other than treatment of adrenal insufficiency
- ☐ 295 = Colostomy present
- ☐ 300 = Enterostomy of small intestine present
- ☐ 305 = Esophagostomy present
- ☐ 307 = Gastrostomy present
- ☐ 310 = Hepatic dysfunction
- ☐ 320 = Necrotizing entero-colitis, Treated medically
- ☐ 330 = Necrotizing entero-colitis, Treated surgically
- ☐ 340 = Coagulation disorder, Hypercoagulable state
- ☐ 350 = Coagulation disorder, Hypocoagulable state not secondary to medication (intrinsic hypocoagulable state)
- ☐ 360 = Coagulation disorder, Hypocoagulable state secondary to medication
- ☐ 370 = Endocarditis
- ☐ 380 = Sepsis
- ☐ 390 = Sepsis with positive blood culture
- ☐ 400 = Preoperative neurological deficit
- ☐ 410 = Seizure during lifetime
- ☐ 420 = Seizure within 48 hours prior to surgery
- ☐ 430 = Stroke, CVA, or Intracranial hemorrhage > Grade 2 during lifetime
- ☐ 440 = Stroke, CVA, or Intracranial hemorrhage > Grade 2 within 48 hours prior to surgery
- ☐ 450 = Renal dysfunction
- ☐ 460 = Renal failure requiring dialysis
- ☐ 470 = Mechanical ventilation to treat cardiorespiratory failure
- ☐ 480 = Respiratory Syncytial Virus
- ☐ 490 = Single lung
- ☐ 500 = Tracheostomy present
- ☐ 777 = Other preoperative factors

DIAGNOSIS

Antenatal Diagnosis of Congenital Heart Disease: ☐ Yes ☐ No

		Select ALL diagnosis that apply (↓)	CIRCLE the ONE PRIMARY diagnosis for this operation	Select the ONE FUNDAMENTAL diagnosis for this patient (↓)
Septal Defects	ASD	☐	10 = PFO	☐
		☐	20 = ASD, Secundum	☐
		☐	30 = ASD, Sinus venosus	☐
		☐	40 = ASD, Coronary sinus	☐
		☐	50 = ASD, Common atrium (single atrium)	☐
	VSD	☐	71 = VSD, Type 1 (Subarterial) (Supracristal) (Conal septal defect) (Infundibular)	☐
		☐	73 = VSD, Type 2 (Perimembranous) (Paramembranous) (Conoventricular)	☐
		☐	75 = VSD, Type 3 (Inlet) (AV canal type)	☐
		☐	77 = VSD, Type 4 (Muscular)	☐
		☐	79 = VSD, Type: Gerbode type (LV-RA communication)	☐
		☐	80 = VSD, Multiple	☐
	AV Canal	☐	100 = AVC (AVSD), Complete (CAVSD)	☐
		☐	110 = AVC (AVSD), Intermediate (transitional)	☐
		☐	120 = AVC (AVSD), Partial (incomplete) (PAVSD) (ASD, primum)	☐
	AP Window	☐	140 = AP window (aortopulmonary window)	☐
		☐	150 = Pulmonary artery origin from ascending aorta (hemitruncus)	☐
	Truncus Arteriosus	☐	160 = Truncus arteriosus	☐

		☐	170 = Truncal valve insufficiency	☐
		☐	2010 = Truncus arteriosus + Interrupted aortic arch	☐
Pulmonary Venous Anomalies	Partial Anomalous Pulmonary Venous Connection	☐	180 = Partial anomalous pulmonary venous connection (PAPVC)	☐
		☐	190 = Partial anomalous pulmonary venous connection (PAPVC), scimitar	☐
	Total Anomalous Pulmonary Venous Connection	☐	200 = Total anomalous pulmonary venous connection (TAPVC), Type 1 (supracardiac)	☐
		☐	210 = Total anomalous pulmonary venous connection (TAPVC), Type 2 (cardiac)	☐
		☐	220 = Total anomalous pulmonary venous connection (TAPVC), Type 3 (infracardiac)	☐
		☐	230 = Total anomalous pulmonary venous connection (TAPVC), Type 4 (mixed)	☐
Cor Triatriatum		☐	250 = Cor triatriatum	☐
Pulmonary Venous Stenosis		☐	260 = Pulmonary venous stenosis	☐
Systemic Venous Anomalies	Anomalous Systemic Venous Connection	☐	270 = Systemic venous anomaly	☐
	Systemic venous obstruction	☐	280 = Systemic venous obstruction	☐
Right Heart Lesions	Tetralogy of Fallot	☐	290 = TOF	☐
		☐	2140 = TOF, Pulmonary stenosis	☐
		☐	300 = TOF, AVC (AVSD)	☐
		☐	310 = TOF, Absent pulmonary valve	☐
	Pulmonary Atresia	☐	320 = Pulmonary atresia	☐
		☐	330 = Pulmonary atresia, IVS	☐
		☐	340 = Pulmonary atresia, VSD (Including TOF, PA)	☐
		☐	350 = Pulmonary atresia, VSD-MAPCA (pseudotruncus)	☐
		☐	360 = MAPCA(s) (major aortopulmonary collateral[s]) (without PA-VSD)	☐
	Tricuspid Valve Disease and Ebstein's Anomaly	☐	370 = Ebstein's anomaly	☐
		☐	380 = Tricuspid regurgitation, non-Ebstein's related	☐
		☐	390 = Tricuspid stenosis	☐
		☐	400 = Tricuspid regurgitation and tricuspid stenosis	☐
		☐	410 = Tricuspid valve, Other	☐
	RVOT Obstruction and/or Pulmonary Stenosis	☐	420 = Pulmonary stenosis, Valvar	☐
		☐	430 = Pulmonary artery stenosis (hypoplasia), Main (trunk)	☐
		☐	440 = Pulmonary artery stenosis, Branch, Central (within the hilar bifurcation)	☐
		☐	450 = Pulmonary artery stenosis, Branch, Peripheral (at or beyond the hilar bifurcation)	☐
		☐	470 = Pulmonary artery, Discontinuous	☐
		☐	490 = Pulmonary stenosis, Subvalvar	☐
		☐	500 = DCRV	☐
	Pulmonary Valve Disease	☐	510 = Pulmonary valve, Other	☐
		☐	530 = Pulmonary insufficiency	☐
		☐	540 = Pulmonary insufficiency and pulmonary stenosis	☐
Shunt failure	Shunt failure	☐	2130 = Shunt Failure	NA
Conduit failure	Conduit failure	☐	520 = Conduit failure	☐
Left Heart Lesions	Aortic Valve Disease	☐	550 = Aortic stenosis, Subvalvar	☐
		☐	560 = Aortic stenosis, Valvar	☐
		☐	570 = Aortic stenosis, Supravalvar	☐
		☐	590 = Aortic valve atresia	☐
		☐	600 = Aortic insufficiency	☐
		☐	610 = Aortic insufficiency and aortic stenosis	☐
		☐	620 = Aortic valve, Other	☐
	Sinus of Valsalva Fistula/Aneurysm	☐	630 = Sinus of Valsalva aneurysm	☐
	LV to Aorta Tunnel	☐	640 = LV to aorta tunnel	☐

	Mitral Valve Disease	☐	650 = Mitral stenosis, Supravalvar mitral ring	☐
		☐	660 = Mitral stenosis, Valvar	☐
		☐	670 = Mitral stenosis, Subvalvar	☐
		☐	680 = Mitral stenosis, Subvalvar, Parachute	☐
		☐	695 = Mitral stenosis	☐
		☐	700 = Mitral regurgitation and mitral stenosis	☐
		☐	710 = Mitral regurgitation	☐
		☐	720 = Mitral valve, Other	☐
	Hypoplastic Left Heart Syndrome	☐	730 = Hypoplastic left heart syndrome (HLHS)	☐
	Shone's syndrome	☐	2080 = Shone's syndrome *{CAN NOT BE PRIMARY DIAGNOSIS}*	☐
Cardiomyopathy		☐	740 = Cardiomyopathy (including dilated, restrictive, and hypertrophic)	☐
		☐	750 = Cardiomyopathy, End-stage congenital heart disease	☐
Pericardial Disease		☐	760 = Pericardial effusion	☐
		☐	770 = Pericarditis	☐
		☐	780 = Pericardial disease, Other	☐
Single Ventricle		☐	790 = Single ventricle, DILV	☐
		☐	800 = Single ventricle, DIRV	☐
		☐	810 = Single ventricle, Mitral atresia	☐
		☐	820 = Single ventricle, Tricuspid atresia	☐
		☐	830 = Single ventricle, Unbalanced AV canal	☐
		☐	840 = Single ventricle, Heterotaxia syndrome	☐
		☐	850 = Single ventricle, Other	☐
		☐	851 = Single Ventricle + Total anomalous pulmonary venous connection (TAPVC)	☐
Transposition of the Great Arteries	Congenitally Corrected TGA	☐	870 = Congenitally corrected TGA	☐
		☐	872 = Congenitally corrected TGA, IVS	☐
		☐	874 = Congenitally corrected TGA, IVS-LVOTO	☐
		☐	876 = Congenitally corrected TGA, VSD	☐
		☐	878 = Congenitally corrected TGA, VSD-LVOTO	☐
	Transposition of the Great Arteries	☐	880 = TGA, IVS	☐
		☐	890 = TGA, IVS-LVOTO	☐
		☐	900 = TGA, VSD	☐
		☐	910 = TGA, VSD-LVOTO	☐
DORV		☐	930 = DORV, VSD type	☐
		☐	940 = DORV, TOF type	☐
		☐	950 = DORV, TGA type	☐
		☐	960 = DORV, Remote VSD (uncommitted VSD)	☐
		☐	2030 = DORV + AVSD (AV Canal)	☐
		☐	975 = DORV, IVS	☐
DOLV		☐	980 = DOLV	☐
Thoracic Arteries and Veins	Coarctation of Aorta and Aortic arch hypoplasia	☐	990 = Coarctation of aorta	☐
		☐	1000 = Aortic arch hypoplasia	☐
		☐	92 = VSD + Aortic arch hypoplasia	☐
		☐	94 = VSD + Coarctation of aorta	☐
	Coronary Artery Anomalies	☐	1010 = Coronary artery anomaly, Anomalous aortic origin of coronary artery from aorta (AAOCA)	☐
		☐	1020 = Coronary artery anomaly, Anomalous pulmonary origin (includes ALCAPA)	☐
		☐	1030 = Coronary artery anomaly, Fistula	☐
		☐	1040 = Coronary artery anomaly, Aneurysm	☐
		☐	1050 = Coronary artery anomaly, Other	☐
	Interrupted Arch	☐	1070 = Interrupted aortic arch	☐

		☐	2020 = Interrupted aortic arch + VSD	☐
		☐	2000 = Interrupted aortic arch + AP window (aortopulmonary window)	☐
	Patent Ductus Arteriosus	☐	1080 = Patent ductus arteriosus	☐
	Vascular rings and Slings	☐	1090 = Vascular ring	☐
		☐	1100 = Pulmonary artery sling	☐
	Aortic Aneurysm	☐	1110 = Aortic aneurysm (including pseudoaneurysm)	☐
	Aortic Dissection	☐	1120 = Aortic dissection	☐
Thoracic and Mediastinal Disease	Lung Disease	☐	1130 = Lung disease, Benign	☐
		☐	1140 = Lung disease, Malignant	☐
	Pectus Excavatum, Carinatum	☐	1150 = Pectus	☐
	Tracheal Stenosis	☐	1160 = Tracheal stenosis	☐
		☐	1170 = Airway disease	☐
	Pleural Disease	☐	1430 = Pleural disease, Benign	☐
		☐	1440 = Pleural disease, Malignant	☐
		☐	1450 = Pneumothorax	☐
		☐	1460 = Pleural effusion	☐
		☐	1470 = Chylothorax	☐
		☐	1480 = Empyema	☐
	Esophageal Disease	☐	1490 = Esophageal disease, Benign	☐
		☐	1500 = Esophageal disease, Malignant	☐
	Mediastinal Disease	☐	1505 = Mediastinal disease	☐
		☐	1510 = Mediastinal disease, Benign	☐
		☐	1520 = Mediastinal disease, Malignant	☐
	Diaphragmatic Disease	☐	1540 = Diaphragm paralysis	☐
		☐	1550 = Diaphragm disease, Other	☐
Electrophysiological		☐	1180 = Arrhythmia	☐
		☐	2040 = Arrhythmia, Atrial	☐
		☐	2050 = Arrhythmia, Junctional	☐
		☐	2060 = Arrhythmia, Ventricular	☐
		☐	1185 = Arrhythmia, Heart block	☐
		☐	1190 = Arrhythmia, Heart block, Acquired	☐
		☐	1200 = Arrhythmia, Heart block, Congenital	☐
		☐	1220 = Arrhythmia, Pacemaker, Indication for replacement	☐
Miscellaneous, Other		☐	1230 = Atrial Isomerism, Left *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	1240 = Atrial Isomerism, Right *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	2090 = Dextrocardia *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	2100 = Levocardia *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	2110 = Mesocardia *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	2120 = Situs inversus *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	1250 = Aneurysm, Ventricular, Right (including pseudoaneurysm)	☐
		☐	1260 = Aneurysm, Ventricular, Left (including pseudoaneurysm)	☐
		☐	1270 = Aneurysm, Pulmonary artery	☐
		☐	1280 = Aneurysm, Other	☐
		☐	1290 = Hypoplastic RV	☐
		☐	1300 = Hypoplastic LV	☐
		☐	2070 = Postoperative bleeding	☐
		☐	1310 = Mediastinitis	☐
		☐	1320 = Endocarditis	☐
		☐	1325 = Rheumatic heart disease *{CAN NOT BE PRIMARY DIAGNOSIS}*	NA
		☐	1330 = Prosthetic valve failure	☐

		☐ 1340 = Myocardial infarction	☐
		☐ 1350 = Cardiac tumor	☐
		☐ 1360 = Pulmonary AV fistula	☐
		☐ 1370 = Pulmonary embolism	☐
		☐ 1385 = Pulmonary vascular obstructive disease	☐
		☐ 1390 = Pulmonary vascular obstructive disease (Eisenmenger's)	☐
		☐ 1400 = Primary pulmonary hypertension	☐
		☐ 1410 = Persistent fetal circulation	☐
		☐ 1420 = Meconium aspiration	☐
		☐ 1560 = Cardiac, Other	☐
		☐ 1570 = Thoracic and/or mediastinal, Other	☐
		☐ 1580 = Peripheral vascular, Other	☐
		☐ 7000 = Normal heart	☐
		☐ 7777 = Miscellaneous, Other	☐
STATUS POST (No "Status post – diagnoses" can be a primary diagnosis or fundamental diagnosis)			
Septal Defects	ASD	☐ 4010 = Status post - PFO, Primary closure	
		☐ 4020 = Status post - ASD repair, Primary closure	
		☐ 4030 = Status post - ASD repair, Patch	
		☐ 4040 = Status post - ASD repair, Device	
		☐ 6110 = Status post - ASD repair, Patch + PAPVC repair	
		☐ 4050 = Status post - ASD, Common atrium (single atrium), Septation	
		☐ 4060 = Status post - ASD creation/enlargement	
		☐ 4070 = Status post - ASD partial closure	
		☐ 4080 = Status post - Atrial septal fenestration	
		☐ 4085 = Status post - Atrial fenestration closure	
	VSD	☐ 4100 = Status post - VSD repair, Primary closure	
		☐ 4110 = Status post - VSD repair, Patch	
		☐ 4120 = Status post - VSD repair, Device	
		☐ 4130 = Status post - VSD, Multiple, Repair	
		☐ 4140 = Status post - VSD creation/enlargement	
		☐ 4150 = Status post - Ventricular septal fenestration	
	AV Canal	☐ 4170 = Status post - AVC (AVSD) repair, Complete (CAVSD)	
		☐ 4180 = Status post - AVC (AVSD) repair, Intermediate (Transitional)	
		☐ 4190 = Status post - AVC (AVSD) repair, Partial (Incomplete) (PAVSD)	
		☐ 6300 = Status post - Valvuloplasty, Common atrioventricular valve	
		☐ 6250 = Status post - Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve	
		☐ 6230 = Status post - Valve replacement, Common atrioventricular valve	
	AP Window	☐ 4210 = Status post - AP window repair	
		☐ 4220 = Status post - Pulmonary artery origin from ascending aorta (hemitruncus) repair	
	Truncus Arteriosus	☐ 4230 = Status post - Truncus arteriosus repair	
		☐ 4240 = Status post - Valvuloplasty, Truncal valve	
		☐ 6290 = Status post - Valvuloplasty converted to valve replacement in the same operation, Truncal valve	
		☐ 4250 = Status post - Valve replacement, Truncal valve	
		☐ 6220 = Status post - Truncus + Interrupted aortic arch repair (IAA) repair	
Pulmonary Venous Anomalies	Partial Anomalous Pulmonary Venous Connection	☐ 4260 = Status post - PAPVC repair	
		☐ 4270 = Status post - PAPVC, Scimitar, Repair	
		☐ 6120 = Status post - PAPVC repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	

	Total Anomalous Pulmonary Venous Connection	☐ 4280 = Status post - TAPVC repair ☐ 6200 = Status post - TAPVC repair + Shunt - systemic-to-pulmonary
Cor Triatriatum		☐ 4290 = Status post - Cor triatriatum repair
Pulmonary Venous Stenosis		☐ 4300 = Status post - Pulmonary venous stenosis repair
Systemic Venous Anomalies	Anomalous Systemic Venous Connection	☐ 4310 = Status post - Atrial baffle procedure (non-Mustard, non-Senning) ☐ 4330 = Status post - Anomalous systemic venous connection repair
	Systemic venous obstruction	☐ 4340 = Status post - Systemic venous stenosis repair
Right Heart Lesions	Tetralogy of Fallot	☐ 4350 = Status post - TOF repair, No ventriculotomy ☐ 4360 = Status post - TOF repair, Ventriculotomy, Nontransanular patch ☐ 4370 = Status post - TOF repair, Ventriculotomy, Transanular patch ☐ 4380 = Status post - TOF repair, RV-PA conduit ☐ 4390 = Status post - TOF - AVC (AVSD) repair ☐ 4400 = Status post - TOF - Absent pulmonary valve repair
	Pulmonary Atresia	☐ 4420 = Status post - Pulmonary atresia - VSD (including TOF, PA) repair ☐ 4430 = Status post - Pulmonary atresia - VSD - MAPCA (pseudotruncus) repair ☐ 4440 = Status post - Unifocalization MAPCA(s) ☐ 4450 = Status post - Occlusion MAPCA(s)
	Tricuspid Valve Disease and Ebstein's Anomaly	☐ 4460 = Status post - Valvuloplasty, Tricuspid ☐ 6280 = Status post - Valvuloplasty converted to valve replacement in the same operation, Tricuspid ☐ 4465 = Status post - Ebstein's repair ☐ 4470 = Status post - Valve replacement, Tricuspid (TVR) ☐ 4480 = Status post - Valve closure, Tricuspid (exclusion, univentricular approach) ☐ 4490 = Status post - Valve excision, Tricuspid (without replacement) ☐ 4500 = Status post - Valve surgery, Other, Tricuspid
	RVOT Obstruction, IVS Pulmonary Stenosis	☐ 4510 = Status post - RVOT procedure ☐ 4520 = Status post - 1 1/2 ventricular repair ☐ 4530 = Status post - PA, reconstruction (plasty), Main (trunk) ☐ 4540 = Status post - PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation) ☐ 4550 = Status post - PA, reconstruction (plasty), Branch, Peripheral (at or beyond the hilar bifurcation) ☐ 4570 = Status post - DCRV repair
	Pulmonary Valve Disease	☐ 4590 = Status post - Valvuloplasty, Pulmonic ☐ 6270 = Status post - Valvuloplasty converted to valve replacement in the same operation, Pulmonic ☐ 4600 = Status post - Valve replacement, Pulmonic (PVR) ☐ 4630 = Status post - Valve excision, Pulmonary (without replacement) ☐ 4640 = Status post - Valve closure, Semilunar ☐ 4650 = Status post - Valve surgery, Other, Pulmonic
Conduit operations	Conduit operations	☐ 4610 = Status post - Conduit placement, RV to PA ☐ 4620 = Status post - Conduit placement, LV to PA ☐ 5774 = Status post - Conduit placement, Ventricle to aorta ☐ 5772 = Status post - Conduit placement, Other
	Conduit Stenosis / Insufficiency	☐ 4580 = Status post - Conduit reoperation
Left Heart Lesions	Aortic Valve Disease	☐ 4660 = Status post - Valvuloplasty, Aortic ☐ 6240 = Status post - Valvuloplasty converted to valve replacement in the same operation, Aortic ☐ 6310 = Status post - Valvuloplasty converted to valve replacement in the same operation, Aortic – with Ross procedure ☐ 6320 = Status post - Valvuloplasty converted to valve replacement in the same operation, Aortic – with Ross-Konno procedure ☐ 4670 = Status post - Valve replacement, Aortic (AVR)

		☐ 4680 = Status post - Valve replacement, Aortic (AVR), Mechanical
		☐ 4690 = Status post - Valve replacement, Aortic (AVR), Bioprosthetic
		☐ 4700 = Status post - Valve replacement, Aortic (AVR), Homograft
		☐ 4715 = Status post - Aortic root replacement, Bioprosthetic
		☐ 4720 = Status post - Aortic root replacement, Mechanical
		☐ 4730 = Status post - Aortic root replacement, Homograft
		☐ 4735 = Status post - Aortic root replacement, Valve sparing
		☐ 4740 = Status post - Ross procedure
		☐ 4750 = Status post - Konno procedure
		☐ 4760 = Status post - Ross-Konno procedure
		☐ 4770 = Status post - Other annular enlargement procedure
		☐ 4780 = Status post - Aortic stenosis, Subvalvar, Repair
		☐ 6100 = Status post - Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS
		☐ 4790 = Status post - Aortic stenosis, Supravalvar, Repair
		☐ 4800 = Status post - Valve surgery, Other, Aortic
	Sinus of Valsalva Aneurysm	☐ 4810 = Status post - Sinus of Valsalva, Aneurysm repair
	LV to Aorta Tunnel	☐ 4820 = Status post - LV to aorta tunnel repair
	Mitral Valve Disease	☐ 4830 = Status post - Valvuloplasty, Mitral
		☐ 6260 = Status post - Valvuloplasty converted to valve replacement in the same operation, Mitral
		☐ 4840 = Status post - Mitral stenosis, Supravalvar mitral ring repair
		☐ 4850 = Status post - Valve replacement, Mitral (MVR)
		☐ 4860 = Status post - Valve surgery, Other, Mitral
	Hypoplastic Left Heart	☐ 4870 = Status post - Norwood procedure
		☐ 4880 = Status post - HLHS biventricular repair
		☐ 6160 = Status post - Hybrid Approach "Stage 1", Application of RPA & LPA bands
		☐ 6170 = Status post - Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA)
		☐ 6180 = Status post - Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) + application of RPA & LPA bands
		☐ 6140 = Status post - Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)
		☐ 6150 = Status post - Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair
Cardiomyopathy		☐ 1590 = Status post - Transplant, Heart
		☐ 1610 = Status post - Transplant, Heart and lung
		☐ 4910 = Status post - Partial left ventriculectomy (LV volume reduction surgery) (Batista)
Pericardial Disease		☐ 4920 = Status post - Pericardial drainage procedure
		☐ 4930 = Status post - Pericardiectomy
		☐ 4940 = Status post - Pericardial procedure, Other
Single Ventricle		☐ 4950 = Status post - Fontan, Atrio-pulmonary connection
		☐ 4960 = Status post - Fontan, Atrio-ventricular connection
		☐ 4970 = Status post - Fontan, TCPC, Lateral tunnel, Fenestrated
		☐ 4980 = Status post - Fontan, TCPC, Lateral tunnel, Nonfenestrated
		☐ 5000 = Status post - Fontan, TCPC, External conduit, Fenestrated
		☐ 5010 = Status post - Fontan, TCPC, External conduit, Nonfenestrated
		☐ 5025 = Status post - Fontan revision or conversion (Re-do Fontan)
		☐ 5030 = Status post - Fontan, Other
		☐ 6340 = Status post - Fontan + Atrioventricular valvuloplasty
		☐ 5035 = Status post - Ventricular septation

