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The Importance of Patient-Specific Preoperative Factors: An Analysis of The Society of Thoracic Surgeons Congenital Heart Surgery Database

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Abstract

Background—The most common forms of risk adjustment for pediatric and congenital heart surgery used today are based mainly on the estimated risk of mortality of the primary procedure of the operation. The goals of this analysis were to assess the association of patient-specific preoperative factors with mortality and to determine which of these preoperative factors to include in future pediatric and congenital cardiac surgical risk models.

Methods—All index cardiac operations in The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSD) during 2010 through 2012 were eligible for inclusion. Patients weighing less than 2.5 kg undergoing patent ductus arteriosus closure were excluded. Centers with more than 10% missing data and patients with missing data for discharge mortality or other key

variables were excluded. Rates of discharge mortality for patients with or without specific preoperative factors were assessed across age groups and were compared using Fisher's exact test.

Results—In all, 25,476 operations were included (overall discharge mortality 3.7%, $n = 943$). The prevalence of common preoperative factors and their associations with discharge mortality were determined. Associations of the following preoperative factors with discharge mortality were all highly significant ($p < 0.0001$) for neonates, infants, and children: mechanical circulatory support, renal dysfunction, shock, and mechanical ventilation.

Conclusions—Current STS-CHSD risk adjustment is based on estimated risk of mortality of the primary procedure of the operation as well as age, weight, and prematurity. The inclusion of additional patient-specific preoperative factors in risk models for pediatric and congenital cardiac surgery could lead to increased precision in predicting risk of operative mortality and comparison of observed to expected outcomes.

Meaningful analysis of outcomes requires adjustment for differences in case-mix across hospitals. The importance of this concept is magnified in the current era of public reporting of outcomes. Public reporting without risk adjustment is misleading and can lead to risk averse practices, with efforts made to avoid caring for the sickest of patients who might benefit the most from cardiac surgery [1, 2].

The most common forms of risk adjustment for analysis and reporting of outcomes from pediatric and congenital cardiac surgery in use today are based mainly on the estimated risk of mortality of the primary procedure of the operation [3-5]. With increased availability of robust clinical data, it should now be possible to add a variety of specific patient characteristics to pediatric and congenital cardiac surgical risk models, including prematurity, chromosomal abnormalities (such as trisomy 18 and trisomy 21), syndromes (such as Marfan and Noonan), noncardiac congenital anatomic abnormalities (such as omphalocele and congenital diaphragmatic hernia), and preoperative factors (such as preoperative mechanical circulatory support and preoperative mechanical ventilation to treat cardiorespiratory failure). The term “preoperative factors” is used rather than “preoperative risk factors” because not all of these preoperative factors are associated with risk. Importantly, the relative degree of risk attributable to each of these preoperative factors depends on the age groups and procedural groups under consideration, and on the endpoints being considered (be they mortality, length of stay, complications, or others). The purpose of this analysis is to assess the association of patient-specific preoperative factors with mortality, and to determine which of these preoperative factors may be considered for future inclusion in pediatric and congenital cardiac surgical risk models.

Patients and Methods

Data Source

The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSD) was used for this study. The STS-CHSD is the largest database in the world of patients who have undergone congenital and pediatric cardiac surgical operations. It is a voluntary registry that contains preoperative, operative, and outcomes data for all patients undergoing congenital and pediatric cardiovascular operations at participating centers. As of January 2014, the

STS-CHSD contains data on more than 292,000 surgeries conducted since 1998 at 120 hospitals in North America, representing more than 90% of all US centers performing congenital heart surgery and more than 90% of all pediatric and congenital cardiac operations in the United States [6]. Coding for this database is accomplished by clinicians and ancillary support staff using the International Pediatric and Congenital Cardiac Code [7, 8] and is entered into the contemporary version of the STS-CHSD data collection form (version 3.0) [9]. The definitions of all terms and codes from the STS-CHSD used in this article, including all of the preoperative factors evaluated in this analysis, have been standardized and published [9]. Evaluation of data quality includes the intrinsic verification of data, along with a formal process of in-person site visits and data audits at approximately 10% of all participating centers each year conducted by a panel of independent quality personnel and pediatric cardiac surgeons [10]. The Duke Clinical Research Institute serves as the data warehouse and analytic center for all STS national databases. Approval for the study was obtained from the Duke University Medical Center Institutional Review Board as well as from the Quality Measurement Task Force of the STS Workforce on National Databases.