Transposition of the Great Arteries	Congenitally Corrected TGA	☐ 5050 = Status post - Congenitally corrected TGA repair, Atrial switch and ASO (double switch) ☐ 5060 = Status post - Congenitally corrected TGA repair, Atrial switch and Rastelli ☐ 5070 = Status post - Congenitally corrected TGA repair, VSD closure ☐ 5080 = Status post - Congenitally corrected TGA repair, VSD closure and LV to PA conduit ☐ 5090 = Status post - Congenitally corrected TGA repair, Other
	Transposition of the Great Arteries	☐ 5110 = Status post - Arterial switch operation (ASO) ☐ 5120 = Status post - Arterial switch operation (ASO) and VSD repair ☐ 5123 = Status post - Arterial switch procedure + Aortic arch repair ☐ 5125 = Status post - Arterial switch procedure and VSD repair + Aortic arch repair ☐ 5130 = Status post - Senning ☐ 5140 = Status post - Mustard ☐ 5145 = Status post - Atrial baffle procedure, Mustard or Senning revision ☐ 5150 = Status post - Rastelli ☐ 5160 = Status post - REV ☐ 6190 = Status post - Aortic root translocation over left ventricle (Including Nikaidoh procedure) ☐ 6210 = Status post - TGA, Other procedures (Kawashima, LV-PA conduit, other)
DORV		☐ 5180 = Status post - DORV, Intraventricular tunnel repair
DOLV		☐ 5200 = Status post - DOLV repair
Thoracic Arteries and Veins	Coarctation of Aorta and Aortic arch hypoplasia	☐ 5210 = Status post - Coarctation repair, End to end ☐ 5220 = Status post - Coarctation repair, End to end, Extended ☐ 5230 = Status post - Coarctation repair, Subclavian flap ☐ 5240 = Status post - Coarctation repair, Patch aortoplasty ☐ 5250 = Status post - Coarctation repair, Interposition graft ☐ 5260 = Status post - Coarctation repair, Other ☐ 5275 = Status post - Coarctation repair + VSD repair ☐ 5280 = Status post - Aortic arch repair ☐ 5285 = Status post - Aortic arch repair + VSD repair
	Coronary Artery Anomalies	☐ 5290 = Status post - Coronary artery fistula ligation ☐ 5291 = Status post - Anomalous origin of coronary artery from pulmonary artery repair ☐ 5300 = Status post - Coronary artery bypass ☐ 5305 = Status post - Anomalous aortic origin of coronary artery from aorta (AAOCA) repair ☐ 5310 = Status post - Coronary artery procedure, Other
	Interrupted Arch	☐ 5320 = Status post - Interrupted aortic arch repair
	Patent Ductus Arteriosus	☐ 5330 = Status post - PDA closure, Surgical ☐ 5340 = PDA closure, Device
	Vascular Rings and Slings	☐ 5360 = Status post - Vascular ring repair ☐ 5365 = Status post - Aortopexy ☐ 5370 = Status post - Pulmonary artery sling repair
	Aortic Aneurysm	☐ 5380 = Status post - Aortic aneurysm repair
	Aortic Dissection	☐ 5390 = Status post - Aortic dissection repair
Thoracic and Mediastinal Disease	Lung Disease	☐ 5400 = Status post - Lung biopsy ☐ 1600 = Status post - Transplant, lung(s) ☐ 5420 = Status post - Lung procedure, Other
	Pectus Excavatum, Carinatum	☐ 5430 = Status post - Pectus repair
	Tracheal Stenosis	☐ 5440 = Status post - Tracheal procedure
Electrophysiological		☐ 5450 = Status post - Pacemaker implantation, Permanent ☐ 5460 = Status post - Pacemaker procedure ☐ 6350 = Status post - Explantation of pacing system

	☐ 5470 = Status post - ICD (AICD) implantation ☐ 5480 = Status post - ICD (AICD) ([automatic] implantable cardioverter defibrillator) procedure ☐ 5490 = Status post - Arrhythmia surgery - atrial, Surgical Ablation ☐ 5500 = Status post - Arrhythmia surgery - ventricular, Surgical Ablation
Interventional Cardiology Procedures	☐ 6500 = Status post - Cardiovascular catheterization procedure, Diagnostic ☐ 6520 = Status post - Cardiovascular catheterization procedure, Diagnostic, Angiographic data obtained ☐ 6550 = Status post - Cardiovascular catheterization procedure, Diagnostic, Electrophysiology alteration ☐ 6540 = Status post - Cardiovascular catheterization procedure, Diagnostic, Hemodynamic alteration ☐ 6510 = Status post - Cardiovascular catheterization procedure, Diagnostic, Hemodynamic data obtained ☐ 6530 = Status post - Cardiovascular catheterization procedure, Diagnostic, Transluminal test occlusion ☐ 6410 = Status post - Cardiovascular catheterization procedure, Therapeutic ☐ 6670 = Status post - Cardiovascular catheterization procedure, Therapeutic, Adjunctive therapy ☐ 6570 = Status post - Cardiovascular catheterization procedure, Therapeutic, Balloon dilation ☐ 6590 = Status post - Cardiovascular catheterization procedure, Therapeutic, Balloon valvotomy ☐ 6600 = Status post - Cardiovascular catheterization procedure, Therapeutic, Coil implantation ☐ 6610 = Status post - Cardiovascular catheterization procedure, Therapeutic, Device implantation ☐ 6640 = Status post - Cardiovascular catheterization procedure, Therapeutic, Perforation (establishing interchamber and/or intervessel communication) ☐ 6580 = Status post - Cardiovascular catheterization procedure, Therapeutic, Septostomy ☐ 6620 = Status post - Cardiovascular catheterization procedure, Therapeutic, Stent insertion ☐ 6630 = Status post - Cardiovascular catheterization procedure, Therapeutic, Stent re-dilation ☐ 6650 = Status post - Cardiovascular catheterization procedure, Therapeutic, Transcatheter Fontan completion ☐ 6660 = Status post - Cardiovascular catheterization procedure, Therapeutic, Transcatheter implantation of valve ☐ 6680 = Status post - Cardiovascular electrophysiological catheterization procedure ☐ 6690 = Status post - Cardiovascular electrophysiological catheterization procedure, Therapeutic ablation
Palliative Procedures	☐ 5590 = Status post - Shunt, Systemic to pulmonary, Modified Blalock-Taussig Shunt (MBTS) ☐ 5600 = Status post - Shunt, Systemic to pulmonary, Central (from aorta or to main pulmonary artery) ☐ 5610 = Status post - Shunt, Systemic to pulmonary, Other ☐ 5630 = Status post - Shunt, Ligation and takedown ☐ 6095 = Status post - Shunt, Reoperation ☐ 5640 = Status post - PA banding (PAB) ☐ 5650 = Status post - PA debanding ☐ 5660 = Status post - Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction) ☐ 5670 = Status post - Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn) ☐ 5680 = Status post - Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn) ☐ 5690 = Status post - Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn) ☐ 5700 = Status post - HemiFontan ☐ 6330 = Status post - Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty ☐ 6130 = Status post - Superior Cavopulmonary anastomosis(es) + PA reconstruction ☐ 5710 = Status post - Palliation, Other
Mechanical Support	☐ 6360 = Status post - ECMO cannulation ☐ 6370 = Status post - ECMO decannulation ☐ 5910 = Status post - ECMO procedure ☐ 5900 = Status post - Intraaortic balloon pump (IABP) insertion

		☐ 5920 = Status post - Right/left heart assist device procedure ☐ 6390 = Status post - VAD explantation ☐ 6380 = Status post - VAD implantation
Anesthetic procedures		☐ 6420 = Status post - Echocardiography procedure, Sedated transesophageal echocardiogram ☐ 6430 = Status post - Echocardiography procedure, Sedated transthoracic echocardiogram ☐ 6435 = Status post - Non-cardiovascular, Non-thoracic procedure on cardiac patient with cardiac anesthesia ☐ 6440 = Status post - Radiology procedure on cardiac patient, Cardiac Computerized Axial Tomography (CT Scan) ☐ 6450 = Status post - Radiology procedure on cardiac patient, Cardiac Magnetic Resonance Imaging (MRI) ☐ 6460 = Status post - Radiology procedure on cardiac patient, Diagnostic radiology ☐ 6470 = Status post - Radiology procedure on cardiac patient, Non-Cardiac Computerized Tomography (CT) on cardiac patient ☐ 6480 = Status post - Radiology procedure on cardiac patient, Non-cardiac Magnetic Resonance Imaging (MRI) on cardiac patient ☐ 6490 = Status post - Interventional radiology procedure on cardiac patient
Miscellaneous Procedures		☐ 5720 = Status post - Aneurysm, Ventricular, Right, Repair ☐ 5730 = Status post - Aneurysm, Ventricular, Left, Repair ☐ 5740 = Status post - Aneurysm, Pulmonary artery, Repair ☐ 5760 = Status post - Cardiac tumor resection ☐ 5780 = Status post - Pulmonary AV fistula repair/occlusion ☐ 5790 = Status post - Ligation, Pulmonary artery ☐ 5802 = Status post - Pulmonary embolectomy, Acute pulmonary embolus ☐ 5804 = Status post - Pulmonary embolectomy, Chronic pulmonary embolus ☐ 5810 = Status post - Pleural drainage procedure ☐ 5820 = Status post - Pleural procedure, Other ☐ 5830 = Status post - Ligation, Thoracic duct ☐ 5840 = Status post - Decortication ☐ 5850 = Status post - Esophageal procedure ☐ 5860 = Status post - Mediastinal procedure ☐ 5870 = Status post - Bronchoscopy ☐ 5880 = Status post - Diaphragm plication ☐ 5890 = Status post - Diaphragm procedure, Other ☐ 5930 = Status post - VATS (video-assisted thoracoscopic surgery) ☐ 5940 = Status post - Minimally invasive procedure ☐ 5950 = Status post - Bypass for noncardiac lesion ☐ 5960 = Status post - Delayed sternal closure ☐ 5970 = Status post - Mediastinal exploration ☐ 5980 = Status post - Sternotomy wound drainage ☐ 5990 = Status post - Thoracotomy, Other ☐ 6000 = Status post - Cardiotomy, Other ☐ 6010 = Status post - Cardiac procedure, Other ☐ 6020 = Status post - Thoracic and/or mediastinal procedure, Other ☐ 6030 = Status post - Peripheral vascular procedure, Other ☐ 6040 = Status post - Miscellaneous procedure, Other ☐ 6050 = Status post - Organ procurement ☐ 11777 = Status post - Other procedure

PROCEDURES		
Select ALL procedures that apply. (↓)		Circle the ONE PRIMARY procedure for this operation.
Septal Defects	ASD	☐ 10 = PFO, Primary closure ☐ 20 = ASD repair, Primary closure ☐ 30 = ASD repair, Patch

		☐ 40 = ASD repair, Device
		☐ 2110 = ASD repair, Patch + PAPVC repair
		☐ 50 = ASD, Common atrium (single atrium), Septation
		☐ 60 = ASD creation/enlargement
		☐ 70 = ASD partial closure
		☐ 80 = Atrial septal fenestration
		☐ 85 = Atrial fenestration closure
	VSD	☐ 100 = VSD repair, Primary closure
		☐ 110 = VSD repair, Patch
		☐ 120 = VSD repair, Device
		☐ 130 = VSD, Multiple, Repair
		☐ 140 = VSD creation/enlargement
		☐ 150 = Ventricular septal fenestration
	AV Canal	☐ 170 = AVC (AVSD) repair, Complete (CAVSD)
		☐ 180 = AVC (AVSD) repair, Intermediate (Transitional)
		☐ 190 = AVC (AVSD) repair, Partial (Incomplete) (PAVSD)
		☐ 2300 = Valvuloplasty, Common atrioventricular valve
		☐ 2250 = Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve
		☐ 2230 = Valve replacement, Common atrioventricular valve
	AP Window	☐ 210 = AP window repair
		☐ 220 = Pulmonary artery origin from ascending aorta (hemitruncus) repair
	Truncus Arteriosus	☐ 230 = Truncus arteriosus repair
		☐ 240 = Valvuloplasty, Truncal valve
		☐ 2290 = Valvuloplasty converted to valve replacement in the same operation, Truncal valve
		☐ 250 = Valve replacement, Truncal valve
		☐ 2220 = Truncus + Interrupted aortic arch repair (IAA) repair
Pulmonary Venous Anomalies	Partial Anomalous Pulmonary Venous Connection	☐ 260 = PAPVC repair
		☐ 270 = PAPVC, Scimitar, Repair
		☐ 2120 = PAPVC repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)
	Total Anomalous Pulmonary Venous Connection	☐ 280 = TAPVC repair
		☐ 2200 = TAPVC repair + Shunt - systemic-to-pulmonary
Cor Triatriatum		☐ 290 = Cor triatriatum repair
Pulmonary Venous Stenosis		☐ 300 = Pulmonary venous stenosis repair
Systemic Venous Anomalies	Anomalous Systemic Venous Connection	☐ 310 = Atrial baffle procedure (non-Mustard, non-Senning)
		☐ 330 = Anomalous systemic venous connection repair
	Systemic venous obstruction	☐ 340 = Systemic venous stenosis repair
Right Heart Lesions	Tetralogy of Fallot	☐ 350 = TOF repair, No ventriculotomy
		☐ 360 = TOF repair, Ventriculotomy, Nontransanular patch
		☐ 370 = TOF repair, Ventriculotomy, Transanular patch
		☐ 380 = TOF repair, RV-PA conduit
		☐ 390 = TOF - AVC (AVSD) repair
		☐ 400 = TOF - Absent pulmonary valve repair
	Pulmonary Atresia	☐ 420 = Pulmonary atresia - VSD (including TOF, PA) repair
		☐ 430 = Pulmonary atresia - VSD - MAPCA (pseudotruncus) repair
		☐ 440 = Unifocalization MAPCA(s)
		☐ 450 = Occlusion MAPCA(s)
	Tricuspid Valve Disease and Ebstein's Anomaly	☐ 460 = Valvuloplasty, Tricuspid
		☐ 2280 = Valvuloplasty converted to valve replacement in the same operation, Tricuspid

		☐ 465 = Ebstein's repair
		☐ 470 = Valve replacement, Tricuspid (TVR)
		☐ 480 = Valve closure, Tricuspid (exclusion, univentricular approach)
		☐ 490 = Valve excision, Tricuspid (without replacement)
		☐ 500 = Valve surgery, Other, Tricuspid
	RVOT Obstruction, IVS Pulmonary Stenosis	☐ 510 = RVOT procedure
		☐ 520 = 1 1/2 ventricular repair
		☐ 530 = PA, reconstruction (plasty), Main (trunk)
		☐ 540 = PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)
		☐ 550 = PA, reconstruction (plasty), Branch, Peripheral (at or beyond the hilar bifurcation)
		☐ 570 = DCRV repair
	Pulmonary Valve Disease	☐ 590 = Valvuloplasty, Pulmonic
		☐ 2270 = Valvuloplasty converted to valve replacement in the same operation, Pulmonic
		☐ 600 = Valve replacement, Pulmonic (PVR)
		☐ 630 = Valve excision, Pulmonary (without replacement)
		☐ 640 = Valve closure, Semilunar
		☐ 650 = Valve surgery, Other, Pulmonic
Conduit operations	Conduit operations	☐ 610 = Conduit placement, RV to PA
		☐ 620 = Conduit placement, LV to PA
		☐ 1774 = Conduit placement, Ventricle to aorta
		☐ 1772 = Conduit placement, Other
	Conduit Stenosis / Insufficiency	☐ 580 = Conduit reoperation
Left Heart Lesions	Aortic Valve Disease	☐ 660 = Valvuloplasty, Aortic
		☐ 2240 = Valvuloplasty converted to valve replacement in the same operation, Aortic
		☐ 2310 = Valvuloplasty converted to valve replacement in the same operation, Aortic – with Ross procedure
		☐ 2320 = Valvuloplasty converted to valve replacement in the same operation, Aortic – with Ross-Konno procedure
		☐ 670 = Valve replacement, Aortic (AVR)
		☐ 680 = Valve replacement, Aortic (AVR), Mechanical
		☐ 690 = Valve replacement, Aortic (AVR), Bioprosthetic
		☐ 700 = Valve replacement, Aortic (AVR), Homograft
		☐ 715 = Aortic root replacement, Bioprosthetic
		☐ 720 = Aortic root replacement, Mechanical
		☐ 730 = Aortic root replacement, Homograft
		☐ 735 = Aortic root replacement, Valve sparing
		☐ 740 = Ross procedure
		☐ 750 = Konno procedure
		☐ 760 = Ross-Konno procedure
		☐ 770 = Other annular enlargement procedure
		☐ 780 = Aortic stenosis, Subvalvar, Repair
		☐ 2100 = Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS
		☐ 790 = Aortic stenosis, Supravalvar, Repair
		☐ 800 = Valve surgery, Other, Aortic
	Sinus of Valsalva Aneurysm	☐ 810 = Sinus of Valsalva, Aneurysm repair
	LV to Aorta Tunnel	☐ 820 = LV to aorta tunnel repair
	Mitral Valve Disease	☐ 830 = Valvuloplasty, Mitral
		☐ 2260 = Valvuloplasty converted to valve replacement in the same operation, Mitral
		☐ 840 = Mitral stenosis, Supravalvar mitral ring repair
		☐ 850 = Valve replacement, Mitral (MVR)

		☐ 860 = Valve surgery, Other, Mitral
	Hypoplastic Left Heart	☐ 870 = Norwood procedure ☐ 880 = HLHS biventricular repair ☐ 2160 = Hybrid Approach "Stage 1", Application of RPA & LPA bands ☐ 2170 = Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) ☐ 2180 = Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) + application of RPA & LPA bands ☐ 2140 = Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding) ☐ 2150 = Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair
Cardiomyopathy		☐ 890 = Transplant, Heart ☐ 900 = Transplant, Heart and lung ☐ 910 = Partial left ventriculectomy (LV volume reduction surgery) (Batista)
Pericardial Disease		☐ 920 = Pericardial drainage procedure ☐ 930 = Pericardiectomy ☐ 940 = Pericardial procedure, Other
Single Ventricle		☐ 950 = Fontan, Atrio-pulmonary connection ☐ 960 = Fontan, Atrio-ventricular connection ☐ 970 = Fontan, TCPC, Lateral tunnel, Fenestrated ☐ 980 = Fontan, TCPC, Lateral tunnel, Nonfenestrated ☐ 1000 = Fontan, TCPC, External conduit, Fenestrated ☐ 1010 = Fontan, TCPC, External conduit, Nonfenestrated ☐ 1025 = Fontan revision or conversion (Re-do Fontan) ☐ 1030 = Fontan, Other ☐ 2340 = Fontan + Atrioventricular valvuloplasty ☐ 1035 = Ventricular septation
Transposition of the Great Arteries	Congenitally Corrected TGA	☐ 1050 = Congenitally corrected TGA repair, Atrial switch and ASO (double switch) ☐ 1060 = Congenitally corrected TGA repair, Atrial switch and Rastelli ☐ 1070 = Congenitally corrected TGA repair, VSD closure ☐ 1080 = Congenitally corrected TGA repair, VSD closure and LV to PA conduit ☐ 1090 = Congenitally corrected TGA repair, Other
	Transposition of the Great Arteries	☐ 1110 = Arterial switch operation (ASO) ☐ 1120 = Arterial switch operation (ASO) and VSD repair ☐ 1123 = Arterial switch procedure + Aortic arch repair ☐ 1125 = Arterial switch procedure and VSD repair + Aortic arch repair ☐ 1130 = Senning ☐ 1140 = Mustard ☐ 1145 = Atrial baffle procedure, Mustard or Senning revision ☐ 1150 = Rastelli ☐ 1160 = REV ☐ 2190 = Aortic root translocation over left ventricle (Including Nikaidoh procedure) ☐ 2210 = TGA, Other procedures (Kawashima, LV-PA conduit, other)
DORV		☐ 1180 = DORV, Intraventricular tunnel repair
DOLV		☐ 1200 = DOLV repair
Thoracic Arteries and Veins	Coarctation of Aorta and Aortic arch hypoplasia	☐ 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 ☐ 1260 = Coarctation repair, Other ☐ 1275 = Coarctation repair + VSD repair

		☐ 1280 = Aortic arch repair
		☐ 1285 = Aortic arch repair + VSD repair
	Coronary Artery Anomalies	☐ 1290 = Coronary artery fistula ligation
		☐ 1291 = Anomalous origin of coronary artery from pulmonary artery repair
		☐ 1300 = Coronary artery bypass
		☐ 1305 = Anomalous aortic origin of coronary artery from aorta (AAOCA) repair
		☐ 1310 = Coronary artery procedure, Other
	Interrupted Arch	☐ 1320 = Interrupted aortic arch repair
	Patent Ductus Arteriosus	☐ 1330 = PDA closure, Surgical
		☐ 1340 = PDA closure, Device
	Vascular Rings and Slings	☐ 1360 = Vascular ring repair
		☐ 1365 = Aortopexy
		☐ 1370 = Pulmonary artery sling repair
	Aortic Aneurysm	☐ 1380 = Aortic aneurysm repair
	Aortic Dissection	☐ 1390 = Aortic dissection repair
Thoracic and Mediastinal Disease	Lung Disease	☐ 1400 = Lung biopsy
		☐ 1410 = Transplant, lung(s)
		☐ 1420 = Lung procedure, Other
	Pectus Excavatum, Carinatum	☐ 1430 = Pectus repair
	Tracheal Stenosis	☐ 1440 = Tracheal procedure
Electrophysiological		☐ 1450 = Pacemaker implantation, Permanent
		☐ 1460 = Pacemaker procedure
		☐ 2350 = Explantation of pacing system
		☐ 1470 = ICD (AICD) implantation
		☐ 1480 = ICD (AICD) ([automatic] implantable cardioverter defibrillator) procedure
		☐ 1490 = Arrhythmia surgery - atrial, Surgical Ablation
		☐ 1500 = Arrhythmia surgery - ventricular, Surgical Ablation
Interventional Cardiology Procedures		☐ 2500 = Cardiovascular catheterization procedure, Diagnostic
		☐ 2520 = Cardiovascular catheterization procedure, Diagnostic, Angiographic data obtained
		☐ 2550 = Cardiovascular catheterization procedure, Diagnostic, Electrophysiology alteration
		☐ 2540 = Cardiovascular catheterization procedure, Diagnostic, Hemodynamic alteration
		☐ 2510 = Cardiovascular catheterization procedure, Diagnostic, Hemodynamic data obtained
		☐ 2530 = Cardiovascular catheterization procedure, Diagnostic, Transluminal test occlusion
		☐ 2410 = Cardiovascular catheterization procedure, Therapeutic
		☐ 2670 = Cardiovascular catheterization procedure, Therapeutic, Adjunctive therapy
		☐ 1540 = Cardiovascular catheterization procedure, Therapeutic, Balloon dilation
		☐ 2590 = Cardiovascular catheterization procedure, Therapeutic, Balloon valvotomy
		☐ 1580 = Cardiovascular catheterization procedure, Therapeutic, Coil implantation
		☐ 1560 = Cardiovascular catheterization procedure, Therapeutic, Device implantation
		☐ 2640 = Cardiovascular catheterization procedure, Therapeutic, Perforation (establishing interchamber and/or intervessel communication)
		☐ 2580 = Cardiovascular catheterization procedure, Therapeutic, Septostomy
		☐ 1550 = Cardiovascular catheterization procedure, Therapeutic, Stent insertion
		☐ 2630 = Cardiovascular catheterization procedure, Therapeutic, Stent re-dilation
		☐ 2650 = Cardiovascular catheterization procedure, Therapeutic, Transcatheter Fontan completion
		☐ 2660 = Cardiovascular catheterization procedure, Therapeutic, Transcatheter implantation of valve
		☐ 2680 = Cardiovascular electrophysiological catheterization procedure
		☐ 2690 = Cardiovascular electrophysiological catheterization procedure, Therapeutic ablation

Palliative Procedures	☐ 1590 = Shunt, Systemic to pulmonary, Modified Blalock-Taussig Shunt (MBTS) ☐ 1600 = Shunt, Systemic to pulmonary, Central (from aorta or to main pulmonary artery) ☐ 1610 = Shunt, Systemic to pulmonary, Other ☐ 1630 = Shunt, Ligation and takedown ☐ 2095 = Shunt, Reoperation ☐ 1640 = PA banding (PAB) ☐ 1650 = PA debanding ☐ 1660 = Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction) ☐ 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 ☐ 2330 = Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty ☐ 2130 = Superior Cavopulmonary anastomosis(es) + PA reconstruction ☐ 1710 = Palliation, Other
Mechanical Support	☐ 2360 = ECMO cannulation ☐ 2370 = ECMO decannulation ☐ 1910 = ECMO procedure ☐ 1900 = Intraaortic balloon pump (IABP) insertion ☐ 1920 = Right/left heart assist device procedure ☐ 2390 = VAD explantation ☐ 2380 = VAD implantation
Anesthetic procedures	☐ 2420 = Echocardiography procedure, Sedated transesophageal echocardiogram ☐ 2430 = Echocardiography procedure, Sedated transthoracic echocardiogram ☐ 2435 = Non-cardiovascular, Non-thoracic procedure on cardiac patient with cardiac anesthesia ☐ 2440 = Radiology procedure on cardiac patient, Cardiac Computerized Axial Tomography (CT Scan) ☐ 2450 = Radiology procedure on cardiac patient, Cardiac Magnetic Resonance Imaging (MRI) ☐ 2460 = Radiology procedure on cardiac patient, Diagnostic radiology ☐ 2470 = Radiology procedure on cardiac patient, Non-Cardiac Computerized Tomography (CT) on cardiac patient ☐ 2480 = Radiology procedure on cardiac patient, Non-cardiac Magnetic Resonance Imaging (MRI) on cardiac patient ☐ 2490 = Radiology procedure on cardiac patient, Therapeutic radiology
Miscellaneous Procedures	☐ 1720 = Aneurysm, Ventricular, Right, Repair ☐ 1730 = Aneurysm, Ventricular, Left, Repair ☐ 1740 = Aneurysm, Pulmonary artery, Repair ☐ 1760 = Cardiac tumor resection ☐ 1780 = Pulmonary AV fistula repair/occlusion ☐ 1790 = Ligation, Pulmonary artery ☐ 1802 = Pulmonary embolectomy, Acute pulmonary embolus ☐ 1804 = Pulmonary embolectomy, Chronic pulmonary embolus ☐ 1810 = Pleural drainage procedure ☐ 1820 = Pleural procedure, Other ☐ 1830 = Ligation, Thoracic duct ☐ 1840 = Decortication ☐ 1850 = Esophageal procedure ☐ 1860 = Mediastinal procedure ☐ 1870 = Bronchoscopy

☐ 1880 = Diaphragm plication
☐ 1890 = Diaphragm procedure, Other
☐ 1930 = VATS (video-assisted thoracoscopic surgery)
☐ 1940 = Minimally invasive procedure
☐ 1950 = Bypass for noncardiac lesion
☐ 1960 = Delayed sternal closure
☐ 1970 = Mediastinal exploration
☐ 1980 = Sternotomy wound drainage
☐ 1990 = Thoracotomy, Other
☐ 2000 = Cardiotomy, Other
☐ 2010 = Cardiac procedure, Other
☐ 2020 = Thoracic and/or mediastinal procedure, Other
☐ 2030 = Peripheral vascular procedure, Other
☐ 2040 = Miscellaneous procedure, Other
☐ 2050 = Organ procurement
☐ 7777 = Other procedure

OPERATIVE

Procedure Location:
☐ Cardiac OR ☐ ICU ☐ SICU
☐ General OR ☐ CVICU ☐ Radiology Suite
☐ Hybrid Suite ☐ NICU ☐ Procedure Room
☐ Cath lab ☐ PICU ☐ Other

Operation Type: ☐ CPB ☐ No CPB Cardiovascular ☐ ECMO
☐ Thoracic ☐ Interventional Cardiology ☐ VAD w/ CPB
☐ VAD w/out CPB ☐ NonCardiac/NonThoracic Procedure w/ Anesthesia ☐ Other

If Op type is NonCardiac/NonThoracic Procedure w/Anesthesia, skip to Complications section

Surgeon:	Surgeon NPI:	Taxpayer Identification Number:
Assisting Surgeon:	Assisting Surgeon NPI:	
Resident Surgeon:	Resident Surgeon Identifier:	
Consultant Attending:	Consultant Attending Identifier:	
Referring Cardiologist:	Referring Physician:	

Reoperation Within This Admission: ☐ **Yes – Planned reoperation** ☐ **No** ☐ **Yes – Unplanned reoperation**

Number of Prior Cardiothoracic Operations: | Number of Prior CPB Cardiothoracic Operations:

OR Entry Time: *(00:00 – 23:59)* __ __: __ __ | Skin Incision Start Time: *(00:00 – 23:59)* __ __: __ __

(If operation type is No CPB Cardiovascular→) Cross Clamp Time – No CPB: *(minutes):*

(If operation type is CPB or VAD w/ CPB↓)

CPB Time *(minutes):* Cross Clamp Time - CPB:*(minutes):* Circulatory Arrest Time *(minutes):*

Patient Temperature Monitoring Site : (IF Yes, Lowest Core Temperature recorded at site):

Bladder:	☐ Yes ☐ No	*(If Yes →)*	_____ °C
Esophageal:	☐ Yes ☐ No	*(If Yes →)*	_____ °C
Nasopharyngeal:	☐ Yes ☐ No	*(If Yes →)*	_____ °C
Rectal:	☐ Yes ☐ No	*(If Yes →)*	_____ °C
Tympanic:	☐ Yes ☐ No	*(If Yes →)*	_____ °C
Other:	☐ Yes ☐ No	*(If Yes →)*	_____ °C

Cooling Time: *(minutes)* Rewarming Time: *(minutes)*

Cerebral Perfusion Utilized: ☐ Yes ☐ No *(If Yes ↓)*

Cerebral Perfusion Time: _____ *(minutes)*

Cerebral Perfusion Cannulation Site:

Innominate Artery	☐ Yes ☐ No	Right Subvclavian	☐ Yes ☐ No
Right Axillary Artery	☐ Yes ☐ No	Right Carotid Artery	☐ Yes ☐ No
Left Carotid Artery	☐ Yes ☐ No	Superior Vena Cava	☐ Yes ☐ No

Cerebral Perfusion Periods: _____
Cerebral Perfusion Flow Rate: _____ *(mL/kg) per minute*
Cerebral Perfusion Temperature: _____ °C

Arterial Blood Gas Management During Cooling: ☐ Alpha STAT ☐ pH STAT
☐ phSTAT cooling/Alpha STAT rewarming ☐ Other Combination

Hematocrit Prior to Circulatory Arrest or Cerebral Perfusion: _____

Cardioplegia Administered: ☐ Yes ☐ No *(If Yes ↓)*

Cardioplegia Number of Doses: _____
Cardioplegia Delivery Ratio: Blood Solution (BS) ____ Cardioplegia Solution (CS) _____
Initial Delivery Route of Cardioplegia:

Antegrade Aortic Root	☐ Yes ☐ No	Antegrade Right Coronary Ostia	☐ Yes ☐ No
Antegrade Left Coronary Ostia	☐ Yes ☐ No	Retrograde Coronary Sinus	☐ Yes ☐ No

Subsequent Delivery Route of Cardioplegia:

Antegrade Aortic Root	☐ Yes ☐ No	Antegrade Right Coronary Ostia	☐ Yes ☐ No
Antegrade Left Coronary Ostia	☐ Yes ☐ No	Retrograde Coronary Sinus	☐ Yes ☐ No

Longest Myocardial Ischemic Interval: _____ *(minutes)*

Cardioplegia Solution: ☐ Hyperpolarizing ☐ Depolarizing ☐ Modified Depolarizing ☐ None

Lowest Hematocrit on CPB: _____

Endotracheal Intubation Performed ☐ Yes ☐ No *(If Yes ↓)*

Intubation Date/Time: *(mm/dd/yyyy 00:00 – 23:59)* _ _ / _ _ / _ _ _ _ _ _:_ _

Initial Extubation Date/Time: *(mm/dd/yyyy 00:00 – 23:59)* _ _ / _ _ / _ _ _ _ _ _:_ _

Extubated in OR: ☐ Yes ☐ No

Re-Intubated After Initial Postoperative Extubation: ☐ Yes ☐ No *(If Yes ↓)*

Final Extubation Date/Time: *(mm/dd/yyyy 00:00 – 23:59)* _ _ / _ _ / _ _ _ _ _ _:_ _

Time of Skin Closure: *(00:00 – 23:59)* _ _:_ _ | OR Exit Time: *(00:00 – 23:59)* _ _:_ _ | Extended Through Midnight: ☐ Yes ☐ No

Pulmonary Vascular Resistance Measured: ☐ Yes ☐ No

(If Yes and WeightKg >=40 →) PVR: _____ *(Wood units)*

(If Yes and WeightKg <40 →) PVR Index: _____ *(Wood units x m2)*

Intraoperative Near Infrared Spectroscopy (NIRS) Cerebral Metrics Used: ☐ Yes ☐ No *(If Yes ↓)*

Cerebral Oximeter Provided First Indication: ☐ Yes ☐ No

Pre-Induction Baseline Regional Oxygen Saturation: Left: ____ *(%)* Right ____ *(%)* Center ____ *(%)*

Cumulative Saturation Below Threshold: Left: ____ *(minute-%)* Right ____ *(minute-%)* Center ____ *(minute-%)*

Skin Closure Regional Oxygen Saturation: Left: ____ *(%)* Right ____ *(%)* Center ____ *(%)*

Cerebral Regional Oxygen Saturation Percentiles:

Percentile Range:	<=30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Minutes:								

Intraoperative Near Infrared Spectroscopy (NIRS) Somatic Metrics Used: ☐ Yes ☐ No *(If Yes ↓)*

Somatic Oximeter Provided First Indication: ☐ Yes ☐ No

Somatic Sensor Location: ☐ Renal ☐ Mesenteric

Pre-Induction Baseline Somatic Regional Oxygen Saturation: _____ *(%)*

Cumulative Somatic Saturation Below Threshold: _____ *(minute-%)*

Somatic Regional Oxygen Saturation Percentiles:

Percentile Range:	<=30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Minutes:								

Postoperative Near Infrared Spectroscopy (NIRS) Cerebral Metrics Used: ☐ Yes ☐ No *(If Yes ↓)*

Cerebral Oximeter Provided First Indication: ☐ Yes ☐ No

Cumulative Cerebral Saturation Below Threshold:

Left: ____ *(minute-%)* Right: ____ *(minute-%)* Center: ____ *(minute-%)*

Cerebral Regional Oxygen Saturation Percentiles:

Percentile Range:	<=30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Minutes:								

Postoperative Near Infrared Spectroscopy (NIRS) Somatic Metrics Used: ☐ Yes ☐ No *(If Yes ↓)*

Somatic Oximeter Provided First Indication: ☐ Yes ☐ No

Somatic Sensor Location: ☐ Renal ☐ Mesenteric

Cumulative Somatic Saturation Below Threshold: _____ *(minute-%)*

Somatic Regional Oxygen Saturation Percentiles:

Percentile Range:	<=30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Minutes:								

Intraop Blood Products Used: ☐ Yes ☐ No

*(If No →)*Intraop Blood Products Refused: ☐ Yes ☐ No

(If Yes ↓)			Number of donor exposures:	Number of Units:	Number of Milliliters:
Red Blood Cells	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Fresh Frozen Plasma	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____

Cryoprecipitate	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Platelets	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Whole Blood	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Factor VIIa	☐ Yes ☐ No	*(If Yes →)*	Total Dosage: _____ (micrograms / kg)		

Intraop Medications:

Aprotinin:	☐ Yes ☐ No	*(If Yes →)*	Aprotinin – Dose: Full Dose Half Dose
Epsilon Amino-Caproic Acid:	☐ Yes ☐ No	*(If Yes →)*	Dose: _____
Desmopressin:	☐ Yes ☐ No	*(If Yes →)*	Dose: _____
Tranexamic Acid:	☐ Yes ☐ No	*(If Yes →)*	Dose: _____

POST OPERATIVE

Blood Products Used Postoperatively: ☐ Yes ☐ No

(If Yes ↓)			Number of donor exposures:	Number of Units:	Number of Milliliters:
Red Blood Cells	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Fresh Frozen Plasma	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Cryoprecipitate	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Platelets	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Whole Blood	☐ Yes ☐ No	*(If Yes →)*	_____	_____	_____
Factor VIIa	☐ Yes ☐ No	*(If Yes →)*	Total Dosage: _____ (micrograms / kg)		

COMPLICATIONS

☐ 15 = No complications

OR select ALL that apply: (↓)

☐ 16 = No complications during the intraoperative and postoperative time periods (No complications prior to discharge and no complications within < or = 30 days of surgery)

☐ 350 = Intraoperative death or intraprocedural death

☐ 360 = Unplanned readmission to the hospital within 30 days of surgery or intervention

☐ 370 = Multi-System Organ Failure (MSOF) = Multi-Organ Dysfunction Syndrome (MODS)

☐ 30 = Cardiac arrest, Timing = Cardiac arrest (MI) during or following procedure (Perioperative/Periprocedural = Intraoperative/Intraprocedural and/or Postoperative/Postprocedural)

☐ 80 = Cardiac dysfunction resulting in low cardiac output

☐ 384 = Cardiac failure (severe cardiac dysfunction)

☐ 280 = Endocarditis-postprocedural infective endocarditis

☐ 110 = Pericardial effusion, Requiring drainage

☐ 390 = Pulmonary hypertension

☐ 140 = Pulmonary hypertensive crisis (PA pressure > systemic pressure)

☐ 130 = Pulmonary vein obstruction

☐ 120 = Systemic vein obstruction

☐ 240 = Bleeding, Requiring reoperation

☐ 102 = Sternum left open, Planned

☐ 104 = Sternum left open, Unplanned

☐ 22 = Unplanned cardiac reoperation during the postoperative or postprocedural time period, exclusive of reoperation for bleeding

☐ 24 = Unplanned interventional cardiovascular catheterization procedure during the postoperative or postprocedural time period

☐ 26 = Unplanned non-cardiac reoperation during the postoperative or postprocedural time period

☐ 40 = Postoperative/Postprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS)

☐ 71 = Arrhythmia

☐ 72 = Arrhythmia requiring drug therapy

☐ 73 = Arrhythmia requiring electrical cardioversion or defibrillation

☐ 74 = Arrhythmia necessitating pacemaker, Permanent pacemaker

☐ 75 = Arrhythmia necessitating pacemaker, Temporary pacemaker

☐ 210 = Chylothorax

☐ 200 =Pleural effusion, Requiring drainage

☐ 180 = Pneumonia

☐ 190 = Pneumothorax, Requiring intervention

☐ 150 = Postoperative/Postprocedural respiratory insufficiency requiring mechanical ventilatory support > 7 days

☐ 160 = Postoperative/Postprocedural respiratory insufficiency requiring reintubation

☐ 170 = Respiratory failure, Requiring tracheostomy

☐ 230 = Renal failure - acute renal failure, Acute renal failure requiring dialysis at the time of hospital discharge

☐ 223 = Renal failure - acute renal failure, Acute renal failure requiring temporary dialysis with the need for dialysis not present at hospital discharge

☐ 224 = Renal failure - acute renal failure, Acute renal failure requiring temporary hemofiltration with the need for dialysis not present at hospital discharge

☐ 290= Sepsis

☐ 320 = Neurological deficit, Neurological deficit persisting at discharge

☐ 325 = Neurological deficit, Transient neurological deficit not present at discharge

☐ 300 = Paralyzed diaphragm (possible phrenic nerve injury)

☐ 400 = Peripheral nerve injury, Neurological deficit persisting at discharge

☐ 331 = Seizure

☐ 410 = Spinal cord injury, Neurological deficit persisting at discharge

☐ 420 = Stroke

☐ 310 = Vocal cord dysfunction (possible recurrent laryngeal nerve injury)

☐ 250 = Wound dehiscence (sterile)

☐ 255 = Wound dehiscence (sterile), Median sternotomy

☐ 261 = Wound infection

☐ 262 = Wound infection-Deep wound infection

☐ 270 = Wound infection-Mediastinitis

☐ 263 = Wound infection-Superficial wound infection

☐ 900 = Other complication

☐ 901 = Other operative/procedural complication

DISCHARGE/READMISSION

Reoperation after this operation within this admission: ☐ Yes ☐ No

Date of Hospital Discharge: *(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __

Mortality Status at Hospital Discharge: ☐ Alive ☐ Dead

(If Alive →) Discharge Location: ☐ Home ☐ Other Acute Care Center ☐ Other Chronic Care Center

Date of Database Discharge: *(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __

Mortality Status at Database Discharge: ☐ Alive ☐ Dead ☐ Unknown *(If Alive ↓)*

Readmission within 30 days: ☐ Yes ☐ No *(If Yes →)* Readmission Date: *(mm/dd/yyyy)* __ __ / __ __ / __ __ __ __

(If Yes →) Primary Readmission Reason *(select one↓):*

- ☐ 26 = Thrombotic Complication
- ☐ 27 = Embolic Complication
- ☐ 28 = Hemorrhagic Complication
- ☐ 29 = Stenotic Complication
- ☐ 2 = Arrhythmias/Heart Block
- ☐ 3 = Congestive Heart Failure
- ☐ 30 = Cardiac Transplant Rejection
- ☐ 31 = Myocardial Ischemia
- ☐ 14 = Renal Failure
- ☐ 6 = Pericardial Effusion and/or Tamponade
- ☐ 32 = Pleural Effusion
- ☐ 33 = Neurologic Complication
- ☐ 7 = Respiratory Complication/Airway Complication
- ☐ 34 = Septic/Infectious Complication
- ☐ 35 = Cardiovascular Device Complications
- ☐ 36 = Residual/Recurrent Cardiovascular Defects
- ☐ 37 = Failure to Thrive
- ☐ 25 = VAD Complications
- ☐ 39 = Gastrointestinal Complication
- ☐ 38 = Other Cardiovascular Complication
- ☐ 998 = Other - Readmission related to this index operation
- ☐ 999 = Other - Readmission not related to this index operation

Status at 30 days after surgery: ☐ Alive ☐ Dead ☐ Unknown

Mortality Assigned to this Operation: ☐ Yes ☐ No Operative Mortality: ☐ Yes ☐ No

ANESTHESIA

ANESTHESIA Administrative

Primary Anesthesiologist Attending: _____

Secondary Anesthesiologist Attending ☐ Yes ☐ No *(If Yes →)* Name: _____

Fellow or Resident Present ☐ Yes ☐ No

CRNA/SRNA Present ☐ Yes ☐ No *(If Yes →)* Name: _____

Non-CV Physician: _____

ANESTHESIA Preoperative

Preoperative Medications: ☐ None *(If not None, select all pre-operative medications that apply: ↓)*

- ☐ Amiodarone
- ☐ Aspirin
- ☐ Bosentan
- ☐ Captopril (Capoten)
- ☐ Clopidogrel
- ☐ Coumadin
- ☐ Digoxin
- ☐ Diltiazem
- ☐ Dobutamine
- ☐ Dopamine
- ☐ Enalapril
- ☐ Epinephrine (Adrenalin)
- ☐ Esmolol (Brevibloc)
- ☐ Fentanyl
- ☐ Furosemide (Lasix)
- ☐ Heparin
- ☐ Low Molecular Weight Heparin
- ☐ Labetolol
- ☐ Lisinopril
- ☐ Midazolam (Versed)
- ☐ Milrinone
- ☐ Morphine
- ☐ Nitroglycerin
- ☐ Nitroprusside
- ☐ Norepinephrine (Levophed)
- ☐ Propranolol
- ☐ Prostaglandin
- ☐ Sildenafil
- ☐ Sotalol
- ☐ Vasopressin
- ☐ ACE inhibitors not otherwise listed
- ☐ Beta Blockers not otherwise listed
- ☐ Anti-arrhythmics not otherwise listed
- ☐ Inotropes not otherwise listed (e.g., study drugs (levosimendan))
- ☐ Vasodilators not otherwise listed
- ☐ Vasoconstrictors not otherwise listed

Preoperative Sedation ☐ Yes ☐ No

(If Yes →) Preoperative Sedation Route: ☐ IM ☐ IV ☐ Nasal ☐ PO (Oral) ☐ Rectal

(If Yes, select all pre-operative sedation drugs that apply: ↓)

Atropine	☐ Yes ☐ No	Lorazepam	☐ Yes ☐ No
Demerol	☐ Yes ☐ No	Midazolam	☐ Yes ☐ No
Diazepam	☐ Yes ☐ No	Morphine	☐ Yes ☐ No
Glycopyrrolate	☐ Yes ☐ No	Pentobarbital	☐ Yes ☐ No
Ketamine	☐ Yes ☐ No		

Preoperative Oxygen Saturation: _____ %

Date and Time of Transport to Procedure Location Or Anesthesia Start Time: ___/___/___ ___:___

ANESTHESIA Monitoring

Arterial Line ☐ Yes ☐ No *(If Yes →)* Type: *(Select all that apply)*

Radial	☐ Yes ☐ No	Brachial	☐ Yes ☐ No
Axillary	☐ Yes ☐ No	Femoral	☐ Yes ☐ No
Ulnar	☐ Yes ☐ No	Dorsalis Pedis	☐ Yes ☐ No
Posterior Tibial	☐ Yes ☐ No	Central	☐ Yes ☐ No

Cutdown ☐ Yes ☐ No *(If Yes →)* Type: *(Select all that apply)*

Radial	☐ Yes ☐ No	Femoral	☐ Yes ☐ No
Ulnar	☐ Yes ☐ No	Other	☐ Yes ☐ No

Percutaneous Central Pressure ☐ Yes ☐ No

(If Yes →) Location: *(Select all that apply)*

Right Internal Jugular	☐ Yes ☐ No	Left Internal Jugular	☐ Yes ☐ No
Right Subclavian	☐ Yes ☐ No	Left Subclavian	☐ Yes ☐ No
Right Femoral Vein	☐ Yes ☐ No	Left Femoral Vein	☐ Yes ☐ No
Other	☐ Yes ☐ No		

CVP Placed by Anesthesia ☐ Yes ☐ No

Swan-Ganz Catheter ☐ Yes ☐ No

Oximetric Central Line (ScVO2) ☐ Yes ☐ No

Neurologic Monitoring ☐ Yes ☐ No

(If Yes →) Neurological Monitoring Type: ☐ Near Infrared Spectroscopy (NIRS) ☐ Transcranial Doppler (TCD) ☐ Bispectral Index (BIS) ☐ Other

Lowest Recorded Intraoperative Temperature: _____ *° C*

Intraoperative Temperature Site: ☐ Nasal ☐ Esophageal ☐ Bladder ☐ Rectal ☐ Axillary ☐ Skin

Transesophageal Echocardiography ☐ Yes ☐ No

ANESTHESIA Anesthetic Technique

Date and Time of Induction: ___/___/___ ___:___
mm/ dd/ yyyy hh : mm

Induction Type:

Inhalation ☐ Yes ☐ No *(If Yes →)* Primary Induction Agent ☐ Sevoflurane ☐ Halothane

Intraveneous ☐ Yes ☐ No *(If Yes →)* Primary Induction Agent ☐ Propofol ☐ Etomidate ☐ Ketamine ☐ Sodium Thiopental ☐ Fentanyl ☐ Sufentanil ☐ Midazolam

Intramuscular (IM) ☐ Yes ☐ No *(If Yes →)* Primary Induction Agent ☐ Ketamine ☐ Midazolam

Primary Maintenance Agent: ☐ Alfentanil ☐ Desflurane ☐ Dexmedetomidine ☐ Fentanyl ☐ Halothane ☐ Isoflurane ☐ Ketamine ☐ Midazolam ☐ Morphine ☐ Propofol ☐ Remifentanil ☐ Sevoflurane ☐ Sufentanil

Regional Anesthetic ☐ Yes ☐ No

(If Yes →) Regional Anesthetic Site: ☐ Thoracic Epidural Catheter ☐ Lumbar Epidural Catheter ☐ Caudal Epidural Catheter ☐ Lumbar Epidural – Single shot ☐ Caudal Epidural – Single shot ☐ Lumbar Intrathecal Single Shot

(If Yes →) Regional Anesthetic Drug: *(Select all that apply)*

Bupivicaine	☐ Yes ☐ No	Bupivicaine/Fentanyl	☐ Yes ☐ No
Clonidine	☐ Yes ☐ No	Fentanyl	☐ Yes ☐ No
Hydromorphone	☐ Yes ☐ No	Lidocaine	☐ Yes ☐ No
Morphine	☐ Yes ☐ No	Ropivicaine	☐ Yes ☐ No
Ropivicaine/Fentanyl	☐ Yes ☐ No	Tetracaine	☐ Yes ☐ No
Other	☐ Yes ☐ No		

ANESTHESIA Airway

Airway Type: ☐ No airway support ☐ Bag-mask ☐ Nasal cannulae ☐ Laryngeal Mask Airway (LMA) ☐ Endotracheal intubation ☐ Tracheostomy

(If LMA →) Airway Size *(mm):* ☐ 1.0 ☐ 1.5 ☐ 2.0 ☐ 2.5 ☐ 3.0 ☐ 4.0 ☐ 5.0

(If Endotracheal intubation →) Airway Size *(mm):* ☐ 2.5 ☐ 3.0 ☐ 3.5 ☐ 4.0 ☐ 4.5 ☐ 5.0 ☐ 5.5 ☐ 6.0 ☐ 6.5 ☐ 7.0 ☐ 7.5 ☐ 8.0

Cuffed ☐ Yes ☐ No

Airway Site: ☐ Oral ☐ Nasal ☐ Tracheostomy

ANESTHESIA Transfusion

Transfusion ☐ Yes ☐ No

(If Yes ↓) Number of donor exposures:

Packed Red Blood Cells (PRBC)	☐ Yes ☐ No	*(If Yes →)*	_____
Platelets	☐ Yes ☐ No	*(If Yes →)*	_____
Fresh Frozen Plasma (FFP)	☐ Yes ☐ No	*(If Yes →)*	_____
Cryoprecipitate	☐ Yes ☐ No	*(If Yes →)*	_____
Whole Blood	☐ Yes ☐ No	*(If Yes →)*	_____
Factor VIIa	☐ Yes ☐ No	*(If Yes →)*	Total dosage : _____ *(micrograms / kg)*

ANESTHESIA Intraoperative Pharmacology

Intraoperative Medications: ☐ None *(If not None, select all intra-operative medications that apply: ↓)*

- ☐ Adenosine bolus
- ☐ Alfentanil infusion
- ☐ Aminocaproic Acid (Amicar)
- ☐ Amiodarone bolus/infusion
- ☐ Aprotinin (Trasylol)
- ☐ Calcium (Gluconate or Chloride) infusion
- ☐ Dexmetetomidine (Precedex)
- ☐ Dobutamine infusion
- ☐ Dopamine infusion
- ☐ Epinephrine (Adrenalin) infusion
- ☐ Esmolol bolus/infusion
- ☐ Fentanyl bolus/infusion
- ☐ Furosemide bolus/infusion
- ☐ Insulin bolus/infusion
- ☐ Intraoperative Steroids (Hydrocortisone/Methylprednisolone/Dexamethasone)
- ☐ Isoproterenol infusion
- ☐ Levophed (Norepinephrine) infusion
- ☐ Magnesium Sulfate bolus
- ☐ Midazolam bolus/infusion
- ☐ Milrinone bolus/infusion
- ☐ Morphine bolus/infusion
- ☐ Nesiritide Infusion
- ☐ Nicardipine Infusion
- ☐ Nitric Oxide inhalation
- ☐ Nitroglycerin (Tridil) infusion
- ☐ Nitroprusside (Nipride)
- ☐ Phenoxybenzamine bolus
- ☐ Phentolamine (Regitine) Bolus/Infusion
- ☐ Phenylephrine infusion
- ☐ Propofol (Diprivan) infusion
- ☐ Prostaglandin infusion
- ☐ Remifentanil infusion
- ☐ Thyroid Hormone bolus/infusion
- ☐ Tranexamic Acid infusion
- ☐ Vasopressin infusion
- ☐ Other Inotrope
- ☐ Other Vasodilator
- ☐ Other Vasoconstrictor