Study Population

All index cardiac operations in the STS-CHSD during 2010 through 2012 were eligible for inclusion. Patients weighing less than 2.5 kg undergoing isolated closure of patent ductus arteriosus (PDA) were excluded. Patients with missing data for discharge mortality were also excluded from the analysis. Centers with more than 10% missing data for discharge mortality or other key variables including preoperative factors were also excluded. Table 1 documents the inclusionary and exclusionary criteria applied to obtain the final study cohort. The final study cohort included 25,476 index cardiac operations performed in 23,019 patients at 72 centers from January 1, 2010, to December 31, 2012.

Data Collection

Data collected included patient age, preoperative factors, primary procedure, and discharge mortality. The STS-CHSD includes variables pertaining to a variety of patient characteristics including age, weight, age-for-weight Z score, prematurity, chromosomal abnormalities, syndromes, noncardiac congenital anatomic abnormalities, and preoperative factors. This analysis focuses on the association of patient-specific preoperative factors with discharge mortality. This analysis does not evaluate other patient characteristics, including age, weight, age-for-weight Z score, prematurity, chromosomal abnormalities, syndromes, and noncardiac congenital anatomic abnormalities.

Risk models for future use in the STS-CHSD will include a variety of categories of patient characteristics, including prematurity, chromosomal abnormalities, syndromes, noncardiac congenital anatomic abnormalities, and preoperative factors. The present study is confined to the factors coded in the STS-CHSD under the heading “preoperative factors,” which are patient preoperative “status” factors such as preoperative mechanical circulatory support and preoperative renal dysfunction, among many others. These preoperative status factors can be distinguished from other patient characteristics, including patient-related genetic and structural factors such as chromosomal abnormalities, syndromes, and noncardiac congenital

anatomic abnormalities. Ultimately, plans are eventually to include in future risk models in the STS-CHSD both these preoperative status factors and other patient characteristics, including patient-related genetic and structural factors such as chromosomal abnormalities, syndromes, and noncardiac congenital anatomic abnormalities. (A separate article is now in preparation that discusses the details of incorporation of these patient-related genetic and structural factors into such a risk model.)

Data Analysis

Discharge mortality was determined for patients with or without preoperative factors in the STS-CHSD. Of 34 preoperative factors for which data are collected in STS-CHSD version 3.0, specific preoperative factors were included in the analysis if their age group–specific prevalence was greater than 2% or if the number of associated deaths was 20 or more (Table 2). These cutoffs (or “thresholds for inclusion”) were selected based on the expert consensus of the investigative team to eliminate rarely occurring preoperative factors that are rarely associated with mortality before discharge. The rationale for these thresholds for inclusion was to avoid a situation wherein information that might be considered for inclusion in a future risk model might reflect the influence of a small number of events that could conceivably have occurred at random. The actual death rates of patients with each preoperative factor and patients without each preoperative factor were compared using Fisher’s exact test.

Institutional Review Board Approval

The Duke University Health System Institutional Review Board approved the study and provided a waiver of informed consent. Although the STS data used in the analysis contain patient identifiers, they were originally collected for nonresearch purposes and the risk to patients was deemed to be minimal [11].

Results

The final analysis included 25,476 operations, with an overall discharge mortality of 3.7% ($n = 943$). Table 2 shows the prevalence of preoperative factors that were analyzed and their associated discharge mortality. The associations of discharge mortality with the following preoperative factors were all highly significant ($p < 0.0001$) for all three pediatric age categories (neonates, infants, and children): mechanical circulatory support, renal dysfunction, shock, and mechanical ventilation.

Other individual risk factors were highly significant ($p < 0.0001$) in one or more age groups, but not in all three pediatric age categories. The only preoperative factors found significant ($p < 0.05$) for adults with congenital heart disease were preoperative mechanical ventilation and preoperative neurological deficit. Meanwhile, a number of other preoperative factors, such as preoperative gastrostomy, were significant for infants and children, but not for neonates.

Comment

Current risk adjustment in the STS-CHSD is based on estimated risk of mortality of the primary procedure of the operation, as well as on age, weight, and prematurity. Our analysis has demonstrated the significant association of certain patient-specific preoperative risk factors with discharge mortality after surgery for pediatric and congenital cardiac disease. Based on our analysis, the inclusion of additional patient-specific preoperative factors in risk models for pediatric and congenital cardiac surgery could lead to increased precision in predicting risk of operative mortality and comparison of observed to expected outcomes.