ANESTHESIA Pharmacology On Arrival To ICU/PACU

Medications Given At Time Of Transfer: ☐ None *(If not None, select all medications that apply: ↓)*

- ☐ Aminocaproic Acid (Amicar) infusion
- ☐ Amiodarone infusion
- ☐ Aprotinin (Trasylol) infusion
- ☐ Calcium Chloride infusion
- ☐ Calcium Gluconate infusion
- ☐ Dexmetetomidine (Precedex) infusion
- ☐ Dobutamine infusion
- ☐ Dopamine infusion
- ☐ Epinephrine (Adrenalin) infusion
- ☐ Fentanyl infusion
- ☐ Insulin infusion
- ☐ Isoproterenol infusion
- ☐ Midazolam (Versed) infusion
- ☐ Milrinone infusion
- ☐ Morphine infusion
- ☐ Muscle Relaxant infusion
- ☐ Nesiritide Infusion
- ☐ Nicardipine infusion
- ☐ Nitric Oxide inhalation
- ☐ Nitroglycerin (Tridil) infusion
- ☐ Nitroprusside (Nipride) infusion
- ☐ Norepinephrine (Levophed) infusion
- ☐ Phentolamine (Regitine)Infusion
- ☐ Phenylephrine infusion
- ☐ Propofol (Diprivan) infusion
- ☐ Prostaglandin infusion
- ☐ Thyroid Hormone infusion
- ☐ Tranexamic Acid infusion
- ☐ Vasopressin infusion
- ☐ Other Inotrope
- ☐ Other Vasodilator
- ☐ Other Vasoconstrictor

ANESTHESIA ICU/PACU Care

Date and Time of ICU/PACU Arrival: ___/___/___ ___:___
mm/ dd/ yyyy hh : mm

Initial FiO2: _____

Mechanical circulatory support ☐ Yes ☐ No

ABG ☐ Yes ☐ No *(If Yes →)* pH: _____ Base Excess: _____
pCO2: _____ Lactate: _____
pO2: _____

Initial pulse oximeter _____ %

Temperature on ICU/PACU Arrival: _____ ° C

Temperature Measurement Site: ☐ Forehead scan ☐ Tympanic membrane ☐ Skin ☐ Rectal ☐ Bladder ☐ Oral ☐ Axillary

Need for Temporary Pacemaker on Arrival In ICU/PACU ☐ Yes ☐ No

(If Yes →) Site of Temporary Pace Maker: ☐ Epicardial ☐ Transvenous

(If Yes →) Type of Temporary Pacing: ☐ Atria ☐ Atrio-ventricular ☐ Ventricular ☐ Other

ANESTHESIA Anesthesia Adverse Events

Anesthesia adverse events: ☐ None *(If not None, select all adverse events that apply: ↓)*

- ☐ Dental Injury
- ☐ Respiratory Arrest
- ☐ Difficult Intubation/Reintubation
- ☐ Stridor / Sub-glottic Stenosis
- ☐ Extubation
- ☐ Endotracheal Tube Migration
- ☐ Airway Injury
- ☐ Arrythmia - Central Venous Line Placement
- ☐ Myocardial Injury - Central Venous Line Placement
- ☐ Vascular Compromise - Central Venous Line Placement
- ☐ Pneumothorax - Central Venous Line Placement
- ☐ Vascular Access
- ☐ Hematoma
- ☐ Arterial Puncture
- ☐ Intravenous/Intra-arterial Air Embolism
- ☐ Bleeding - Regional Anesthetic Site
- ☐ Intrathecal Puncture - Regional
- ☐ Local Anesthetic Toxicity - Regional
- ☐ Neurologic Injury - Regional
- ☐ Anaphylaxis/Anaphylactoid Reaction
- ☐ Non-allergic Drug Reaction
- ☐ Medication Administration
- ☐ Medication Dosage
- ☐ Intraoperative Recall
- ☐ Malignant Hyperthermia
- ☐ Protamine Reaction
- ☐ Cardiac Arrest - Unrelated To Surgery
- ☐ Esophageal Bleeding / Rupture
- ☐ Esophageal Chemical Burn
- ☐ Airway Compromise
- ☐ TEE Related-Extubation
- ☐ Patient Transfer Event
- ☐ Neurologic Injury

ADULT DATA

ADULT PREOPERATIVE FACTORS *(if 18 yrs or older)*

Current Or Recent Cigarette Smoker: ☐ Yes ☐ No

Family History of Coronary Artery Disease: ☐ Yes ☐ No

Last Hematocrit: _____

Last White Blood Cell Count: _____

Diabetes: ☐ Yes ☐ No *(If Yes →)* Diabetes Control: *(select one)* ☐ None ☐ Diet ☐ Oral ☐ Insulin ☐ Other

Last A1c Level: _____

Dyslipidemia: ☐ Yes ☐ No

Last Creatinine Level: _____

Renal Failure – Dialysis: ☐ Yes ☐ No

Hypertension: ☐ Yes ☐ No

Infectious Endocarditis: ☐ Yes ☐ No *(If Yes →)* Infectious Endocarditis Type: ☐ Treated ☐ Active

Chronic Lung Disease: ☐ No ☐ Mild ☐ Moderate ☐ Severe

Immunosuppressive Therapy: ☐ Yes ☐ No

Peripheral Arterial Disease: ☐ Yes ☐ No

Cerebrovascular Disease: ☐ Yes ☐ No

(If Yes →) Coma: ☐ Yes ☐ No

CVA: ☐ Yes ☐ No *(If Yes →)* CVA-When: ☐ Recent (<=2 weeks) ☐ Remote (>2 weeks)

CVD TIA: ☐ Yes ☐ No

CVD NonInvasive >75%: ☐ Yes ☐ No

CVD Prior Carotid Surgery: ☐ Yes ☐ No

CORONARY BYPASS *(if 18 yrs or older)*

Coronary Artery Bypass Grafting Done: ☐ Yes ☐ No *(If Yes ↓)*

Number of Distal Anastomoses with Arterial Conduits: _____

Number of Distal Anastomoses with Venous Conduits: _____

(If 1 or more →) Distal Anastomoses - Vein Harvest Technique: ☐ Endovascular ☐ Direct Vision ☐ Both

Saphenous Vein Harvest Time: _____ *(minutes)*

Anastomotic Device Used: ☐ Yes ☐ No *(If Yes →)* Anastomotic Device: ☐ Glue ☐ Magnets ☐ Clips ☐ Staples ☐ Other

Internal Mammary Arteries Used for Grafts: ☐ Left IMA ☐ Right IMA ☐ Both IMAs ☐ No IMA If Left, Right, or Both ↓

IMA Harvest Technique: ☐ Direct Vision ☐ Thoracoscopy

☐ Combination ☐ Robotic Assisted

Number of IMA Distal Anastomoses: _____

Radial Artery Used: ☐ No Radial ☐ Left Radial ☐ Right Radial ☐ Both Radials If Left, Right, or Both ↓

Number of Radial Artery Distal Anastomoses: _____

Radial Distal Anastomoses Harvest Technique: ☐ Endovascular ☐ Direct Vision ☐ Both

Radial Artery Harvest Time: _____ (minutes)

Number of Gastro-Epiploic Artery Distal Anastomoses: _____

Number of Other Arterial Distal Anastomoses: _____

Valve Surgery *(if 18 yrs or older)*

Surgical Procedure done on Aortic, Mitral, Tricuspid, or Pulmonic Valves: ☐ Yes ☐ No *(If Yes ↓)*

Aortic Procedure:	Mitral Procedure:	Tricuspid Procedure:	Pulmonic Procedure
No	No	No	No
Replacement	Annuloplasty Only	Annuloplasty Only	Replacement
Repair/Reconstruction	Replacement	Replacement	Reconstruction
Root Reconstruction w/ Valve Conduit	Reconstruction w/ Annuloplasty	Reconstruction w/ Annuloplasty	
Replacement + Aortic Graft Conduit	Reconstruction w/o Annuloplasty	Reconstruction w/o Annuloplasty	
Root Reconstruction w/ Valve Sparing	↓	Valvectomy	
Resuspension Aortic Valve w/ Replacement Ascending Aorta	*(If Replacement)* Mitral Repair Attempt: ☐ Yes ☐ No		
Resuspension Aortic Valve w/o Replacement Ascending Aorta			
Resection Sub-Aortic Stenosis			

Aortic Annular Enlargement: ☐ Yes ☐ No

↓ **Key** M = Mechanical B = Bioprosthesis H = Homograft A = Autograft (Ross) R = Ring/Annuloplasty BA = Band/Annuloplasty

Aortic Prosthesis -	Implant Type:	None M B H A R BA	Implant: _____	Size: _____
Mitral Prosthesis -	Implant Type:	None M B H A R BA	Implant: _____	Size: _____
Tricuspid Prosthesis -	Implant Type:	None M B H A R BA	Implant: _____	Size: _____
Pulmonic Prosthesis -	Implant Type:	None M B H A R BA	Implant: _____	Size: _____

Valve Key

Mechanical

112 = Carpentier-Edwards PERIMOUNT Theon RSR Pericardial Bioprosthesis

2 = ATS Mechanical Prosthesis

3 = Björk-Shiley Convex-Concave Mechanical Prosthesis

4 = Björk-Shiley Monostrut Mechanical Prosthesis

6 = CarboMedics Mechanical Prosthesis

57 = CarboMedics Carbo-Seal Ascending Aortic Valved Conduit Prosthesis

58 = CarboMedics Carbo-Seal Valsalva Ascending Aortic Valved Conduit Prosthesis

59 = CarboMedics Reduced Cuff Aortic Valve

60 = CarboMedics Standard Aortic Valve

61 = CarboMedics Top-Hat Supra-annular Aortic Valve

62 = CarboMedics OptiForm Mitral Valve

63 = CarboMedics Standard Mitral Valve

64 = CarboMedics Orbis Universal Valve

65 = CarboMedics Small Adult Aortic and Mitral Valves

53 = Lillehei-Kaster Mechanical Prosthesis

10 = MCRI On-X Mechanical Prosthesis

8 = Medtronic-Hall/Hall Easy-Fit Mechanical Prosthesis

66 = Medtronic ADVANTAGE Mechanical Prosthesis

9 = OmniCarbon Mechanical Prosthesis

54 = OmniScience Mechanical Prosthesis

11 = Sorin Bicarbon (Baxter Mira) Mechanical Prosthesis

12 = Sorin Monoleaflet Allcarbon Mechanical Prosthesis

13 = St. Jude Medical Mechanical Heart Valve

67 = St. Jude Medical Masters Series Mechanical Heart Valve

68 = St. Jude Medical Masters Series Aortic Valve Graft Prosthesis

69 = St. Jude Medical Mechanical Heart Valve Hemodynamic Plus (HP) Series

70 = St. Jude Medical Masters Series Hemodynamic Plus Valve with FlexCuff Sewing Ring

71 = St. Jude Medical Regent Valve

14 = Starr-Edwards Caged-Ball Prosthesis

15 = Ultracor Mechanical Prosthesis

Bioprosthesis

108 = ATS 3f Aortic Bioprosthesis

72 = Edwards Prima Stentless Porcine Bioprosthesis - Subcoronary

73 = Edwards Prima Stentless Porcine Bioprosthesis - Root

19 = Biocor Porcine Bioprosthesis

74 = Biocor Stentless Porcine Bioprosthesis - Subcoronary

75 = Biocor Stentless Porcine Bioprosthesis - Root

21 = CarboMedics PhotoFix Pericardial Bioprosthesis

76 = Carpentier-Edwards Duraflex Porcine Bioprosthesis

77 = Carpentier-Edwards Prima Plus Stentless Porcine Bioprosthesis - Subcoronary

78 = Carpentier-Edwards Prima Plus Stentless Porcine Bioprosthesis - Root

22 = Carpentier-Edwards PERIMOUNT Pericardial Bioprosthesis

103 = Carpentier-Edwards PERIMOUNT Pericardial Magna Bioprosthesis

23 = Carpentier-Edwards Standard Porcine Bioprosthesis

25 = Carpentier-Edwards Supra-Annular Aortic Porcine Bioprosthesis

79 = Cryolife O'Brien Stentless Porcine Bioprosthesis - Subcoronary

80 = Cryolife O'Brien Stentless Porcine Bioprosthesis - Root

113 = Carpentier-Edwards PERIMOUNT RSR Pericardial Bioprosthesis

114 = Carpentier-Edwards PERIMOUNT Theon Pericardial Bioprosthesis

115 = Carpentier-Edwards S.A.V. Porcine Bioprosthesis

116 = Edwards Prima Plus Stentless Bioprosthesis

117 = Carpentier-Edwards PERIMOUNT Plus Pericardial Bioprosthesis with Tricentrix Holder

118 = Carpentier-Edwards Duraflex Low Pressure Porcine Bioprosthesis

119 = Carpentier-Edwards Duraflex Low Pressure ESR Porcine Bioprosthesis

120 = Carpentier-Edwards PERIMOUNT Theon Pericardial Bioprosthesis with Tricentrix Holder.

121 = St. Jude Medical Biocor Supra Stented Porcine Bioprosthesis

122 = St. Jude Medical Epic Supra Stented Porcine Bioprosthesis.

Homograft

89 = CryoLife Aortic Homograft

90 = CryoLife Pulmonary Homograft

91 = CryoLife CryoValve SG(Decellularized)Aortic Homograft

92 = CryoLife CryoValve SG Pulmonary Homograft

41 = Homograft Aortic - Subcoronary

42 = Homograft Aortic - Root

43 = Homograft Mitral

44 = Homograft Pulmonic Root

93 = LifeNet CV Allografts

Autograft

45 = Pulmonary Autograft to aortic root (Ross Procedure)

Ring/Annuloplasty

109 = ATS Simulus Flex-O Ring

110 = ATS Simulus Flex-C Band

94 = CarboMedics AnnuloFlo Ring

95 = CarboMedics AnnuloFlex Ring

96 = CarboMedics CardioFix Bovine Pericardium with PhotoFix Technology

46 = Carpentier-Edwards Classic Annuloplasty Ring

104 = Carpentier-Edwards Geoform Ring

105 = Carpentier-Edwards IMR Etlogix Ring

47 = Carpentier-Edwards Physio Annuloplasty System Ring

48 = Cosgrove-Edwards Annuloplasty System Ring

97 = Edwards MC³ Tricuspid Annuloplasty System G Future Band

98 = Genesee Sculptor Annuloplasty Ring

49 = Medtronic Sculptor Ring

50 = Medtronic-Duran AnCore Ring

51 = Sorin-Puig-Messana Ring

52 = St. Jude Medical Séguin Annuloplasty Ring.

106 = St. Jude Medical Rigid Saddle Ring

99 = St. Jude Medical Tailor Annuloplasty Ring

123 = ATS Simulus Flexible Annuloplasty ring.

124 = ATS Simulus Semi-Rigid Annuloplasty ring

125 = Carpentier-Edwards Classic Annuloplasty Ring with Duraflo Treatment

55 = Hancock Standard Porcine Bioprosthesis

28 = Hancock II Porcine Bioprosthesis

29 = Hancock Modified Orifice Porcine Bioprosthesis

30 = Ionescu-Shiley Pericardial Bioprosthesis

31 = Labcor Stented Porcine Bioprosthesis

81 = Labcor Stentless Porcine Bioprosthesis - Subcoronary

82 = Labcor Stentless Porcine Bioprosthesis - Root

83 = Medtronic Freestyle Stentless Porcine Bioprosthesis - Subcoronary

84 = Medtronic Freestyle Stentless Porcine Bioprosthesis - Root

35 = Medtronic Intact Porcine Bioprosthesis

36 = Medtronic Mosaic Porcine Bioprosthesis

85 = Medtronic Contegra Bovine Jugular Bioprosthesis

37 = Mitroflow Pericardial Bioprosthesis

39 = St. Jude Medical Toronto SPV Stentless Porcine Bioprosthesis

40 = St. Jude Medical-Bioimplant Porcine Bioprosthesis

86 = St. Jude Medical Biocor Stented Tissue Valve

87 = St. Jude Medical Epic Stented Porcine Bioprosthesis

88 = St. Jude Medical Toronto Root Stentless Porcine Bioprosthesis

38 = Sorin Pericarbon Stentless Pericardial Bioprosthesis

111 = Carpentier-Edwards PERIMOUNT MAGNA Pericardial Bioprosthesis with Carpentier-Edwards Thermafix Tissue Process

126 = Carpentier-Edwards Physio Annuloplasty Ring with Duraflo Treatment

127 = Cosgrove-Edwards Annuloplasty System with Duraflo Treatment

128 = Myxo Etlogix Annuloplasty Ring

131 = Sorin Memo 3D Ring

132 = UNIRING, Universal Annuloplasty System

Band / Annuloplasty

100 = Medtronic Colvin Galloway Future Band

101 = Medtronic Duran Band

102 = Medtronic Duran - Ancore Band

107 = St. Jude Medical Tailor Annuloplasty Band

Other

777 = Other

VAD *(if 18 yrs or older)*

Ventricular Assist Device Implanted: ☐ Yes ☐ No *(If Yes ↓)*

Previous VAD: ☐ Yes ☐ No *(If Yes →)* Implanted at another facility: ☐ Yes ☐ No

References to "Initial VAD" refer to the initial VAD for this hospitalization, not a VAD placed during a previous hospitalization.

Current Circulatory Support: For Initial VAD Only

Indication for VAD: ☐ Bridge to Transplantation ☐ Bridge to Recovery ☐ Destination
☐ Postcardiotomy Ventricular Failure (Separation from CPB) ☐ Device Malfunction ☐ End of Life

Intubated Pre VAD: ☐ Yes ☐ No

Hemodynamics Pre VAD:

PCWP: _____mm/Hg CVP: _____mm/Hg CI: _____L/ (min x m2)

RV Function: ☐ Normal ☐ Mildly Impaired ☐ Moderately Impaired ☐ Severely Impaired

VAD Device Data:

Implant Type: **Fill in below:** Right VAD (RVAD) Left VAD (LVAD) BiVentricular BiVAD (BiVAD) Total Artificial Heart (TAH)

Product Type: **Fill in below:** 1. HeartQuest VAD 2. Lion Heart 3. Novacor LVAS 4. Heartsaver VAD 5. Jarvik 2000 6. DeBakey VAD 7. TandemHeart pVAD 8. AB-180 iVAD 9. CardioWest TAH 10. Thoratec IVAD 11. HeartMate VE 12. HeartMate IP LVAS 13. HeartMate SNAP-VE 14. HeartMate XVE 15. HeartMate II 16. HeartMate III 17. BVS5000i 18. AbioCor 19. Incor 20. Excor 22. Abiomed AB 5000 23. Abiomed Impella 24. VentrAssist 25. Circulite LVAD 26. HeartWare – HVAD 27. Terumo – DuraHeart LVAD 28. WorldHeart – Levacor LVAD 29. Levitronix – CentriMag 21. Other

Explant Reason: **Fill in below:** 1. Cardiac Transplant 2. Recovery 3. Device Transfer 4. Device Related Infection 5. Device Malfunction 6. End of Life

Initial Implant Data

Implant Type	Product Type	Implant Date	Explant	Explant Date	Explant Reason	Transplant Date
_____	_____	___ / __ / _____ mm dd yyyy	☐ Yes ☐ No	___ / ___ / _____ mm dd yyyy	_____	___ / ___ / _____ mm dd yyyy

Initial VAD Cannulation/Attach Site:

LVAD Inflow: ☐ Left Atrium ☐ Left Ventricle

RVAD Inflow: ☐ Right Atrium ☐ Right Ventricle

Additional Implant(s) Data

Second Device Implanted: ☐ Yes ☐ No *(If Yes ↓)*

Implant Type #2	Product Type #2	Implant Date #2	Explant #2	Explant Date #2	Explant Reason #2	Transplant Date #2
_____	_____	___ / ___ / ____ mm dd yyyy	☐ Yes ☐ No	___ / ___ / ___ mm dd yyyy	_____	___ / ___/____ mm dd yyyy

Implant #2 VAD Cannulation/Attach Site:

LVAD Inflow: ☐ Left Atrium ☐ Left Ventricle

RVAD Inflow: ☐ Right Atrium ☐ Right Ventricle

Third Device Implanted: ☐ Yes ☐ No *(If Yes ↓)*

Implant Type #3	Product Type #3	Implant Date #3	Explant #3	Explant Date #3	Explant Reason #3	Transplant Date #3
_____	_____	___ / ___ / ____ mm dd yyyy	☐ Yes ☐ No	___ / ___ / ___ mm dd yyyy	_____	___ / ___/____ mm dd yyyy

Implant #3 VAD Cannulation/Attach Site:

LVAD Inflow: ☐ Left Atrium ☐ Left Ventricle

RVAD Inflow: ☐ Right Atrium ☐ Right Ventricle

Primary VAD Complications Data:

Intracranial Bleed: ☐ Yes ☐ No

Embolic Stroke: ☐ Yes ☐ No

Driveline and/or Cannula Infection: ☐ Yes ☐ No

Pump Pocket Infection: ☐ Yes ☐ No

VAD Endocarditis: ☐ Yes ☐ No

Device Malfunction: ☐ Yes ☐ No

Bowel Obstruction: ☐ Yes ☐ No

Additional Complications (not specific to initial VAD as above) to be collected in Complications.

VAD Discharge Status: ☐ With VAD

☐ Without VAD

☐ Expired in hospital (where initial VAD was implanted)

An empirically based tool for analyzing mortality associated with congenital heart surgery

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Objective: Analysis of congenital heart surgery results requires a reliable method of estimating the risk of adverse outcomes. Two major systems in current use are based on projections of risk or complexity that were predominantly subjectively derived. Our goal was to create an objective, empirically based index that can be used to identify the statistically estimated risk of in-hospital mortality by procedure and to group procedures into risk categories.

Methods: Mortality risk was estimated for 148 types of operative procedures using data from 77,294 operations entered into the European Association for Cardiothoracic Surgery (EACTS) Congenital Heart Surgery Database (33,360 operations) and the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database (43,934 patients) between 2002 and 2007. Procedure-specific mortality rate estimates were calculated using a Bayesian model that adjusted for small denominators. Each procedure was assigned a numeric score (the STS–EACTS Congenital Heart Surgery Mortality Score [2009]) ranging from 0.1 to 5.0 based on the estimated mortality rate. Procedures were also sorted by increasing risk and grouped into 5 categories (the STS–EACTS Congenital Heart Surgery Mortality Categories [2009]) that were chosen to be optimal with respect to minimizing within-category variation and maximizing between-category variation. Model performance was subsequently assessed in an independent validation sample (n = 27,700) and compared with 2 existing methods: Risk Adjustment for Congenital Heart Surgery (RACHS-1) categories and Aristotle Basis Complexity scores.

Results: Estimated mortality rates ranged across procedure types from 0.3% (atrial septal defect repair with patch) to 29.8% (truncus plus interrupted aortic arch repair). The proposed STS–EACTS score and STS–EACTS categories demonstrated good discrimination for predicting mortality in the validation sample (C-index = 0.784 and 0.773, respectively). For procedures with more than 40 occurrences, the Pearson correlation coefficient between a procedure's STS–EACTS score and its actual mortality rate in the validation sample was 0.80. In the subset of procedures for which RACHS-1 and Aristotle Basic Complexity scores are defined, discrimination was highest for the STS–EACTS score (C-index = 0.787), followed by STS–EACTS categories (C-index = 0.778), RACHS-1 categories (C-index = 0.745), and Aristotle Basic Complexity scores (C-index = 0.687). When patient covariates were added to each model, the C-index improved: STS–EACTS score (C-index = 0.816), STS–EACTS categories (C-index = 0.812), RACHS-1 categories (C-index = 0.802), and Aristotle Basic Complexity scores (C-index = 0.795).

Conclusion: The proposed risk scores and categories have a high degree of discrimination for predicting mortality and represent an improvement over existing consensus-based methods. Risk models incorporating these measures may be used to compare mortality outcomes across institutions with differing case mixes.

Cardiac surgeons have recognized and emphasized the need to establish clinical registries and quantitative tools for responsible reporting of outcomes. Large multi-institutional databases, such as the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database, among others, have developed, applied, and validated methods of risk adjustment in reporting outcomes. This has addressed appropriate concerns that the reporting of raw, unadjusted mortality data is misleading and potentially penalizes surgeons and centers

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Abbreviations and Acronyms

ABC = Aristotle Basic Complexity
EACTS = European Association for Cardiothoracic Surgery
RACHS-1 = Risk Adjustment for Congenital Heart Surgery
STS = Society of Thoracic Surgeons

that manage high-risk patients and complex procedures because observed mortality rates might be higher than in centers dealing with less challenging cases. The kinds of statistical tools and risk models that have been developed to address these issues when the clinical substrate is adult patients with acquired cardiovascular disease cannot simply be applied to the population of pediatric and adult patients with congenital heart disease. Here the problem is considerably more complex, in large part because the individual diagnoses and distinct types of surgical procedures number in the hundreds, despite the fact that the universe of patients with congenital heart disease is considerably smaller than that of adult patients with ischemic and valvular heart disease. As a result, the number of patients in some diagnostic and procedural groups is quite small. Nonetheless, it is recognized that the need to establish tools for case-mix adjustment is fundamental to any systematic attempt to measure outcomes, compare performance, and sustain a program of continual quality improvement.

As a response to the need for case-mix adjustment of outcome data but in the absence of significant amounts of registry data in 2000, the Aristotle Complexity score was developed.[1,2] Using the expert opinions of 50 internationally based surgeons, the Aristotle Basic Complexity (ABC) score was constructed for 145 distinct congenital heart surgery procedures. Three components (potential for mortality, potential for morbidity, and technical difficulty) were subjectively scored, and the sum became the ABC score.

Separately, another group of researchers developed the Risk Adjustment for Congenital Heart Surgery (RACHS-1) system, also using an expert panel.[3,4] RACHS-1 groups procedures into 6 levels of increasing risk of mortality. This allocation of procedures was subsequently refined using empirical data from 2 multi-institutional registries. When compared with the ABC score, the RACHS-1 categories appear to have better discrimination for predicting mortality, whereas the ABC score covers a larger proportion of congenital heart surgery case volume.[5-7]

The largest validation study of the ABC score was recently conducted by using a combined sample of nearly 36,000 patients from the STS Congenital Heart Surgery Database and the European Association for Cardiothoracic Surgery (EACTS) Congenital Heart Surgery Database.[7] In that study there was a significant increasing association between the ABC score and in-hospital mortality, with an overall C-index of 0.70. Although it was clear that the ABC score generally discriminated between low-risk and high-risk procedures, it was also clear that for a relatively small number of individual procedures, the initial estimation of mortality risk by the Aristotle international panel of surgical experts did not accurately predict the actual empirical estimates observed over the ensuing decade.

The goal of the present study was to derive a new system for classifying congenital heart surgery procedures based on their potential for in-hospital mortality using empirical data from the STS and EACTS databases. There were 3 specific objectives.

First, we sought to estimate procedure-specific relative risks of in-hospital mortality using a statistical model that accounts for uncertainty in procedures with small sample sizes.

Second, we sought to convert these procedure-specific mortality estimates into a scale ranging from 0.1 to 5.0. The range of this scale was chosen for consistency with the Aristotle method. The resulting score has been named the STS–EACTS Congenital Heart Surgery Mortality Score (2009) (or, briefly, the STS–EACTS score).

Third, we sought to group procedures with similar estimated mortality risk into a small number of relatively homogeneous categories (the STS–EACTS Congenital Heart Surgery Mortality Categories [2009] or, briefly, the STS–EACTS categories). These categories are intended to serve as a stratification variable that can be used to adjust for case mix when analyzing outcomes and comparing institutions.

MATERIALS AND METHODS

Study Population

The STS Congenital Heart Surgery Database and the EACTS Database are described elsewhere.[8] The study population consisted of patients who underwent a congenital cardiovascular operation at an STS-participating hospital between January 1, 2002, and December 31, 2006, or at an EACTS-participating hospital between January 1, 2002, and April 4, 2007. Data from 1 STS center were excluded because this participant did not consistently report outcomes during the study period. Only the first operation of each hospital admission was analyzed. Operations were included if they involved one of the 148 cardiovascular procedures listed in Table 1. This list includes all cardiovascular procedures that were included in the short-list nomenclature of the STS and EACTS databases and appeared at least once as the primary procedure of an operation in the STS–EACTS dataset. Patients weighing less than or equal to 2500 g undergoing patent ductus arteriosus ligation as their primary procedure were excluded from the analysis because they are not included in mortality calculations in the EACTS and STS Congenital Database reports. In addition, 244 (0.3%) patients with missing in-hospital mortality status were excluded. The final study population consisted of 43,934 operations from 57 centers in the STS database and 33,360 operations from 91 centers in the EACTS database for a total of 77,294 operations.

The risk tool developed using this dataset was subsequently validated in a separate sample of STS and EACTS patients meeting the same inclusion criteria described above. This validation sample consisted of 20,042 operations performed between January 1, 2007, and June 30, 2008, in the STS database and 7658 operations performed between April 5, 2007, and April 8, 2008, in the EACTS database.

TABLE 1. Procedure names, proposed scores and categories, and data for model development

	Procedure scores			No. of operations		Estimated mortality risk	
Procedure name	Difficulty ranking	Mortality score	Mortality category	All operations	No. with nonmissing mortality	Unadjusted % (95% interval*)	Model based % (95% interval†)
ASD repair, patch	8	0.1	1	4035	4028	0.2% (0.1%–0.4%)	0.3% (0.1%–0.5%)
AVC (AVSD) repair, partial (incomplete) (PAVSD)	31	0.1	1	1064	1062	0.3% (0.1%–0.8%)	0.5% (0.2%–0.9%)
ASD repair, patch + PAPCV repair	28	0.2	1	438	438	0.2% (0.0%–1.3%)	0.6% (0.2%–1.4%)
Aortic stenosis, subvalvar, repair	42	0.2	1	1834	1828	0.5% (0.3%–1.0%)	0.6% (0.3%– 1.0%)
ICD (AICD) implantation	14	0.2	1	391	384	0.3% (0.0%–1.4%)	0.7% (0.2%–1.6%)
DCRV repair	48	0.2	1	467	467	0.4% (0.1%–1.5%)	0.8% (0.2%–1.6%)
ASD repair, primary closure	7	0.2	1	2230	2229	0.8% (0.5%–1.3%)	0.9% (0.5%–1.3%)
VSD repair, patch	32	0.2	1	6717	6702	0.9% (0.7%–1.1%)	0.9% (0.7%–1.1%)
Vascular ring repair	19	0.2	1	899	895	0.8% (0.3%–1.6%)	0.9% (0.4%–1.6%)
Coarctation repair, end to end	24	0.2	1	1703	1702	0.9% (0.5%– 1.5%)	1.0% (0.6%–1.5%)
ICD (AICD) procedure	15	0.2	1	127	126	0.0% (0.0%–2.9%)	1.0% (0.2%–2.9%)
PFO, primary closure	6	0.2	1	217	216	0.5% (0.0%–2.6%)	1.1% (0.3%–2.5%)
AVR, bioprosthetic	55	0.3	1	101	101	0.0% (0.0%–3.6%)	1.2% (0.2%–3.4%)
VSD repair, primary closure	30	0.3	1	754	752	1.1% (0.5%–2.1%)	1.2% (0.6%–2.1%)
PVR	44	0.3	1	682	680	1.2% (0.5%–2.3%)	1.3% (0.6%–2.3%)
Conduit reoperation	77	0.3	1	1303	1299	1.3% (0.8%–2.1%)	1.4% (0.8%–2.1%)
Pacemaker procedure	3	0.3	1	1411	1408	1.3% (0.8%–2.1%)	1.4% (0.9%–2.1%)
PAPVC repair	27	0.3	1	481	481	1.2% (0.5%–2.7%)	1.5% (0.7%–2.7%)
TOF repair, ventriculotomy, nontransanular patch	62	0.3	1	930	928	1.4% (0.7%–2.4%)	1.5% (0.8%–2.4%)
TOF repair, no ventriculotomy	81	0.3	1	862	860	1.4% (0.7%–2.4%)	1.5% (0.8%–2.3%)
Glenn (unidirectional cavopulmonary anastomosis; unidirectional Glenn procedure)	41	0.3	1	65	65	0.0% (0.0%–5.5%)	1.5% (0.2%–4.3%)
AVC (AVSD) repair, intermediate (transitional)	33	0.3	1	421	420	1.4% (0.5%–3.1%)	1.6% (0.7%–3.0%)
Coarctation repair, interposition graft	49	0.3	1	114	114	0.9% (0.0%–4.8%)	1.7% (0.4%–4.1%)
Fontan, TCPC, lateral tunnel, fenestrated	101	0.3	1	743	742	1.6% (0.8%–2.8%)	1.7% (0.9%–2.7%)
Sinus of Valsalva, aneurysm repair	61	0.3	1	53	53	0.0% (0.0%–6.7%)	1.7% (0.3%–5.2%)
AVR, mechanical	52	0.3	1	384	383	1.6% (0.6%–3.4%)	1.7% (0.7%–3.2%)
PDA closure, surgical	5	0.4	2	1922	1910	1.8% (1.3%–2.5%)	1.9% (1.3%–2.5%)
PA, reconstruction (plasty), main (trunk)	25	0.4	2	192	191	1.6% (0.3%–4.5%)	1.9% (0.6%–4.0%)
LV to aorta tunnel repair	90	0.4	2	42	42	0.0% (0.0%–8.4%)	1.9% (0.3%–5.9%)
Valvuloplasty, mitral	76	0.4	2	1751	1747	1.9% (1.3%–2.6%)	1.9% (1.3%–2.6%)
Valvuloplasty, aortic	72	0.4	2	861	861	1.9% (1.1%–3.0%)	1.9% (1.1%–2.9%)
11/2 Ventricular repair	58	0.4	2	39	39	0.0% (0.0%–9.0%)	2.0% (0.3%–6.2%)

CHD

TABLE 1. Continued

Procedure name	Procedure scores: Difficulty ranking	Procedure scores: Mortality score	Procedure scores: Mortality category	No. of operations: All operations	No. of operations: No. with nonmissing mortality	Estimated mortality risk: Unadjusted % (95% interval*)	Estimated mortality risk: Model based % (95% interval†)
Arrhythmia surgery–ventricular, surgical ablation	85	0.4	2	33	33	0.0% (0.0%–10.6%)	2.2% (0.3%–6.8%)
Pacemaker implantation, permanent	2	0.4	2	1086	1077	2.1% (1.4%–3.2%)	2.2% (1.4%–3.1%)
Ross procedure	127	0.4	2	620	617	2.1% (1.1%–3.6%)	2.2% (1.3%–3.4%)
Glenn+PA reconstruction	71	0.4	2	428	426	2.1% (1.0%–4.0%)	2.2% (1.1%–3.8%)
Aortopexy	4	0.4	2	30	30	0.0% (0.0%–11.6%)	2.3% (0.3%–7.3%)
Fontan, atriopulmonary connection	94	0.4	2	30	30	0.0% (0.0%–11.6%)	2.3% (0.3%–6.9%)
Bilateral bidirectional cavopulmonary anastomosis (bilateral bidirectional Glenn procedure)	63	0.4	2	449	449	2.2% (1.1%–4.1%)	2.4% (1.2%–3.8%)
Aortic root replacement, mechanical	111	0.5	2	145	145	2.1% (0.4%–5.9%)	2.4% (0.7%–5.1%)
Conduit placement, LV to PA	73	0.5	2	25	25	0.0% (0.0%–13.7%)	2.4% (0.3%–7.9%)
Coarctation repair, end to end, extended	50	0.5	2	1965	1961	2.5% (1.9%–3.3%)	2.5% (1.9%–3.3%)
Anomalous origin of coronary artery repair	119	0.5	2	327	326	2.5% (1.1%–4.8%)	2.6% (1.2%–4.4%)
RVOT procedure	40	0.5	2	1591	1583	2.6% (1.9%–3.5%)	2.6% (1.9%–3.5%)
Aortic aneurysm repair	93	0.5	2	322	321	2.5% (1.1%–4.9%)	2.6% (1.3%–4.5%)
Congenitally corrected TGA repair, VSD closure	106	0.5	2	21	21	0.0% (0.0%–16.1%)	2.6% (0.3%–8.8%)
AP window repair	35	0.5	2	125	125	2.4% (0.5%–6.9%)	2.7% (0.9%–5.6%)
Valvuloplasty, pulmonic	26	0.5	2	307	307	2.6% (1.1%–5.1%)	2.7% (1.3%–4.7%)
TOF repair, ventriculotomy, transannular patch	79	0.5	2	2541	2535	2.7% (2.1%–3.4%)	2.7% (2.1%–3.4%)
Aortic root replacement, bioprosthetic	120	0.5	2	20	20	0.0% (0.0%–16.8%)	2.7% (0.3%–9.3%)
Bidirectional cavopulmonary anastomosis (bidirectional Glenn procedure)	43	0.5	2	2502	2492	2.7% (2.1%–3.4%)	2.7% (2.1%–3.4%)
Aortic stenosis, supravalvar, repair	64	0.5	2	336	335	2.7% (1.2%–5.0%)	2.8% (1.4%–4.6%)
Pericardiectomy	20	0.5	2	48	48	2.1% (0.1%–11.1%)	2.9% (0.5%–7.5%)
Conduit placement, other	75	0.5	2	16	16	0.0% (0.0%–20.6%)	2.9% (0.3%–9.8%)
Aneurysm, ventricular, left, repair	107	0.5	2	47	46	2.2% (0.1%–11.5%)	3.0% (0.5%–7.8%)
Fontan, TCPC, external conduit, fenestrated	96	0.6	2	1241	1238	3.0% (2.1%–4.1%)	3.0% (2.1%–4.0%)
Pulmonary artery origin from ascending aorta (hemitruncus) repair	89	0.6	2	43	43	2.3% (0.1%–12.3%)	3.1% (0.6%–8.2%)

TABLE 1. Continued

Procedure name	Procedure scores: Difficulty ranking	Procedure scores: Mortality score	Procedure scores: Mortality category	No. of operations: All operations	No. of operations: No. with nonmissing mortality	Estimated mortality risk: Unadjusted % (95% interval*)	Estimated mortality risk: Model based % (95% interval†)
ASD, common atrium (single atrium), septation	18	0.6	2	44	44	2.3% (0.1%–12.0%)	3.1% (0.5%–8.3%)
PAPVC, scimitar, repair	91	0.6	2	72	72	2.8% (0.3%–9.7%)	3.2% (0.8%–7.7%)
Fontan, TCPC, external conduit, nonfenestrated	97	0.6	2	809	807	3.2% (2.1%–4.7%)	3.2% (2.1%–4.6%)
Ligation, pulmonary artery	16	0.6	2	11	11	0.0% (0.0%–28.5%)	3.4% (0.4%–12.1%)
Coronary artery fistula ligation	17	0.6	2	39	38	2.6% (0.1%–13.8%)	3.4% (0.6%–9.2%)
Aortic root replacement, valve sparing	142	0.6	2	37	37	2.7% (0.1%–14.2%)	3.4% (0.6%–9.2%)
Mitral stenosis, supravalvar mitral ring repair	74	0.6	2	86	86	3.5% (0.7%–9.9%)	3.6% (1.0%–7.7%)
Arrhythmia surgery–atrial, surgical ablation	84	0.7	2	273	272	3.7% (1.8%–6.7%)	3.6% (1.9%–5.9%)
Systemic venous stenosis repair	56	0.7	2	59	59	3.4% (0.4%–11.7%)	3.7% (0.9%–8.6%)
PA, reconstruction (plasty), branch, peripheral (at or beyond the hilar bifurcation)	70	0.7	2	189	189	3.7% (1.5%–7.5%)	3.7% (1.6%–6.5%)
Valvuloplasty, tricuspid	57	0.7	2	1182	1178	3.7% (2.7%–5.0%)	3.7% (2.8%–4.9%)
TVR	65	0.7	2	133	133	3.8% (1.2%–8.6%)	3.8% (1.5%–7.3%)
Valve replacement, truncal valve	46	0.7	2	8	8	0.0% (0.0%–36.9%)	3.8% (0.4%–13.8%)
Fontan, TCPC, lateral tunnel, nonfenestrated	99	0.7	2	104	104	3.8% (1.1%–9.6%)	3.9% (1.3%–7.9%)
Atrial fenestration closure	38	0.7	2	29	29	3.4% (0.1%–17.8%)	3.9% (0.7%–11.3%)
Cor triatriatum repair	60	0.7	2	177	176	4.0% (1.6%–8.0%)	4.0% (1.8%–7.2%)
VSD, multiple, repair	113	0.7	2	325	324	4.0% (2.2%–6.8%)	4.0% (2.2%–6.3%)
Atrial baffle procedure (non-Mustard, non-Senning)	67	0.7	2	26	26	3.8% (0.1%–19.6%)	4.0% (0.7%–11.0%)
Coarctation repair, subclavian flap	23	0.7	2	219	219	4.1% (1.9%–7.7%)	4.1% (2.0%–6.9%)
Partial left ventriculectomy (LV volume reduction surgery; Batista)	133	0.7	2	26	26	3.8% (0.1%–19.6%)	4.1% (0.7%–11.3%)
TOF repair, RV–PA conduit	80	0.7	2	362	358	4.2% (2.4%–6.8%)	4.2% (2.4%–6.4%)
Transplantation, lung(s)	129	0.8	3	94	93	4.3% (1.2%–10.6%)	4.2% (1.4%–8.6%)
Occlusion MAPCA(s)	51	0.8	3	26	26	3.8% (0.1%–19.6%)	4.2% (0.7%–12.1%)
Coarctation repair + VSD repair	112	0.8	3	329	327	4.3% (2.4%–7.1%)	4.2% (2.4%–6.6%)
Konno procedure	131	0.8	3	162	162	4.3% (1.8%–8.7%)	4.3% (1.9%–7.6%)
Coarctation repair, patch aortoplasty	22	0.8	3	395	393	4.3% (2.5%–6.8%)	4.3% (2.6%–6.5%)

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TABLE 1. Continued

Procedure name	Procedure scores: Difficulty ranking	Procedure scores: Mortality score	Procedure scores: Mortality category	No. of operations: All operations	No. of operations: No. with nonmissing mortality	Estimated mortality risk: Unadjusted % (95% interval*)	Estimated mortality risk: Model based % (95% interval†)
PA, reconstruction (plasty), branch, central (within the hilar bifurcation)	68	0.8	3	646	644	4.3% (2.9%–6.2%)	4.3% (2.9%–5.9%)
Aneurysm, pulmonary artery, repair	53	0.8	3	23	23	4.3% (0.1%–21.9%)	4.3% (0.8%–12.2%)
Aneurysm, ventricular, right, repair	86	0.8	3	91	91	4.4% (1.2%–10.9%)	4.3% (1.4%–8.8%)
Ventricular septal fenestration	45	0.8	3	24	24	4.2% (0.1%–21.1%)	4.4% (0.8%–12.4%)
Shunt, ligation and takedown	11	0.8	3	65	65	4.6% (1.0%–12.9%)	4.5% (1.3%–9.9%)
Hemi-Fontan procedure	78	0.8	3	262	260	4.6% (2.4%–7.9%)	4.5% (2.4%–7.1%)
AVC (AVSD) repair, complete	87	0.8	3	2869	2860	4.6% (3.9%–5.4%)	4.6% (3.9%–5.4%)
Anomalous systemic venous connection repair	54	0.8	3	166	166	4.8% (2.1%–9.3%)	4.8% (2.2%–8.2%)
ASO	115	0.8	3	2069	2068	4.8% (3.9%–5.8%)	4.8% (3.9%–5.7%)
Valvuloplasty, truncal valve	59	0.8	3	20	20	5.0% (0.1%–24.9%)	4.8% (0.8%–13.5%)
Fontan, atrioventricular connection	102	0.9	3	2	2	0.0% (0.0%–84.2%)	4.9% (0.4%–20.1%)
Pulmonary embolectomy, acute pulmonary embolus	34	0.9	3	2	2	0.0% (0.0%–84.2%)	5.0% (0.4%–19.7%)
ASD partial closure	10	0.9	3	37	37	5.4% (0.7%–18.2%)	5.1% (1.1%–12.7%)
Rastelli operation	125	0.9	3	333	333	5.4% (3.2%–8.4%)	5.3% (3.2%–7.8%)
Conduit placement, ventricle to aorta	95	0.9	3	1	1	0.0% (0.0%–97.5%)	5.3% (0.5%–21.4%)
AVR, homograft	110	1	3	30	30	6.7% (0.8%–22.1%)	5.8% (1.3%–13.8%)
REV	126	1.1	3	26	26	7.7% (0.9%–25.1%)	6.3% (1.3%–15.5%)
Pulmonary artery sling repair	105	1.1	3	88	86	7.0% (2.6%–14.6%)	6.4% (2.5%–11.9%)
Mustard procedure	100	1.1	3	25	25	8.0% (1.0%–26.0%)	6.4% (1.4%–15.9%)
Pulmonary atresia–VSD (including TOF, PA) repair	92	1.1	3	289	289	6.6% (4.0%–10.1%)	6.4% (4.0%–9.3%)
Conduit placement, RV to PA	66	1.2	3	965	964	6.7% (5.2%–8.5%)	6.7% (5.2%–8.4%)
Pulmonary embolectomy	37	1.2	3	9	9	11.1% (0.3%–48.2%)	7.1% (1.0%–22.1%)
MVR	69	1.3	4	637	636	7.4% (5.5%–9.7%)	7.3% (5.4%–9.4%)
Pericardial drainage procedure	1	1.3	4	258	256	7.8% (4.8%–11.8%)	7.5% (4.7%–11.0%)
Aortic arch repair	82	1.4	4	787	782	7.9% (6.1%–10.0%)	7.8% (6.1%–9.8%)
Fontan revision or conversion (redo Fontan procedure)	143	1.4	4	68	68	8.8% (3.3%–18.2%)	7.9% (3.1%–14.6%)
DOLV repair	130	1.4	4	7	7	14.3% (0.4%–57.9%)	7.9% (1.0%–24.0%)
DORV, intraventricular tunnel repair	132	1.4	4	583	582	8.1% (6.0%–10.6%)	8.0% (6.0%–10.3%)

TABLE 1. Continued

Procedure name	Procedure scores: Difficulty ranking	Procedure scores: Mortality score	Procedure scores: Mortality category	No. of operations: All operations	No. of operations: No. with nonmissing mortality	Estimated mortality risk: Unadjusted % (95% interval*)	Estimated mortality risk: Model based % (95% interval†)
Arterial switch procedure + aortic arch repair	136	1.4	4	18	18	11.1% (1.4%–34.7%)	8.0% (1.7%–20.6%)
PA debanding	29	1.4	4	104	104	8.7% (4.0%–15.8%)	8.0% (3.7%–13.7%)
ASO and VSD repair	138	1.4	4	987	985	8.3% (6.7%–10.2%)	8.2% (6.6%–10.0%)
Cardiac tumor resection	88	1.4	4	221	220	8.6% (5.3%–13.2%)	8.3% (5.1%–12.2%)
Transplantation, heart	103	1.4	4	626	625	8.5% (6.4%–10.9%)	8.4% (6.3%–10.6%)
Coronary artery bypass	98	1.5	4	62	62	9.7% (3.6%–19.9%)	8.5% (3.5%–16.0%)
TOF–absent pulmonary valve repair	109	1.5	4	166	165	9.1% (5.2%–14.6%)	8.6% (5.0%–13.1%)
Valve excision, tricuspid (without replacement)	13	1.5	4	5	5	20.0% (0.5%–71.6%)	8.8% (1.2%–28.1%)
Shunt, systemic to pulmonary, MBTS	39	1.5	4	2793	2785	8.9% (7.9%–10.1%)	8.9% (7.9%– 10.0%)
TOF–AVC (AVSD) repair	122	1.6	4	145	144	9.7% (5.4%–15.8%)	9.1% (5.0%–14.1%)
Ross–Konno procedure	146	1.6	4	205	205	9.8% (6.1%–14.7%)	9.4% (5.8%–13.9%)
Senning procedure	108	1.6	4	45	45	11.1% (3.7%–24.1%)	9.4% (3.5%–18.6%)
Ebstein's repair	124	1.6	4	65	65	10.8% (4.4%–20.9%)	9.5% (4.0%–17.6%)
Aortic arch repair + VSD repair	123	1.7	4	339	338	10.1% (7.1%–13.8%)	9.8% (6.9%–13.1%)
PA banding	21	1.7	4	1298	1292	9.9% (8.3%–11.7%)	9.8% (8.3%–11.5%)
Aortic root replacement, homograft	121	1.7	4	104	102	10.8% (5.5%–18.5%)	9.9% (5.1%–16.2%)
Unifocalization MAPCA(s)	116	1.7	4	319	319	10.3% (7.2%–14.2%)	10.0% (7.1%–13.4%)
Aortic dissection repair	128	1.7	4	32	31	12.9% (3.6%–29.8%)	10.0% (3.0%–21.1%)
Congenitally corrected TGA repair, VSD closure and LV to PA conduit	135	1.7	4	12	12	16.7% (2.1%–48.4%)	10.1% (2.0%–25.9%)
Pulmonary atresia–VSD–MAPCA (pseudotruncus) repair	137	1.7	4	160	158	10.8% (6.4%–16.7%)	10.2% (6.1%–15.3%)
VSD creation/enlargement	83	1.8	4	107	106	11.3% (6.0%–18.9%)	10.4% (5.6%–16.6%)
HLHS biventricular repair	145	1.9	4	64	64	12.5% (5.6%–23.2%)	10.9% (4.8%– 18.8%)
TAPVC repair	104	1.9	4	1381	1379	11.2% (9.6%–13.0%)	11.2% (9.5%–12.8%)
Pulmonary venous stenosis repair	117	2	4	270	268	11.9% (8.3%–16.4%)	11.4% (8.0%–15.3%)
Shunt, systemic to pulmonary, central (from aorta or to main pulmonary artery)	47	2.1	4	663	661	12.3% (9.9%–15.0%)	12.1% (9.7%–14.6%)
Interrupted aortic arch repair	118	2.1	4	519	515	12.4% (9.7%–15.6%)	12.2% (9.6%–15.1%)
Arterial switch procedure and VSD repair + aortic arch repair	144	2.4	4	113	113	15.0% (9.0%–23.0%)	14.0% (8.5%–20.5%)
Truncus arteriosus repair	134	2.4	4	592	586	14.3% (11.6%–17.4%)	14.1% (11.4%–16.8%)
ASD creation/enlargement	9	2.5	4	138	136	15.4% (9.8%–22.6%)	14.5% (9.4%–20.9%)
Atrial septal fenestration	12	2.6	4	18	18	22.2% (6.4%–47.6%)	15.1% (4.5%–30.8%)