The importance of risk adjustment derives from the inadequacy of an analysis of outcomes using raw measurements of mortality, without adjustment for complexity. The mix of cases can vary greatly from program to program. Without risk adjustment, the analysis of outcomes will be flawed. Therefore, the analysis of outcomes after surgery requires a reliable method of estimating the risk of adverse events based on case mix. However, formal risk modeling is challenging when many of the individual operative procedures are performed in small numbers in the entire cohort and very rarely in many individual centers. Complexity stratification provides an alternative methodology that can facilitate the analysis of outcomes of rare operations. Complexity stratification is a method of analysis in which the data are divided into relatively homogeneous groups (called strata). The data are analyzed within each stratum.

The earliest forms of risk adjustment used by the STS-CHSD were based on complexity stratification. The data are analyzed and reported within each stratum. The STS-CHSD currently uses three methods of procedural complexity stratification: (1) The Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (EACTS) Congenital Heart Surgery Mortality Categories (STAT Mortality Categories); (2) Aristotle Basic Complexity (ABC) Levels; and (3) Risk Adjustment for Congenital Heart Surgery-1 (RACHS-1) Categories. These three methods provide three different ways of grouping types of pediatric and congenital cardiac operations according to their estimated risk or complexity. The STAT Mortality Categories are empirically derived based on data in the STS and EACTS congenital heart surgery databases and use five categories; the STAT Mortality Categories serve as the main complexity adjustment tool for the STS-CHSD. The ABC method uses four categories. The RACHS-1 method uses six categories, but functionally has five categories when applied to the STS-CHSD.

The ABC levels were introduced into the STS-CHSD in 2002. The ABC score is a measure of procedural complexity that was developed by the EACTS/STS Aristotle Committee and is based on expert opinion regarding the potential for mortality, the potential for morbidity, and the technical difficulty of the operation [3, 4]. The RACHS-1 categories were introduced into the STS-CHSD in 2006. The RACHS-1 categories are procedure-driven categories developed to adjust for baseline case mix differences when comparing discharge mortality for groups of patients undergoing pediatric congenital heart surgery. The RACHS-1 method was created using a combination of judgment-based and empirical methodology [4]; it uses procedural and patient level information as components to provide adjustment for the influence of differences in case mix on postoperative surgical mortality.

The procedural component contains congenital cardiac surgical procedures categorized into six categories. The second component of the RACHS-1 method contains patient characteristics that may influence pediatric cardiac surgical outcomes, including age at surgery, prematurity (defined as less than 36 weeks) and major noncardiac structural abnormalities (such as tracheoesophageal fistula) or major chromosomal abnormalities or syndromes (such as DiGeorge syndrome).

The RACHS-1 and the ABC scores were developed at a time when limited multiinstitutional clinical data were available, and were, therefore, based in large part on subjective probability (expert opinion). With the increasing availability of multiinstitutional clinical data, the STAT Mortality Categories were introduced into the STS-CHSD in 2010. The STAT Mortality Categories are an empirically derived methodology of complexity stratification based on statistical estimation of the risk of mortality from an analysis of objective data from the STS-CHSD and the EACTS Congenital Heart Surgery Data-base (EACTS-CHSD) [5]. The STAT Mortality Categories are a tool for complexity stratification that was developed from an analysis of 77,294 operations entered into the EACTS-CHSD (33,360 operations) and the STS-CHSD (43,934 patients) between 2002 and 2007.

Procedure-specific mortality rate estimates were calculated using a Bayesian model that adjusted for small denominators. Operations were sorted by increasing risk and grouped into five categories (STAT Mortality Categories) that were designed to be optimal with respect to minimizing within-category variation and maximizing between-category variation. The STS and EACTS have transitioned from the primary use of Aristotle and RACHS-1 to the primary use of the STAT Mortality Categories for three reasons: (1) the STAT Mortality Score and Categories were developed primarily based on objective data whereas RACHS-1 and Aristotle were developed primarily based on expert opinion (subjective probability); (2) the STAT Mortality Score and Categories allow for classification of more operations than RACHS-1 or Aristotle; and (3) the STAT Mortality Score and Categories have a higher c-statistic than RACHS-1 or Aristotle [5].