TABLE 1. Continued

Procedure name	Procedure scores: Difficulty ranking	Procedure scores: Mortality score	Procedure scores: Mortality category	No. of operations: All operations	No. of operations: No. with nonmissing mortality	Estimated mortality risk: Unadjusted % (95% interval*)	Estimated mortality risk: Model based % (95% interval†)
Valve closure, tricuspid (exclusion, univentricular approach)	36	2.6	4	5	5	40.0% (5.3%–85.3%)	15.6% (2.7%–41.6%)
Damus–Kaye–Stansel procedure (creation of AP anastomosis without arch reconstruction)	114	2.9	5	344	343	17.5% (13.6%–21.9%)	17.1% (13.2%–21.5%)
Transplantation, heart and lung	141	3.2	5	13	13	30.8% (9.1%–61.4%)	18.7% (5.4%–39.8%)
Congenitally corrected TGA repair, atrial switch and Rastelli operation	139	3.2	5	18	18	27.8% (9.7%–53.5%)	18.9% (6.3%–37.2%)
Congenitally corrected TGA repair, atrial switch and ASO (double switch)	148	3.4	5	32	32	25.0% (11.5%–43.4%)	20.0% (9.1%–34.7%)
Norwood procedure	147	4	5	2383	2359	23.7% (22.0%–25.4%)	23.6% (21.9%–25.3%)
Truncus + IAA repair	140	5	5	43	43	34.9% (21.0%–50.9%)	29.8% (17.7%–44.3%)

ASD, Atrial septal defect; *AVC*, atrioventricular canal; *AVSD*, atrioventricular septal defect; *PAVSD*, partial atrioventricular septal defect; *PAPVC*, partial anomalous pulmonary venous connection; *ICD*, implantable cardioverter defibrillator; *AICD*, automatic implantable cardioverter defibrillator; *DCRV*, double-chambered right ventricle; *VSD*, ventricular septal defect; *PFO*, patent foramen ovale; *AVR*, aortic valve replacement; *PVR*, pulmonary valve replacement; *TOF*, tetralogy of Fallot; *TCPC*, total cavopulmonary connection; *PDA*, patent ductus arteriosus; *PA*, pulmonary artery; *LV*, left ventricle; *RVOT*, right ventricular outflow tract; *TGA*, transposition of the great arteries; *AP*, aortopulmonary; *TVR*, tricuspid valve replacement; *RV*, right ventricle; *MAPCA*, major aortopulmonary collateral artery; *ASO*, arterial switch operation; *REV*, réparation à l'étage ventriculaire (REV procedure); *MVR*, mitral valve replacement; *DOLV*, double-outlet left ventricle; *MBTS*, modified Blalock–Taussig shunt; *HLHS*, hypoplastic left heart syndrome; *TAPVC*, total anomalous pulmonary venous connection; *IAA*, interrupted aortic arch. *Denotes 95% exact binomial confidence interval. †Denotes 95% Bayesian credible interval.

Hospitals participating in the STS and EACTS registries are required to comply with local regulatory and privacy guidelines. The Duke Clinical Research Institute serves as the data analysis center for the STS database and has an agreement, as well as institutional review board approval, to analyze the aggregate deidentified data for research purposes.

Classification of Multiple-Procedure Operations

Several procedures listed in Table 1 are actually combinations of 2 or more procedures. These combinations were identified by the Aristotle expert panel because they occur frequently in the STS and EACTS databases and because the complexity of the combination is regarded as being different from the complexity of the component procedures when performed in isolation. For all other operations involving combinations of procedures, the operation was classified according to the most technically complex procedure, as determined by the difficulty component of the 2007 update of the ABC score. The ABC score contains some ties and is not defined for 3 of the procedures listed in Table 1. To deal with undefined or tied Aristotle scores, 6 of the study authors independently ranked the difficulty of each procedure listed in Table 1. Undefined or tied Aristotle scores were adjudicated by assigning the operation to the procedure with the highest average ranking determined by the 6 graders. The difficulty rankings are included in Table 1 so that users of the risk tool will be able to replicate our method of classifying multiple-procedure operations.

End Point

The study end point was in-hospital mortality, which was defined as death during the same hospitalization as surgery regardless of cause.

Estimation of Procedure-Specific Mortality Rates

Mortality estimates were calculated by using a Bayesian random effects model that adjusted each procedure's mortality rate based on the size of the denominator. Using a statistical model was considered advantageous because several individual procedures had small denominators, and hence their unadjusted mortality rates were susceptible to chance fluctuations. Unlike conventional methods, random effects models use data from all of the procedures in the database when estimating the probability of mortality for any single procedure. This "borrowing of information" across procedures produces estimates with good statistical properties, including smaller standard errors than conventional estimates. Heuristically, the model-based estimate is a weighted average of a procedure's actual observed mortality rate and the overall average mortality rate for all procedures in the database. The model weights an individual procedure's own data more heavily when the denominator is large enough to be reliable and weights the overall average mortality rate more heavily when the denominator is too small to support a reliable mortality estimate. For procedures with more than 200 occurrences, the model-based estimates were virtually identical to the usual unadjusted (raw) mortality percentages (Appendix 1).

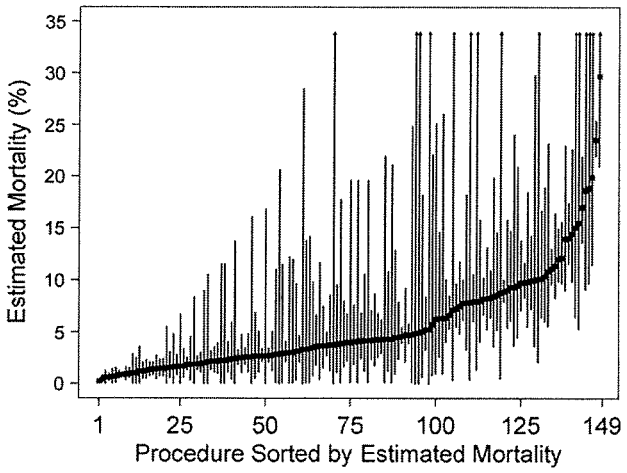

FIGURE 1. Procedure-specific estimated mortality rates. *Square dots* represent model-based procedure-specific mortality estimates. *Vertical lines* represent exact 95% binomial confidence intervals.

Creation of the Mortality Score

Each procedure was assigned a numeric score (STS–EACTS score) ranging from 0.1 to 5.0. The scores were assigned by shifting and rescaling the estimated procedure-specific mortality rates to lie in the interval from 0.1 to 5.0 and then rounding to one decimal place. The following formula was used:

$$\text{Mortality score of } j\text{-th procedure} = 0.1 + 4.9 \times \frac{p_j - \min}{\max - \min},$$

where p_j denotes the estimated risk of the *j-th* procedure, and *max* and *min* denote the maximum and minimum values of p_j across the 148 procedures.

Creation of Mortality Categories

Procedures were sorted by increasing estimated risk and partitioned into 5 relatively homogeneous categories (STS–EACTS categories). Five categories was the smallest number that did not result in excessive within-category heterogeneity. Within-category homogeneity was measured objectively using a weighted sum of squares criterion (Appendix 2).[9] A dynamic programming algorithm was then used to find the categorization that maximizes the homogeneity criterion. This data-driven approach ensures that procedures in the same category will be as similar as possible with respect to their estimated mortality risk.

To determine the number of categories, we evaluated the performance of different categorizations consisting of 2 to 20 categories. Performance was assessed internally based on 2 criteria. First, we evaluated the internal homogeneity of the categories using the criterion described in Appendix 2. Second, we assessed the discrimination of the categories as predictors of mortality. Discrimination was quantified by the area under the receiver operating characteristic curve (also known as the C-index).[10] The C-index is interpreted as the probability that a randomly selected patient who died was considered to be higher risk than a randomly selected patient who survived. The C-index generally ranges from 0.5 to 1.0, with 0.5 representing no discrimination (ie, a coin flip) and 1.0 representing perfect discrimination.

TABLE 2. Characteristics of proposed risk categories in 2002–2007 STS and EACTS data

	STS–EACTS mortality category				
	1	2	3	4	5
Range of scores	0.1–0.3	0.4–0.7	0.8–1.2	1.3–2.6	2.7–5.0
No. of procedures	26	52	27	37	6
No. of patients	28,363	23,235	9026	13,862	2808
No. of deaths	234	601	449	1374	650
Mortality	0.8%	2.6%	5.0%	9.9%	23.1%

STS–EACTS, Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery.

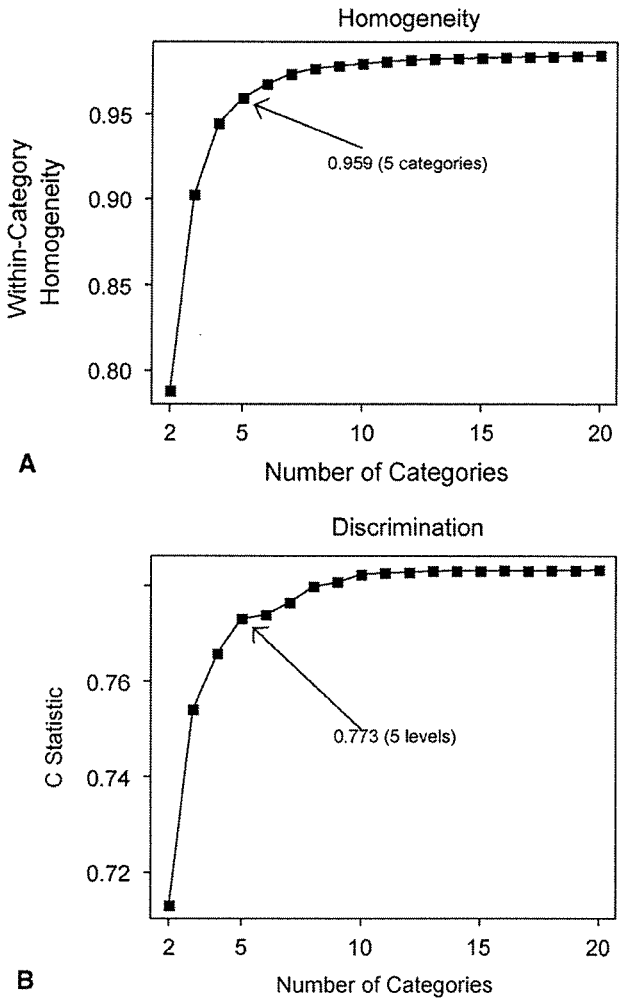

FIGURE 2. Association between number of procedure categories and within-category homogeneity of mortality risk (Panel A) and discrimination for predicting mortality (Panel B). Performance improves with increasing numbers of categories. See Appendix 2 for definition of within-category homogeneity.

Models Combining Scores and Categories With Patient-Level Risk Factors

Two logistic regression models were developed to illustrate the utility of modeling the proposed scores and categories together with patient-level risk factors. The first model included the STS–EACTS score (modeled as a continuous variable) plus 3 patient-level factors: age, weight, and preoperative length of stay. To allow for possible nonlinear effects, the score and the square of the score were both entered in the model. Age and weight were modeled jointly by converting them into a single categorical variable with 7 levels (see Results). Preoperative length of stay was dichotomized as less than or equal to 2 days versus more than 2 days. The second model was identical but used the STS–EACTS categories

TABLE 3. Summary of logistic regression models combining the proposed STS–EACTS scores and categories with patient-level risk factors

Variable	Odds ratio (95% confidence interval)	
	Model 1: STS–EACTS score + patient factors	Model 2: STS–EACTS categories + patient factors
STS–EACTS mortality score		
0.5 vs 0.25	1.4 (1.4–1.5)	–
1.0 vs 0.25	2.6 (2.4–2.8)	–
2.0 vs 0.25	6.3 (5.6–7.1)	–
4.0 vs 0.25	9.4 (8.2–10.8)	–
STS–EACTS mortality category		
Category 1	–	Reference
Category 2	–	2.9 (2.4–3.3)
Category 3	–	4.3 (3.6–5.0)
Category 4	–	7.5 (6.5–8.7)
Category 5	–	15.9 (13.3–18.9)
Age and weight category		
Age ≥1 y	Reference	Reference
Age 1–11 mo, weight ≥6.0 kg	1.0 (0.8–1.2)	0.9 (0.8–1.1)
Age 1–11 mo, weight 4.0–5.9 kg	1.4 (1.2–1.6)	1.3 (1.2–1.5)
Age 1–11 mo, weight <4.0 kg	2.6 (2.2–3.0)	2.6 (2.3–3.0)
Age <1 mo, weight ≥3.0 kg	2.0 (1.8–2.2)	1.9 (1.7–2.2)
Age <1 mo, weight 2.0–2.9 kg	3.3 (2.8–3.8)	3.2 (2.8–3.7)
Age <1 mo, weight <2.0 kg	4.9 (4.2–5.8)	4.9 (4.2–5.7)
Preoperative LOS		
≤2 d	Reference	Reference
>2 d	1.4 (1.3–1.6)	1.4 (1.3–1.5)

STS–EACTS, Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery; *LOS*, length of stay.

(modeled as a set of category indicators) instead of the STS–EACTS score. Additional patient factors, such as comorbidities, were not included because these data were not available to us for the EACTS subset at the time of analysis.

Comparisons With RACHS-1 Categories and ABC Scores

The models described above were also estimated with RACHS-1 categories in place of the STS–EACTS categories and with the ABC score in place of the STS–EACTS score to facilitate comparisons with existing methods. Briefly, the ABC score of a procedure is a number ranging from 1.5 to 15 points that reflects the Aristotle expert panel's assessment of that type of procedure's potential for mortality, morbidity, and technical difficulty. When analyzing operations with multiple procedures, the ABC score was defined as the maximum ABC score across all procedures in the operation. The RACHS-1 methodology divides procedures into 6 categories based on an expert panel's assessment of the procedure's average

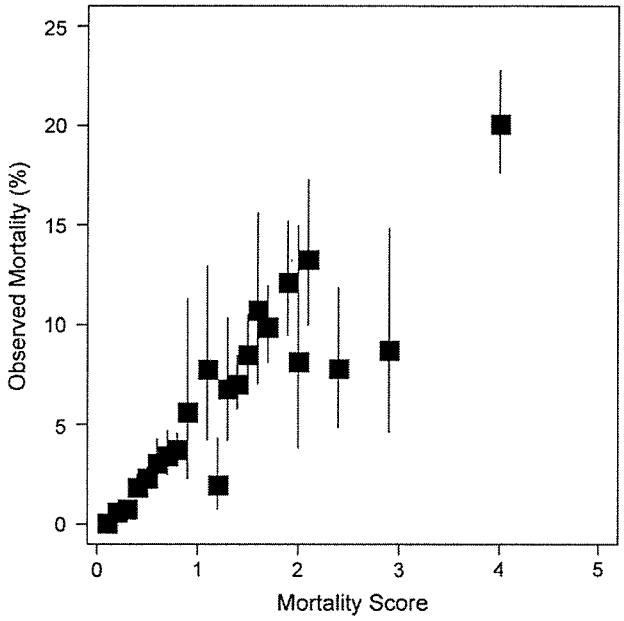

FIGURE 3. Association between Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery score and in-hospital mortality in the validation sample. *Square dots* represent the aggregate mortality rate of procedures sharing the same risk score. Data points with fewer than 40 observations were excluded from the figure. *Vertical lines* represent 95% binomial confidence intervals.

mortality risk, where category 1 has the lowest risk of mortality and category 6 has the highest. Unlike the ABC method, the classification of some procedures is allowed to depend on the patient's age. When analyzing operations with multiple procedures, the operation is assigned to the procedure with the highest RACHS-1 category. Because very few data points

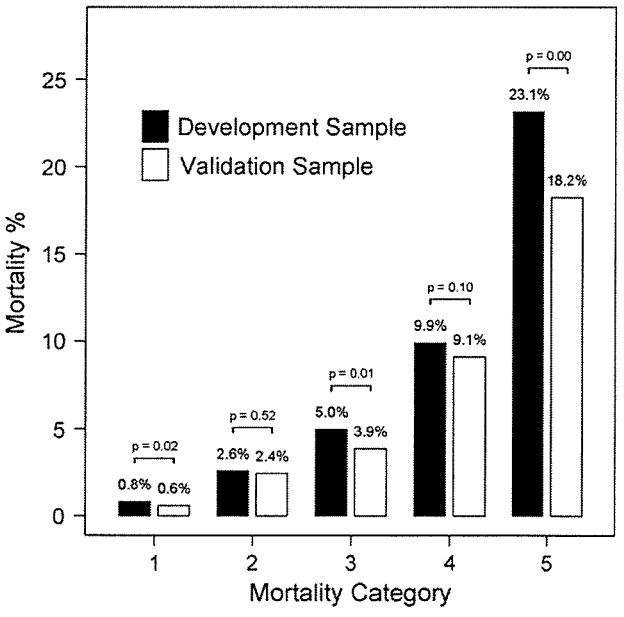

FIGURE 4. Association between proposed risk categories and observed in-hospital mortality.

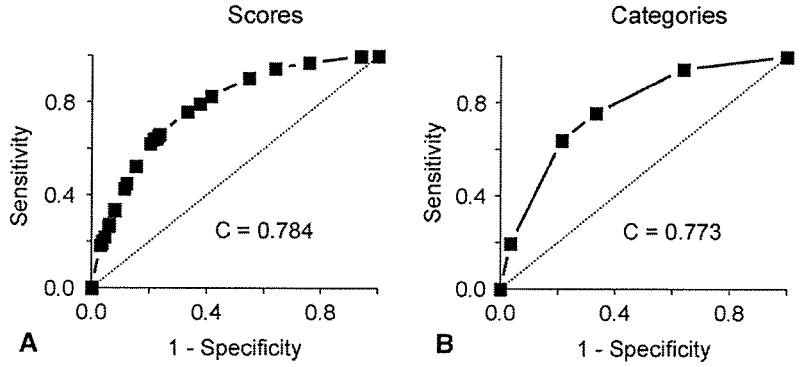

FIGURE 5. Receiver operating characteristic curves for the Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery scores (A) and categories (B) as predictors of in-hospital mortality in the validation sample. The *diagonal line* is provided as a reference. It is the receiver operating characteristic curve that would be observed hypothetically if the scores and categories were not associated with mortality.

were available in RACHS-1 category 5, it was combined with category 6 for analysis. The "full" RACHS-1 methodology involves fitting a logistic regression model that includes indicator variables for the RACHS-1 categories together with an indicator variable for single versus multiple cardiac procedures, plus additional adjustment for 3 patient-level risk factors: age, prematurity, and presence of a major noncardiac structural anomaly. Because the required patient-level risk factors were not available in our dataset, we did not implement the full RACHS-1 methodology but instead focused on evaluating the discrimination of the RACHS-1 categories with and without adjustment for patient age, weight, and preoperative length of stay.

Independent Validation Using 2007–2008 Data

The performance of each model was assessed in a separate, more contemporary sample of STS and EACTS data. Overall discrimination was quantified by the C-index. The ability of the proposed score to predict the risk of individual procedures was quantified by calculating the Pearson correlation coefficient between the score and the actual calculated procedure-specific mortality rate in the validation sample. Because sampling variation in the validation sample might artificially increase or decrease the Pearson correlation coefficient, procedures with fewer than 40 occurrences in the validation sample were excluded when calculating the Pearson correlation coefficient. For graphing the association between the proposed score and observed mortality, data from procedures with the same score were aggregated, and the mortality rate of each group of procedures was plotted as a function of the score, excluding groups with fewer than 40 cases. The entire validation was also repeated in the subset of procedures having at least 200 cases in the development sample. Finally, to permit a fair comparison with RACHS-1 and ABC scores, the performance of each model was assessed in the subset of procedures for which both RACHS-1 categories and ABC scores are defined (n = 25,106 patient operations). Statistical comparisons of the C-index for different models were performed using the method of DeLong and colleagues.[11]

TABLE 4. Comparison of C-index for models using the STS–EACTS score, STS–EACTS categories, RACHS-1 categories, and ABC scores*

Method of modeling procedures	Model without patient covariates (C-index)	Model with patient covariates (C-index)
STS–EACTS score	0.787	0.816
STS–EACTS categories	0.778	0.812
RACHS-1 categories	0.745	0.802
ABC score	0.687	0.795

*Validation sample, subset of procedures for which both RACHS-1 categories and ABC scores are defined. *STS–EACTS*, Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery; *RACHS-1*, Risk Adjustment for Congenital Heart Surgery; *ABC*, Aristotle Basic Complexity.

RESULTS

A total of 77,294 patient operations were analyzed, including 3308 (4.3%) in-hospital deaths. There were 71 procedures with at least 200 occurrences, 104 procedures with at least 50 occurrences, and 133 procedures with at least 20 occurrences. Procedures with at least 200 occurrences accounted for 94% of the total patients and 91% of the deaths.

Mortality Rates for Individual Procedures

The frequency of in-hospital mortality for individual procedures ranged from 0% to 40.0%. There were 18 procedures with zero deaths; all of these had sample sizes smaller than 200. When Bayesian modeling was used to estimate mortality risk for individual procedures, the estimates ranged from 0.3% (atrial septal defect repair with patch) to 29.8% (truncus plus interrupted aortic arch repair, Figure 1). For the procedures with more than 200 cases, the raw and model-based estimates were virtually identical (Pearson correlation coefficient > 0.999, Appendix 1).

Mortality Scores and Categories

Names of the procedures analyzed in this study are listed in Table 1, along with their raw and model-based mortality estimates and their proposed scores and categories. The STS–EACTS score takes on values between 0.1 and 5.0 and has 29 unique values. The STS–EACTS categories consist of 5 groups labeled 1 to 5, with higher numbers implying higher mortality risk. The number of patients and procedures per category and their aggregated mortality rates are summarized in Table 2.

The within-category homogeneity criterion and the C-index were plotted as functions of the number of categories to help us determine the optimal number of mortality categories. As shown in Figure 2, *A*, within-category

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homogeneity increases rapidly with the number of categories when the number of categories is small. With more than 4 or 5 categories, the homogeneity continues to increase, but the marginal improvement per additional category approaches zero. Similarly, Figure 2, *B*, shows that the estimated discrimination of the categories changes dramatically when the number of groups is varied between 2 and 5, but using more than 5 categories has a relatively modest effect on the C-index. Five categories were chosen as the smallest number that produces both acceptable within-category homogeneity and good discrimination.

Examples of regression models using the proposed scores and categories are summarized in Table 3. The C-index was 0.814 for the model that combined patient factors with the STS–EACTS score and 0.810 for the model that combined patient factors with the STS–EACTS categories. For comparison, when age, weight, and preoperative length of stay were analyzed in a logistic regression model without adjustment for the STS–EACTS scores or categories, the C-index was 0.755.

Validation Using 2007–2008 Data

There was a strong positive association between the proposed STS–EACTS score and actual observed mortality in the validation sample (C-index = 0.784). For the 82 procedures with at least 40 occurrences in the validation sample, the Pearson correlation coefficient between the score of a procedure and its actual observed mortality rate in the validation sample was 0.80. An increasing association between the score and mortality was observed across the range of scores, although several groups of procedures had lower than expected mortality (Figure 3).

The observed mortality rate in the validation sample was slightly lower than in the development sample (3.9% vs 4.3%, $P = .004$), reflecting a trend toward lower mortality in a more contemporary sample. This lower mortality was seen in each of the 5 STS–EACTS categories (Figure 4). Despite the trend toward lower absolute mortality in 2007–2008, the chosen categories continued to perform well at discriminating between high-risk and low-risk procedures (C-index = 0.773). Receiver operating characteristic curves for the proposed scores and categories are displayed in Figure 5. When the validation was repeated in the subset of 73 procedures with at least 200 cases in the development sample, there was a similarly high level of discrimination (C-index = 0.790 for STS–EACTS scores; C-index = 0.782 for STS–EACTS categories) and high correlation between the STS–EACTS score and procedure-specific mortality rates (Pearson correlation coefficient = 0.87).

To assess whether the proposed method discriminates mortality better than the existing RACHS-1 categories and Aristotle scores, each of these was evaluated in the validation sample using the subset of procedures for which both RACHS-1 categories and ABC scores are defined. As summarized in Table 4, discrimination was highest for the STS–EACTS score (C-index = 0.787), followed by the STS–EACTS categories (C-index = 0.778), RACHS-1 categories (C-index = 0.745), and ABC scores (C-index = 0.687, all differences $P < .0001$). Adding patient-level covariates substantially improved each model's discrimination. With the addition of these patient variables, discrimination was highest for the STS–EACTS score (C-index = 0.816), followed by STS–EACTS categories (C-index = 0.812; comparison with STS–EACTS score, $P = .035$), RACHS-1 categories (C-index = 0.802; comparison vs STS–EACTS categories, $P = .008$), and ABC scores (C-index = 0.795; comparison vs STS–EACTS score, $P < .0001$).

DISCUSSION

The goal of this study was to derive a valid tool that can be used to stratify congenital heart surgery procedures based on their relative risk of in-hospital mortality. Using the combined resources of the STS and EACTS databases, we estimated the average mortality rate of 148 procedures and then applied a data-driven algorithm to determine the grouping of procedures that was optimal in the sense of creating internally homogeneous strata. The resulting scores and categories are intended to serve as tools for case-mix adjustment when comparing outcomes of hospitals that perform congenital heart surgery. These measures can be used to perform a stratified analysis that adjusts for type of procedure or they can be included along with patient-level variables in a comprehensive risk adjustment model.

Previous investigators have used a combination of expert opinion and empirical data to group procedures with a similar risk of in-hospital mortality. Experts initially used clinical judgment to group procedures with a similar potential for in-hospital mortality to create the RACHS-1 risk categories. This allocation of procedures was subsequently refined by using empirical data from 2 multi-institutional registries. The goals of the present study were similar to those of RACHS-1 in that we also sought to create internally homogeneous procedure categories using the end point of discharge mortality. A major difference between our approach and the derivation of RAHCS-1 categories is that our procedure categories were determined empirically without the input of an expert panel. When the proposed methodology was assessed in an independent validation sample, models based on the STS–EACTS score and categories had substantially better discrimination than comparable models based on RACHS-1 categories and ABC scores.

Despite the advantages of an empirically based risk stratification system, there are several limitations and caveats.

First, our study focused on estimating procedural mortality and determining homogeneous procedure categories. Additional research is needed to determine the best method of

combining these procedural variables with adjustment for patient-specific risk factors.

Second, despite the large database, several individual procedures had small sample sizes, and the true mortality of these procedures may have been estimated with error. We attempted to minimize this error by using a statistical model, which accounted for small denominators.

Third, because the EACTS and STS registries are voluntary, it is possible that the results observed in this database will differ from those of other nonparticipating institutions.

Fourth, because auditing of the STS and EACTS databases has been limited to a small number of sites, the completeness and accuracy of the data are largely unknown. In an audit of 200 patient records from 10 different STS centers, there was 99.0% agreement in the reporting of discharge mortality by STS sites versus independent auditors and no evidence of selective reporting based on discharge mortality status (personal communication, unpublished STS data).

Another potential limitation rests in the fact that mortality was determined only on the basis of status at the time of discharge. Operative mortality has been defined by the STS Congenital Database Taskforce and the Joint STS–EACTS Congenital Database Committee.[12] It requires knowledge not only of status at discharge but of patient status at 30 days after the operation. Going forward, validation of the STS–EACTS scores and categories using this definition will be possible as the completeness of these data fields in the STS and EACTS databases improves (Appendix 3).

In summary, we have developed a new tool for grouping procedures with a similar empirically estimated risk of in-hospital mortality. Empirically based mortality stratification was possible to a considerable extent because of the large sample sizes of the STS and EACTS congenital databases. The resulting scores and categories can be incorporated into case-mix adjustment methods, such as stratification and regression analysis, to compare institutions on a level playing field.

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Appendix 1. Statistical Model for Estimating Procedure-Specific Mortality Rates

Procedure-specific mortality rates were estimated by using a hierachical (random effects) model. For each of the 148 procedures in the analysis, the number of deaths was modeled by using the following binomial distribution:

$$y_j \sim \text{Binomial}(n_j, \pi_j),\ j = 1, 2, \ldots, 148,$$

where π_j denotes the unknown theoretical probability of mortality for the *j-th* procedure, n_j denotes the number of patients undergoing the procedure in the database (denominator), and y_j denotes the actual observed number of mortalities in the database (numerator). Variation in the theoretical probability of mortality was modeled by assuming the log odds were normally distributed. Thus the model is as follows:

$$\log\left(\pi_j/\left[1-\pi_j\right]\right) = \eta_j;$$

$$\eta_j \overset{\text{ind}}{\sim} N\left(\mu, \sigma^2\right),$$

where μ and σ^2 denote the unknown mean and variance, respectively, of the assumed normal random effects distribution. Parameters of the model were estimated in a Bayesian framework using WinBUGS software. A vague (noninformative) prior distribution was chosen for the parameters μ and σ^2. The

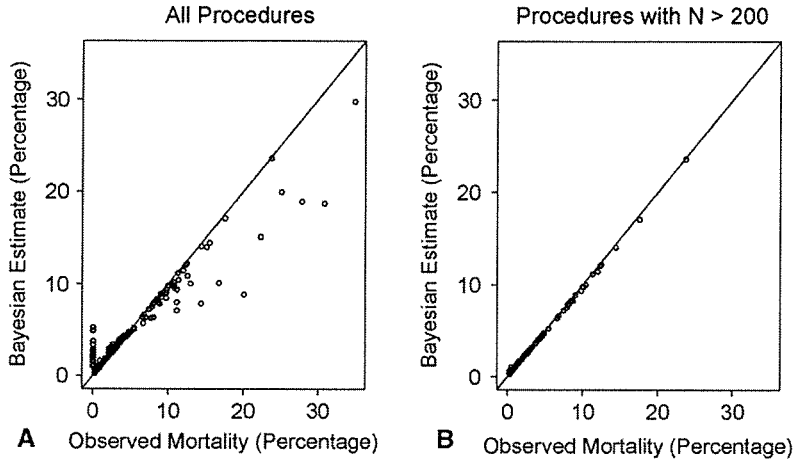

FIGURE 6. Relationship between Bayesian model–based estimates and unadjusted mortality rates for individual procedures in the development sample.

WinBUGS code for this model is available from the authors on request.

As shown in Figure 6, *A*, there was a high degree of correlation between the Bayesian model–based estimate of a procedure's risk and the simple raw unadjusted mortality percentage; however, several procedures had large discrepancies. The difference between the model-based versus raw estimates decreased with increasing sample size. For procedures with more than 200 cases, the raw and model-based estimates were virtually identical (Pearson correlation coefficient > 0.999; Figure 6).

Appendix 2. Methodology for Creating Internally Homogeneous Risk Categories

Procedures were first sorted in order of increasing estimated risk (based on the model in Appendix 1) and then grouped into homogeneous categories to create the risk categories. Let π_i denote the true unknown mortality for the *i-th* procedure, and let $\widehat{\pi}_i$ denote the corresponding estimate. We first sorted procedures so that $\widehat{\pi}_1 < \widehat{\pi}_2 < \cdots < \widehat{\pi}_{148}$. Let k denote the number of categories and let $\boldsymbol{c}_k = \{c_1 < c_2 < \cdots < c_{k-1}\}$ denote a set of category cut points that partition the categories into k groups. The symbol c_j denotes a number between 1 and 148 and represents the index of the highest-risk procedure in the *j-th* category. Also, define $c_0 = 0$ and $c_k = 149$. For any particular choice of k and $\boldsymbol{c}_k$, within-category homogeneity is measured by the weighted sum-of-squares criterion:

$$\mathrm{WSS}(\boldsymbol{c}_k; \pi) = \sum_{j=1}^{k} \sum_{i=c_{j-1}+1}^{c_j} \frac{n_i(\pi_i - \overline{\pi}_j)^2}{\pi_i(1-\pi_i)},$$

where $\overline{\pi}_j = \sum_{i=c_{j-1}+1}^{c_j} n_i \pi_i / \sum_{i=c_{j-1}+1}^{c_j} n_i$ denotes the average risk of mortality among all procedures in the *j-th* category. This criterion is similar to one that has been used previously for defining optimum cut points for categorizing a continuous explanatory variable.[9] The notation $\mathrm{WSS}(\boldsymbol{c}_k; \pi)$ is intended to emphasize that WSS is a function of the chosen cut points $\boldsymbol{c}_k$ and also depends on the unknown procedure-specific probabilities π_i. If the π_i were known instead of unknown, then the "optimal" cut points could (in theory) be determined by enumerating all possible choices for the c_j and choosing the one that minimizes the WSS. Because the π_i are unknown, we instead choose cut points that minimize the Bayesian estimate of $\mathrm{WSS}(\boldsymbol{c}_k; \pi)$. Specifically, we chose the cut points that minimize the estimated Bayesian posterior mean as follows:

$$\widehat{\mathrm{WSS}}(\boldsymbol{c}_k) = \frac{1}{3000} \sum_{h=1}^{3000} \mathrm{WSS}\left(\boldsymbol{c}_k; \pi^{(h)}\right),$$

where $\pi^{(h)}$ denotes a random draw from the joint posterior distribution of the π_i's. Finding the set of cut points that minimizes this quantity exactly is technically challenging and required the use of a novel dynamic programming algorithm (unpublished).

The criterion described above gets smaller as the within-category homogeneity improves. For plotting the change in homogeneity versus k, it is intuitively appealing to use a criterion that increases rather than decreases. The criterion used in Figure 2 (and throughout the article) is defined as follows:

$$\text{Homogeneity} = 1 - \widehat{\mathrm{WSS}}(\boldsymbol{c}_k)/\widehat{\mathrm{WSS}}(\boldsymbol{c}_1).$$

This criterion ranges from 0.0 to 1.0 and increases as the categories become more homogeneous.

Appendix 3. Completeness of STS Mortality Data

The mortality end point for this study was mortality status at the time of discharge, ie, in-hospital mortality. It was chosen over operative mortality (ie, death prior to discharge or after discharge but within 30 days of surgery) or 30-day mortality status in large part because 30-day status is frequently missing whereas discharge mortality is rarely missing. As shown in Figure 7, the completeness of 30-day mortality status has improved over time. In the future, it may be feasible to adapt the STS-EACTS methodology (or develop a new methodology) to predict the endpoint of operative mortality or 30-day mortality, assuming the completeness of 30-day mortality reporting continues to improve.

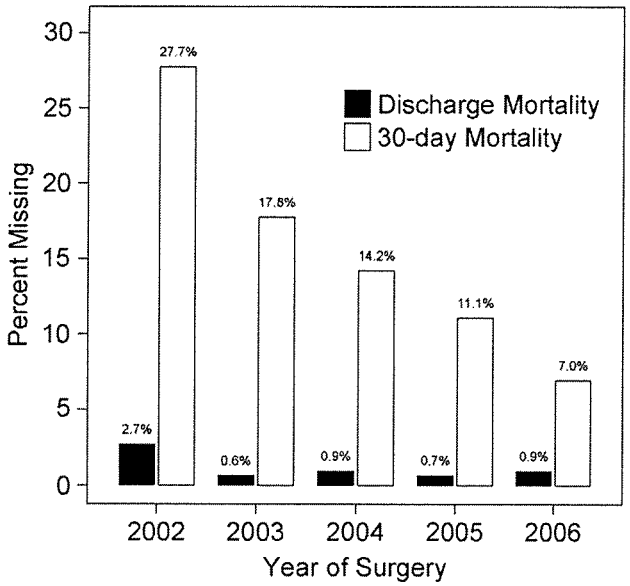

FIGURE 7. Decreasing percentage of missing data in the fields "mortality discharge status" (alive or dead) and "status at 30 days after surgery" (alive, dead, or unknown) in the Society of Thoracic Surgeons Congenital Database from 2002 to 2006.

Procedure Code	Description	Definition
10	PFO, Primary closure	Suture closure of patent foramen ovale (PFO)
20	ASD repair, Primary closure	Suture closure of secundum (most frequently), coronary sinus, sinus venosus or common atrium ASD.
30	ASD repair, Patch	Patch closure (using any type of patch material) of secundum, coronary sinus, or sinus venosus ASD.
40	ASD repair, Device	Closure of any type ASD (including PFO) using a device
2110	ASD repair, Patch + PAPVC repair	
50	ASD, Common atrium (single atrium), Septation	Septation of common (single) atrium using any type patch material.
60	ASD creation/enlargement	Creation of an atrial septal defect or enlargement of an existing atrial septal defect using a variety of modalities including balloon septostomy, blade septostomy, or surgical septectomy. Creation may be accomplished with or without use of cardiopulmonary bypass.
70	ASD partial closure	Intentional partial closure of any type ASD (partial suture or fenestrated patch closure).
80	Atrial septal fenestration	Creation of a fenestration (window) in the septum between the atrial chambers. Usually performed using a hole punch, creating a specifically sized communication in patch material placed on the atrial septum.
85	Atrial fenestration closure	Closure of previously created atrial fenestration using any method including device, primary suture, or patch.
100	VSD repair, Primary closure	Suture closure of any type VSD.
110	VSD repair, Patch	Patch closure (using any type of patch material) of any type VSD.
120	VSD repair, Device	Closure of any type VSD using a device.
130	VSD, Multiple, Repair	Closure of more than one VSD using any method or combination of methods. Further information regarding each type of VSD closed and method of closure can be provided by additionally listing specifics for each VSD closed. In the case of multiple VSDs in which only one is closed the procedure should be coded as closure of a single VSD. The fundamental diagnosis, in this case, would be “VSD, Multiple” and a secondary diagnosis can be the morphological type of VSD that was closed at the time of surgery.
140	VSD creation/enlargement	Creation of a ventricular septal defect or enlargement of an existing ventricular septal defect.
150	Ventricular septal fenestration	Creation of a fenestration (window) in the septum between the ventricular chambers. Usually performed using a hole punch, creating a specifically sized communication in patch material placed on the ventricular septum.
170	AVC (AVSD) repair, Complete (CAVSD)	Repair of complete AV canal (AVSD) using one- or two patch or other technique, with or without mitral valve cleft repair.
180	AVC (AVSD) repair, Intermediate (Transitional)	Repair of intermediate AV canal (AVSD) using ASD and VSD patch, or ASD patch and VSD suture, or other technique, with or without mitral valve cleft repair.
190	AVC (AVSD) repair, Partial (Incomplete) (PAVSD)	Repair of partial AV canal defect (primum ASD), any technique, with or without repair of cleft mitral valve.

2300	Valvuloplasty, Common atrioventricular valve	
2250	Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve	
2230	Valve replacement, Common atrioventricular valve	
210	AP window repair	Repair of AP window using one- or two-patch technique with cardiopulmonary bypass; or, without cardiopulmonary bypass, using transcatheter device or surgical closure.
220	Pulmonary artery origin from ascending aorta (hemitruncus) repair	Repair of pulmonary artery origin from the ascending aorta by direct reimplantation, autogenous flap, or conduit, with or without use of cardiopulmonary bypass.
230	Truncus arteriosus repair	Truncus arteriosus repair that most frequently includes patch VSD closure and placement of a conduit from RV to PA. In some cases, a conduit is not placed but an RV to PA connection is made by direct association. Very rarely, there is no VSD to be closed. Truncal valve repair or replacement should be coded separately (Valvuloplasty, Truncal valve; Valve replacement, Truncal valve), as would be the case as well with associated arch anomalies requiring repair (e.g., Interrupted aortic arch repair).
240	Valvuloplasty, Truncal valve	Truncal valve repair, any type.
2290	Valvuloplasty converted to valve replacement in the same operation, Truncal valve	
250	Valve replacement, Truncal valve	Replacement of the truncal valve with a prosthetic valve.
2220	Truncus + Interrupted aortic arch repair (IAA) repair	
260	PAPVC repair	PAPVC repair revolves around whether an intracardiac baffle is created to redirect pulmonary venous return to the left atrium or if the anomalous pulmonary vein is translocated and
270	PAPVC, Scimitar, Repair	In scimitar syndrome, PAPVC repair also revolves around whether an intracardiac baffle is created to redirect pulmonary venous return to the left atrium or if the anomalous pulmonary vein is translocated and connected to the left atrium directly. If there is an associated ASD and it is closed, that procedure should also be listed. Occasionally an ASD is created; this procedure also must be listed separately.
2120	PAPVC repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	
280	TAPVC repair	Repair of TAPVC, any type. Issues surrounding TAPVC repair involve how the main pulmonary venous confluence anastomosis is fashioned, whether an associated ASD is closed or left open or enlarged (ASD closure and enlargement may be listed separately), and whether, particularly in mixed

2200	TAPVC repair + Shunt - systemic-to-pulmonary	
290	Cor triatriatum repair	Repair of cor triatriatum. Surgical decision making revolves around the approach to the membrane creating the cor triatriatum defect, how any associated ASD is closed, and how any associated anomalous pulmonary vein connection is addressed. Both ASD closure and anomalous pulmonary venous connection may be listed as separate procedures.
300	Pulmonary venous stenosis repair	Repair of pulmonary venous stenosis, whether congenital or acquired. Repair can be accomplished with a variety of approaches: sutureless, patch venoplasty, stent placement, etc.
310	Atrial baffle procedure (non-Mustard, non-Senning)	The atrial baffle procedure code is used primarily for repair of systemic venous anomalies, as in redirection of left superior vena cava drainage to the right atrium.
330	Anomalous systemic venous connection repair	With the exception of atrial baffle procedures (harvest code 310), anomalous systemic venous connection repair includes a range of surgical approaches, including, among others: ligation of anomalous vessels, reimplantation of anomalous vessels (with or without use of a conduit), or redirection of anomalous systemic venous flow through directly to the pulmonary circulation (bidirectional Glenn to redirect LSVC or RSVC to left or right pulmonary artery, respectively).
340	Systemic venous stenosis repair	Stenosis or obstruction of a systemic vein (most commonly SVC or IVC) may be relieved with patch or conduit placement, excision of the stenotic area with primary
350	TOF repair, No ventriculotomy	Tetralogy of Fallot repair (assumes VSD closure and relief of pulmonary stenosis at one or more levels), without use of an incision in the infundibulum of the right ventricle for exposure. In most cases this would be a transatrial and transpulmonary artery approach to repair the VSD and relieve the pulmonary stenosis. If the main pulmonary artery incision is extended proximally through the pulmonary annulus, this must be considered "transannular" and thus a ventricular incision, though the length of the incision onto the ventricle itself may be minimal.
360	TOF repair, Ventriculotomy, Nontransanular patch	Tetralogy of Fallot repair (assumes VSD closure and relief of pulmonary stenosis at one or more levels), with use of a ventriculotomy incision, but without placement of a trans-pulmonary annulus patch. If the main pulmonary artery incision is extended proximally through the pulmonary annulus, this must be considered "transannular" and thus a ventricular incision, though the length of the incision onto the ventricle itself may be minimal.

370	TOF repair, Ventriculotomy, Transanular patch	Tetralogy of Fallot repair (assumes VSD closure and relief of pulmonary stenosis at one or more levels), with use of a ventriculotomy incision and placement of a trans-pulmonary annulus patch. If the main pulmonary artery incision is extended proximally through the pulmonary annulus, this must be considered "transannular" and thus a ventricular incision, though the length of the incision onto the ventricle itself may be minimal.
380	TOF repair, RV-PA conduit	Tetralogy of Fallot repair (assumes VSD closure and relief of pulmonary stenosis at one or more levels), with placement of a right ventricle-to-pulmonary artery conduit. In this procedure the major components of pulmonary stenosis are relieved with placement of the RV-PA conduit.
390	TOF - AVC (AVSD) repair	Tetralogy of Fallot repair (assumes VSD closure and relief of pulmonary stenosis at one or more levels), with repair of associated AV canal defect. Repair of associated atrial septal defect or atrioventricular valve repair(s) should be listed as additional or secondary procedures under the primary TOF-AVC procedure.
400	TOF - Absent pulmonary valve repair	Repair of tetralogy of Fallot with absent pulmonary valve complex. In most cases this repair will involve pulmonary valve replacement (pulmonary or aortic homograft, porcine, other) and reduction pulmonary artery arterioplasty.
420	Pulmonary atresia - VSD (including TOF, PA) repair	For patients with pulmonary atresia with ventricular septal defect without MAPCAs, including those with tetralogy of Fallot with pulmonary atresia, repair may entail either a tetralogy-like repair with transannular patch placement, a VSD closure with placement of an RV-PA conduit, or an intraventricular tunnel VSD closure with transannular patch or RV-PA conduit placement. To assure an accurate count of repairs of pulmonary atresia-VSD without MAPCAs, even if a tetralogy-type repair or Rastelli-type repair is used, the pulmonary atresia-VSD code should be the code used, not Rastelli procedure or tetralogy of Fallot repair with transannular patch.
430	Pulmonary atresia - VSD - MAPCA (pseudotruncus) repair	In the presence of MAPCAs, this code implies implies pulmonary unifocalization (multi- or single-stage), repair of VSD (may be intraventricular tunnel or flat patch VSD closure), and placement of an RV-PA conduit.
440	Unifocalization MAPCA(s)	Anastomosis of aortopulmonary collateral arteries into the left, right, or main pulmonary artery or into a tube graft or other type of confluence. The unifocalization procedure may be done on or
450	Occlusion MAPCA(s)	Occlusion, or closing off, of MAPCAs. This may be done with a transcatheter occluding device, usually a coil, or by surgical techniques
460	Valvuloplasty, Tricuspid	Reconstruction of the tricuspid valve may include but not be limited to a wide range of techniques including: leaflet patch extension, artificial chordae placement, papillary muscle transplocation with or without detachment. Annuloplasty techniques that may be done solely or in combination with leaflet, chordae or muscle repair to achieve a competent valve include: eccentric annuloplasty, Kay annular plication, purse-

2280	Valvuloplasty converted to valve replacement in the same operation, Tricuspid	
465	Ebstein's repair	To assure an accurate count of repairs of Ebstein's anomaly of the tricuspid valve, this procedure code was included. Repair of Ebstein's anomaly may include, among other techniques, repositioning of the tricuspid valve, plication of the atrialized right ventricle, or right reduction atrioplasty. Often associated ASD's may be closed and arrhythmias addressed with surgical ablation procedures. These procedures should be entered as separate procedure codes.
470	Valve replacement, Tricuspid (TVR)	Replacement of the tricuspid valve with a prosthetic valve.
480	Valve closure, Tricuspid (exclusion, univentricular approach)	In a functional single ventricle heart, the tricuspid valve may be closed using a patch, thereby excluding the RV. Tricuspid valve closure may be used for infants with Ebstein's anomaly and severe tricuspid regurgitation or in patients with pulmonary
490	Valve excision, Tricuspid (without replacement)	Excision of the tricuspid valve without placement of a valve prosthesis.
500	Valve surgery, Other, Tricuspid	Other tricuspid valve surgery not specified in procedure codes.
510	RVOT procedure	Included in this procedural code would be all RVOT procedures not elsewhere specified in the nomenclature system. These might be, among others: resection of subvalvar pulmonary stenosis (not DCRV type; may be localized fibrous diaphragm or high infundibular stenosis), right ventricular patch augmentation, or reduction pulmonary artery arterioplasty.
520	1 1/2 ventricular repair	Partial biventricular repair; includes intracardiac repair with bidirectional cavopulmonary anastomosis to volume unload a small ventricle or poorly functioning ventricle
530	PA, reconstruction (plasty), Main (trunk)	Reconstruction of the main pulmonary artery trunk commonly using patch material. If balloon angioplasty is performed or a stent is placed in the main pulmonary artery intraoperatively, this code may be used in addition to the balloon dilation or stent placement code. If MPA reconstruction is performed with PA debanding, both codes should be listed.
540	PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)	Reconstruction of the right or left branch (or both right and left) pulmonary arteries (within the hilar bifurcation) commonly using patch material. If balloon angioplasty is performed or a stent is placed in the right or left (or both) pulmonary artery intraoperatively, this code may be used in addition to the balloon dilation or stent placement code. If, rarely, branch PA
550	PA, reconstruction (plasty), Branch, Peripheral (at or beyond the hilar bifurcation)	Reconstruction of the peripheral right or left branch (or both right and left) pulmonary arteries (at or beyond the hilar bifurcation) commonly using patch material. If balloon angioplasty is performed or a stent is placed in the right or left (or both) peripheral pulmonary artery intraoperatively, this code may be used in addition to the balloon dilation or stent placement code.

570	DCRV repair	Surgical repair of DCRV combines relief of the low infundibular stenosis (via muscle resection) and closure of a VSD when present. A ventriculotomy may be required and is repaired by patch enlargement of the infundibulum. VSD closure and patch enlargement of the infundibulum, if done, should be listed as separate procedure codes.
590	Valvuloplasty, Pulmonic	Valvuloplasty of the pulmonic valve may include a range of techniques including but not limited to: valvotomy with or without bypass, commissurotomy, and valvuloplasty.
2270	Valvuloplasty converted to valve replacement in the same operation, Pulmonic	
600	Valve replacement, Pulmonic (PVR)	Replacement of the pulmonic valve with a prosthetic valve. Care must be taken to differentiate between homograft pulmonic valve replacement and placement of a homograft RV-PA conduit.
630	Valve excision, Pulmonary (without replacement)	Excision of the pulmonary valve without placement of a valve prosthesis.
640	Valve closure, Semilunar	Closure of a semilunar valve (pulmonic or aortic) by any technique.
650	Valve surgery, Other, Pulmonic	Other pulmonic valve surgery not specified in procedure codes.
610	Conduit placement, RV to PA	Placement of a conduit, any type, from RV to PA.
620	Conduit placement, LV to PA	Placement of a conduit, any type, from LV to PA.
1774	Conduit placement, Ventricle to aorta	Placement of a conduit from the right or left ventricle to the aorta.
1772	Conduit placement, Other	Placement of a conduit from any chamber or vessel to any vessel, valved or valveless, not listed elsewhere.
580	Conduit reoperation	Conduit reoperation is the code to be used in the event of conduit failure, in whatever position (LV to aorta, LV to PA, RA to RV, RV to aorta, RV to PA, etc.), and from whatever cause (somatic growth, stenosis, insufficiency, infection, etc).
660	Valvuloplasty, Aortic	Valvuloplasty of the aortic valve for stenosis and/or insufficiency including, but not limited to the following techniques: valvotomy (open or closed), commissurotomy, aortic valve suspension, leaflet (left, right or noncoronary) partial resection, reduction, or leaflet shaving, extended valvuloplasty (freeing of leaflets, commissurotomy, and extension of leaflets using autologous or bovine pericardium), or annuloplasty (partial - interrupted or noncircumferential sutures, or complete - circumferential sutures).
2240	Valvuloplasty converted to valve replacement in the same operation, Aortic	
2310	Valvuloplasty converted to valve replacement in the same operation, Aortic – with Ross procedure	

2320	Valvuloplasty converted to valve replacement in the same operation, Aortic – with Ross-Konno procedure	
670	Valve replacement, Aortic (AVR)	Replacement of the aortic valve with a prosthetic valve (mechanical, bioprosthetic, or homograft). Use this code only if type of valve prosthesis is unknown or does not fit into the specific valve replacement codes available. Autograft valve replacement should be coded as a Ross procedure.
680	Valve replacement, Aortic (AVR), Mechanical	Replacement of the aortic valve with a mechanical prosthetic valve.
690	Valve replacement, Aortic (AVR), Bioprosthetic	Replacement of the aortic valve with a bioprosthetic prosthetic valve.
700	Valve replacement, Aortic (AVR), Homograft	Replacement of the aortic valve with a homograft prosthetic valve.
715	Aortic root replacement, Bioprosthetic	Replacement of the aortic root (that portion of the aorta attached to the heart; it gives rise to the coronary arteries) with a bioprosthesis (e.g., porcine) in a conduit, often composite.
720	Aortic root replacement, Mechanical	Replacement of the aortic root (that portion of the aorta attached to the heart; it gives rise to the coronary arteries) with a mechnical prosthesis in a composite conduit.
730	Aortic root replacement, Homograft	Replacement of the aortic root (that portion of the aorta attached to the heart; it gives rise to the coronary arteries) with a homograft.
735	Aortic root replacement, Valve sparing	Replacement of the aortic root (that portion of the aorta attached to the heart; it gives rise to the coronary arteries) without replacing the aortic valve (using a tube graft).
740	Ross procedure	Replacement of the aortic valve with a pulmonary autograft and replacement of the pulmonary valve with a homograft conduit.
750	Konno procedure	Relief of left ventricular outflow tract obstruction associated with aortic annular hypoplasia, aortic valvar stenosis and/or aortic valvar insufficiency via Konno aortoventriculoplasty. Components of the surgery include a longitudinal incision in the aortic septum, a vertical incision in the outflow tract of the right ventricle to join the septal incision, aortic valve replacement, and patch reconstruction of the outflow tracts of both ventricles.
760	Ross-Konno procedure	Relief of left ventricular outflow tract obstruction associated with aortic annular hypoplasia, aortic valvar stenosis and/or aortic valvar insufficiency via Konno aortoventriculoplasty using a pulmonary autograft root for the aortic root replacement.
770	Other annular enlargement procedure	Techniques included under this procedure code include those designed to effect aortic annular enlargement that are not included in other procedure codes. These include the Manougian and Nicks aortic annular enlargement procedures.

780	Aortic stenosis, Subvalvar, Repair	Subvalvar aortic stenosis repair by a range of techniques including excision, excision and myotomy, excision and myomectomy, myotomy, myomectomy, initial placement of apical-aortic conduit (LV to aorta conduit replacement would be coded as conduit reoperation), Vouhé aortoventriculoplasty (aortic annular incision at commissure of left and right coronary cusps is carried down to the septum and RV infundibulum; septal muscle is resected, incisions are closed, and the aortic annulus is reconstituted), or other aortoventriculoplasty techniques.
2100	Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS	
790	Aortic stenosis, Supravalvar, Repair	Repair of supravalvar aortic stenosis involving all techniques of patch aortoplasty and aortoplasty involving the use of all autologous tissue. In simple patch aortoplasty a diamond-shaped patch may be used, in the Doty technique an extended patch is placed (Y shaped patch, incision carried into two sinuses), and in the Brom repair the ascending aorta is transected, any fibrous ridge is resected, and the three sinuses are patched separately.
800	Valve surgery, Other, Aortic	Other aortic valve surgery not specified in other procedure codes.
810	Sinus of Valsalva, Aneurysm repair	Sinus of Valsalva aneurysm repair can be organized by site of aneurysm (left, right or noncoronary sinus), type of repair (suture, patch graft, or root repair by tube graft or valved conduit), and approach used (from chamber of origin (aorta) or from chamber of penetration (LV, RV, PA, left or right atrium, etc.). Aortic root replacement procedures in association with sinus of Valsalva aneurysm repairs are usually for associated uncorrectable aortic insufficiency or multiple sinus involvement and the aortic root replacement procedure should also be listed. Additional procedures also performed at the time of sinus of Valsalva aneurysm repair include but are not limited to VSD closure, repair or replacement of aortic valve, and coronary reconstruction; these procedures should also be coded separately from the sinus of Valsalva aneurysm repair.
820	LV to aorta tunnel repair	LV to aorta tunnel repair can be accomplished by suture, patch, or both, and may require reimplantation of the right coronary artery. Associated coronary artery procedures should be coded separately from the LV to aorta tunnel repair.
830	Valvuloplasty, Mitral	Repair of mitral valve including, but not limited to: valvotomy (closed or open heart), cleft repair, annuloplasty with or without ring, chordal reconstruction, commissuorotomy, leaflet repair, or papillary muscle repair.
2260	Valvuloplasty converted to valve replacement in the same operation, Mitral	

840	Mitral stenosis, Supravalvar mitral ring repair	Supravalvar mitral ring repair.
850	Valve replacement, Mitral (MVR)	Replacement of mitral valve with prosthetic valve, any kind, in suprannular or annular position.
860	Valve surgery, Other, Mitral	Other mitral valve surgery not specified in procedure codes.
870	Norwood procedure	The Norwood operation is synonymous with the term 'Norwood (Stage 1)' and is defined as an aortopulmonary connection and neoaortic arch construction resulting in univentricular physiology and pulmonary blood flow controlled with a calibrated systemic-to-pulmonary artery shunt, or a right ventricle to pulmonary artery conduit, or rarely, a cavopulmonary connection. When coding the procedure “Norwood procedure”, the primary procedure of the operation should be “Norwood procedure”. The second procedure (Procedure 2 after the Norwood procedure) must then document the source of pulmonary blood flow and be chosen from the following eight choices: 1. Shunt, Systemic to pulmonary, Modified Blalock-Taussig Shunt (MBTS) 2. Shunt, Systemic to pulmonary, Central (from aorta or to main pulmonary artery) 3. Shunt, Systemic to pulmonary, Other 4. Conduit placement, RV to PA 5. Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn) 6. Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn) 7. Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn) 8. HemiFontan
880	HLHS biventricular repair	Performed in patients who have small but adequately sized ventricles to support systemic circulation. These patients usually have small, but not stenotic, aortic and/or mitral valves. Primary biventricular repair has consisted of extensive aortic arch and ascending aorta enlargement with a patch, closure of interventricular and interatrial communications, and conservative approach for left ventricular outflow tract obstruction (which may include mitral stenosis at any level
2160	Hybrid Approach "Stage 1", Application of RPA & LPA bands	A “Hybrid Procedure” is defined as a procedure that combines surgical and transcatheter interventional approaches. The term “Hybrid approach” is used somewhat differently than the term “Hybrid Procedure”. A “Hybrid approach” is defined as any of a group of procedures that fit into the general silo of procedures developed from the combined use of surgical and transcatheter interventional techniques. Therefore, not all procedures classified as “Hybrid approach” are truly “ Hybrid Procedures”.

2170	Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA)	A “Hybrid Procedure” is defined as a procedure that combines surgical and transcatheter interventional approaches. The term “Hybrid approach” is used somewhat differently than the term “Hybrid Procedure”. A “Hybrid approach” is defined as any of a group of procedures that fit into the general silo of procedures developed from the combined use of surgical and transcatheter interventional techniques. Therefore, not all procedures classified as “Hybrid approach” are truly “ Hybrid Procedures”.
2180	Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) + application of RPA & LPA bands	A “Hybrid Procedure” is defined as a procedure that combines surgical and transcatheter interventional approaches. The term “Hybrid approach” is used somewhat differently than the term “Hybrid Procedure”. A “Hybrid approach” is defined as any of a group of procedures that fit into the general silo of procedures developed from the combined use of surgical and transcatheter interventional techniques. Therefore, not all procedures classified as “Hybrid approach” are truly “ Hybrid Procedures”.
2140	Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)	A “Hybrid Procedure” is defined as a procedure that combines surgical and transcatheter interventional approaches. The term “Hybrid approach” is used somewhat differently than the term “Hybrid Procedure”. A “Hybrid approach” is defined as any of a group of procedures that fit into the general silo of procedures developed from the combined use of surgical and transcatheter interventional techniques. Therefore, not all procedures classified as “Hybrid approach” are truly “ Hybrid Procedures”. It should be acknowledged that a Hybrid approach "Stage 2" (Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding, with or without Aortic arch repair) gets its name not because it has any actual hybrid elements, but because it is part of a planned staged approach that is typically commenced with a hybrid procedure.
2150	Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair	A “Hybrid Procedure” is defined as a procedure that combines surgical and transcatheter interventional approaches. The term “Hybrid approach” is used somewhat differently than the term “Hybrid Procedure”. A “Hybrid approach” is defined as any of a group of procedures that fit into the general silo of procedures developed from the combined use of surgical and transcatheter interventional techniques. Therefore, not all procedures classified as “Hybrid approach” are truly “ Hybrid Procedures”. It should be acknowledged that a Hybrid approach "Stage 2" (Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding, with or without Aortic arch repair) gets its name not because it has any actual hybrid elements, but because it is part of a planned staged approach that is typically commenced with a hybrid procedure

890	Transplant, Heart	Heart transplantation, any technique, allograft or xenograft.
900	Transplant, Heart and lung	Heart and lung (single or double) transplantation.
910	Partial left ventriculectomy (LV volume reduction surgery) (Batista)	Wedge resection of LV muscle, with suturing of cut edges together, to reduce LV volume.
920	Pericardial drainage procedure	Pericardial drainage can include a range of therapies including, but not limited to: pericardiocentesis, pericardiostomy tube placement, pericardial window creation, and open pericardial drainage (pericardiotomy).
930	Pericardiectomy	Surgical removal of the pericardium.
940	Pericardial procedure, Other	Other pericardial procedures that include, but are not limited to: pericardial reconstruction for congenital absence of the pericardium, pericardial biopsy, pericardial mass or cyst excision.
950	Fontan, Atrio-pulmonary connection	Fontan-type procedure with atrio-pulmonary connection.
960	Fontan, Atrio-ventricular connection	Fontan-type procedure with atrio-ventricular connection, either direct or with RA-RV conduit, valved or nonvalved.
970	Fontan, TCPC, Lateral tunnel, Fenestrated	Total cavopulmonary connection using an intraatrial lateral tunnel construction, with fenestration.
980	Fontan, TCPC, Lateral tunnel, Nonfenestrated	Total cavopulmonary connection using an intraatrial lateral tunnel construction, with no fenestration.
1000	Fontan, TCPC, External conduit, Fenestrated	Total cavopulmonary connection using an external conduit to connect the infradiaphragmatic systemic venous return to the pulmonary artery, with fenestration.
1010	Fontan, TCPC, External conduit, Nonfenestrated	Total cavopulmonary connection using an external conduit to connect the infradiaphragmatic systemic venous return to the pulmonary artery, with no fenestration.
1025	Fontan revision or conversion (Re-do Fontan)	Revision of a previous Fontan procedure to a total cavopulmonary connection.
1030	Fontan, Other	Other Fontan procedure not specified in procedure codes. May include takedown of a Fontan procedure.
2340	Fontan + Atrioventricular valvuloplasty	
1035	Ventricular septation	Creation of a prosthetic ventricular septum. Surgical procedure used to septate univentricular hearts with two atrioventricular valves. Additional procedures, such as resection of subpulmonic stenosis, should be listed separately.
1050	Congenitally corrected TGA repair, Atrial switch and ASO (double switch)	Repair of congenitally corrected TGA by concomitant atrial switch (Mustard or Senning) and arterial switch operation. VSD closure is usually performed as well; this should be coded separately.
1060	Congenitally corrected TGA repair, Atrial switch and Rastelli	Repair of congenitally corrected TGA by concomitant atrial switch (Mustard or Senning) and VSD closure to the aortic valve with placement of an RV-to-PA conduit.
1070	Congenitally corrected TGA repair, VSD closure	Repair of congenitally corrected TGA by VSD closure only.

1080	Congenitally corrected TGA repair, VSD closure and LV to PA conduit	Repair of congenitally corrected TGA by VSD closure and placement of an LV-to-PA conduit.
1090	Congenitally corrected TGA repair, Other	Any procedures for correction of CCTGA not otherwised specified in other listed procedure codes.
1110	Arterial switch operation (ASO)	Arterial switch operation is used for repair of transposition of the great arteries (TGA). The pulmonary artery and aorta are transected and translocated so that the pulmonary artery arises from the right ventricle and the aorta from the left ventricle. Coronary artery transfer is also accomplished.
1120	Arterial switch operation (ASO) and VSD repair	Arterial switch operation is used for repair of transposition of the great arteries (TGA). The pulmonary artery and aorta are transected and translocated so that the pulmonary artery arises from the right ventricle and the aorta from the left ventricle. Coronary artery transfer is also accomplished. The VSD is closed, usually with a patch.
1123	Arterial switch procedure + Aortic arch repair	Concomitant arterial switch operation and repair of the aortic arch in patients with transposition of the great arteries with intact ventricular septum and associated coarctation of the aorta or interrupted aortic arch.
1125	Arterial switch procedure and VSD repair + Aortic arch repair	Concomitant arterial switch operation with VSD closure and repair of aortic arch in patients with transposition of the great arteries with VSD and associated coarctation of the aorta or interrupted aortic arch.
1130	Senning	Atrial baffle procedure for rerouting of venous flow in TGA effecting a “physiological repair”. The caval flow is directed behind the baffle to the mitral valve, left ventricle and pulmonary artery while the pulmonary venous flow is directed in front of the baffle to the tricuspid valve, right ventricle, and aorta. The Senning procedure uses atrial wall to construct the baffle.
1140	Mustard	Atrial baffle procedure for rerouting of venous flow in TGA effecting a “physiological repair”. The caval flow is directed behind the baffle to the mitral valve, left ventricle and pulmonary artery while pulmonary venous flow is directed in front of the baffle to the tricuspid valve, right ventricle, and aorta. The Mustard procedure uses patch material to construct the baffle.
1145	Atrial baffle procedure, Mustard or Senning revision	Revision of a previous atrial baffle procedure (either Mustard or Senning), for any reason (e.g., obstruction, baffle leak).
1150	Rastelli	Most often used for patients with TGA-VSD and significant LVOTO, the Rastelli operation consists of an LV-to-aorta intraventricular baffle closure of the VSD and

1160	REV	The Lecompte (REV) intraventricular repair is designed for patients with abnormalities of ventriculoarterial connection in whom a standard intraventricular tunnel repair cannot be erformed. It is also suitable for patients in whom an arterial switch procedure with tunneling of the VSD to the pulmonary artery cannot be performed because of pulmonary (left ventricular outflow tract) stenosis. A right ventriculotomy incision is made. The infundibular (conal) septum, located between the two semilunar valves, is aggressively resected if its presence interferes with the construction of a tunnel from the VSD to the aorta. The VSD is then tunneled to the aorta. The decision to perform or not to perform the Lecompte maneuver should be made at the beginning of the operation. If the Lecompte maneuver is not performed the pulmonary artery is translocated to the right ventricular outflow tract on the side of the aorta that provides the shortest route. (When the decision to perform the Lecompte maneuver has been made, the great vessels are transected and this maneuver is performed at the beginning of the operation.) The pulmonary artery orifice is then
2190	Aortic root translocation over left ventricle (Including Nikaidoh procedure)	
2210	TGA, Other procedures (Kawashima, LV-PA conduit, other)	
1180	DORV, Intraventricular tunnel repair	Repair of DORV using a tunnel closure of the VSD to the aortic valve. This also includes the posterior straight tunnel repair of Kawashima
1200	DOLV repair	Because of the morphologic variability of DOLV, there are many approaches to repair, including: intraventricular tunnel repair directing the VSD to the pulmonary valve, the REV procedure, or the Rastelli procedure. In the case of DOLV use this code for tunnel closure to the pulmonary valve. If the REV or Rastelli procedures are performed then use those respective codes.
1210	Coarctation repair, End to end	Repair of coarctation of aorta by excision of the coarctation segment and end-to-end circumferential anastomosis of the aorta.
1220	Coarctation repair, End to end, Extended	Repair of coarctation of the aorta by excision of the coarctation segment and end-to-end anastomosis of the oblique ends of the aorta, creating an extended anastomosis.
1230	Coarctation repair, Subclavian flap	Repair of coarctation of the aorta by ligating, dividing, and opening the subclavian artery, incising the coarctation site, and folding down the subclavian artery onto the incision in the aorta, suturing the subclavian "flap" in place, creating a roof over the area of the previous coarctation.
1240	Coarctation repair, Patch aortoplasty	Repair of coarctation of the aorta by incising the coarctation site with placement of a patch sutured in place longitudinally along the aortotomy edge.

1250	Coarctation repair, Interposition graft	Repair of coarctation of the aorta by resection of the coarctation segment and placement of a prosthetic tubular interposition graft anastomosed circumferentially to the cut ends of the aorta.
1260	Coarctation repair, Other	Any repair of coarctation not specified in procedure codes. This may include, for example, a combination of two approaches for coarctation repair or extra-anatomic bypass graft, etc.
1275	Coarctation repair + VSD repair	Coarctation of aorta repair, any technique, and simultaneous VSD repair, any type VSD, any type repair.
1280	Aortic arch repair	Aortic arch repair, any technique.
1285	Aortic arch repair + VSD repair	Aortic arch repair, any technique, and simultaneous VSD repair, any type VSD, any type repair. This includes repair of IAA with VSD.
1290	Coronary artery fistula ligation	Coronary artery fistula repair using any technique. If additional technique information may be supplied by another procedure code, please list separately (e.g., bypass graft).
1291	Anomalous origin of coronary artery from pulmonary artery repair	Repair of anomalous origin of the coronary artery (any) from the pulmonary artery, by any technique (ligation, translocation with aortic implantation, Takeuchi operation, bypass graft). If additional technique information may be supplied by another procedure code, please list separately (for example, bypass graft).
1300	Coronary artery bypass	Coronary artery bypass graft procedure, any technique (with or without CPB, venous or arterial graft, one or more grafts, etc.), for any coronary artery pathology (coronary arterial fistula, aneurysm, coronary bridging, atresia of left main, acquired coronary artery disease, etc.).
1310	Coronary artery procedure, Other	Any coronary artery procedure not specifically listed.
1320	Interrupted aortic arch repair	Repair of interrupted aortic arch (any type) by any technique (direct anastomosis, prosthetic graft, etc). Does not include repair of IAA-VSD.
1330	PDA closure, Surgical	Closure of a PDA by any surgical technique (ligation, division, clip) using any approach (i.e., thoracotomy, thoracoscopic, etc).
1340	PDA closure, Device	Closure of a PDA by device using transcatheter techniques.
1360	Vascular ring repair	Repair of vascular ring (any type, except pulmonary artery sling) by any technique.
1365	Aortopexy	Surgical fixation of the aorta to another structure (usually the posterior aspect of the sternum) to relieve compression on another vessel or structure (e.g., trachea).
1370	Pulmonary artery sling repair	Pulmonary artery sling repair by any technique.
1380	Aortic aneurysm repair	Aortic aneurysm repair by any technique.
1390	Aortic dissection repair	Aortic dissection repair by any technique
1410	Transplant, lung(s)	Lung or lobe transplantation of any type.

1450	Pacemaker implantation, Permanent	Implantation of a permanent pacemaker of any type (e.g., single-chamber, dual-chamber, atrial antitachycardia), with any lead configuration or type (atrial, ventricular, atrial and ventricular, transvenous, epicardial, transmural), by any technique (sternotomy, thoracotomy etc).
1460	Pacemaker procedure	Any revision to a previously placed pacemaker system including revisions to leads, generators, pacemaker pockets. This may include explantation of pacemakers or leads as well.
2350	Explantation of pacing system	
1470	ICD (AICD) implantation	Implantation of an (automatic) implantable cardioverter defibrillator system.
1480	ICD (AICD) ([automatic] implantable cardioverter defibrillator) procedure	Any revision to a previously placed AICD including revisions to leads, pads, generators, pockets. This may include explantation procedures as well.
1490	Arrhythmia surgery - atrial, Surgical Ablation	Surgical ablation (any type) of any atrial arrhythmia.
1500	Arrhythmia surgery - ventricular, Surgical Ablation	Surgical ablation (any type) of any ventricular arrhythmia.
1590	Shunt, Systemic to pulmonary, Modified Blalock-Taussig Shunt (MBTS)	Placement of a tube graft from a branch of the aortic arch to the pulmonary artery with or without bypass, from any approach (thoracotomy, sternotomy).
1600	Shunt, Systemic to pulmonary, Central (from aorta or to main pulmonary artery)	A direct anastomosis or placement of a tube graft from the aorta to the pulmonary artery with or without bypass, from any approach (thoracotomy, sternotomy).
1610	Shunt, Systemic to pulmonary, Other	Placement of any other systemic-to-pulmonary artery shunt, with or without bypass, from any approach (thoracotomy, sternotomy) that is not otherwise coded. Includes classic Blalock-Taussig systemic-to-pulmonary artery shunt.
1630	Shunt, Ligation and takedown	Takedown of any shunt.
2095	Shunt, Reoperation	
1640	PA banding (PAB)	Placement of a pulmonary artery band, any type.
1650	PA debanding	Debanding of pulmonary artery. Please list separately any pulmonary artery reconstruction required.
1660	Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction)	In the Damus-Kaye-Stansel procedure the proximal transected main pulmonary artery is connected by varying techniques to the aorta.
1670	Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)	Superior vena cava to pulmonary artery anastomosis allowing flow to both pulmonary arteries with an end-to side superior vena-to-pulmonary artery anastomosis.
1680	Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)	Superior vena cava to ipsilateral pulmonary artery anastomosis (i.e., LSVC to LPA, RSVC to RPA).

1690	Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)	Bilateral superior vena cava-to-pulmonary artery anastomoses (requires bilateral SVCs).
1700	HemiFontan	A HemiFontan is an operation that includes a bidirectional superior vena cava (SVC)-to-pulmonary artery anastomosis and the connection of this “SVCpulmonary artery amalgamation” to the atrium, with a “ dam” between this “SVC-pulmonary artery amalgamation” and the atrium. This operation can be accomplished with a variety of operative strategies including the following two techniques and other techniques that combine elements of both of these approaches: (1) Augmenting both branch pulmonary arteries with a patch and suturing the augmented branch pulmonary arteries to an incision in the medial aspect of the superior vena cava. (With this approach, the pulmonary artery patch forms a roof over the SVC-topulmonary artery anastomosis and also forms a “dam” between the SVC-pulmonary artery amalgamation and the right atrium.) (2) Anastomosing both ends of the divided SVC to incisions in the top and bottom of the right pulmonary artery, and using a separate patch to close junction of the SVC and the right atrium.
2330	Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty	
2130	Superior Cavopulmonary anastomosis(es) + PA reconstruction	
1720	Aneurysm, Ventricular, Right, Repair	Repair of right ventricular aneurysm, any technique.
1730	Aneurysm, Ventricular, Left, Repair	Repair of left ventricular aneurysm, any technique.
1740	Aneurysm, Pulmonary artery, Repair	Repair of pulmonary artery aneurysm, any technique.
1760	Cardiac tumor resection	Resection of cardiac tumor, any type.
1780	Pulmonary AV fistula repair/occlusion	Repair or occlusion of a pulmonary arteriovenous fistula.
1790	Ligation, Pulmonary artery	Ligation or division of the pulmonary artery. Most often performed as a secondary procedure.
1802	Pulmonary embolectomy, Acute pulmonary embolus	Acute pulmonary embolism (clot) removal, through catheter or surgery.
1804	Pulmonary embolectomy, Chronic pulmonary embolus	Chronic pulmonary embolism (clot) removal, through catheter or surgery.
1830	Ligation, Thoracic duct	Ligation of the thoracic duct; most commonly for persistent chylothorax.
1860	Mediastinal procedure	Any non-cardiovascular mediastinal procedure not otherwise listed.