One weakness of current systems of risk stratification used for pediatric and congenital cardiac surgery is the limited adjustment made for patient-specific factors. With the increased availability of verified clinical data, it is now possible to incorporate patient-specific factors into the risk models in the STS-CHSD. This analysis demonstrated which preoperative factors may be most important to consider when adjusting for patient-specific risk; these include mechanical circulatory support, renal dysfunction, shock, and mechanical ventilation. A bundle of these major preoperative risk factors could be incorporated into future risk models for pediatric and congenital cardiac surgery.

Future Directions

One important result of this analysis is that beginning with the Spring 2014 STS-CHSD feedback report, new STS-CHSD risk models will be used that will include a number of new patient-specific characteristics, including chromosomal abnormalities, syndromes, noncardiac congenital anatomic abnormalities, and preoperative factors. The present analysis provides the rationale for selection of individual preoperative factors to be included in these models. These new STS-CHSD risk models will improve the ability of the STS-

CHSD to be used as a tool to improve the quality of surgical care delivered to patients with pediatric and congenital cardiac disease [12-14].

In this analysis, the only preoperative factors found significant for adults with congenital heart disease were preoperative mechanical ventilation and preoperative neurologic deficit. The STS is in the process of creating a specific tool for surgical risk adjustment for adults with congenital heart disease. Many adults with congenital heart disease have unique preoperative factors, including ventricular dysfunction and pulmonary hypertension. Many of these preoperative factors in adults with congenital heart disease tend to be quite different from the preoperative factors in children. Eventually, age-specific risk models will complement the overall risk models in the STS-CHSD.

In the January 2014 upgrade of the STS-CHSD, several procedure-specific factors were added to the data collection form. These new procedure-specific factors pertain to the previously published benchmark operations [13] and should eventually facilitate the creation of procedure-specific risk models for these benchmark operations.

In reality, meaningful evaluation and comparison of outcomes require consideration of both mortality and morbidity, but the latter is much harder to quantify. The STAT Mortality Categories provide an empirically based tool for analyzing mortality associated with operations for congenital heart disease [5]. The addition of patient characteristics (including prematurity, chromosomal abnormalities, syndromes, noncardiac congenital anatomic abnormalities, and preoperative factors) can enhance risk adjustment using the STAT Mortality Categories.

To complement the evaluation of quality of care in pediatric and congenital cardiac surgery using the analysis of risk-adjusted mortality, the STS has also developed a tool to analyze risk-adjusted morbidity: the STAT Morbidity Categories [15], which are based on major postoperative complications and postoperative length of stay. Both major postoperative complications and postoperative length of stay were used because models that assume a perfect one-to-one relationship between postoperative complications and postoperative length of stay are not likely to fit the data well. (Indeed, prolonged postoperative length of stay is not always a result of complications but may be secondary to other factors such as sociodemographic variables and availability of beds in post-acute care facilities, among others.) Incorporation of both major postoperative complications and postoperative length of stay allows creation of a much more informative model. The STAT Morbidity Categories provide an empirically based tool for analyzing morbidity associated with operations for congenital heart disease [15]. Future initiatives to assess quality and improve outcomes using the STS-CHSD will adjust for both mortality and morbidity based not only on the operation performed but also on patient-specific factors.

In conclusion, current STS-CHSD risk adjustment is based on estimated risk of mortality of the primary procedure of the operation as well as on age, weight, and prematurity. The inclusion of additional patient-specific preoperative factors in risk models for pediatric and congenital cardiac surgery could lead to increased precision in predicting risk of operative mortality and comparison of observed to expected outcomes.

DISCUSSION

DR CARL LEWIS BACKER (Chicago, IL)

Jeff, congratulations. I want to point out that Dr Jacobs has been the chair of The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS CHSD) for the past 8 years and has done a terrific job in that role. This is a very important analysis. We are now pushing the envelope on our understanding of the influence of preoperative factors and their influence on the eventual outcome. The example of the patient with an anomalous coronary artery who goes to the operating room on extracorporeal membrane oxygenation (ECMO) and in shock being completely different than the elective patient who shows up as an outpatient on the morning of surgery really says it all.

DR BOHDAN MARUSZEWSKI (Warsaw, Poland)

Jeff, this is an opportunity to thank you not only for this very interesting presentation but also for the privilege of working together and being your partner as chair of the European Congenital Database. I have to say, there was nothing more important in my professional life than the work that we've done together.

But looking to the future and thinking about how are we going to progress with our work what do you think, Jeff, how should we address the issue of the stratification of the morbidity? I think the audience should know that the next step is to implement to all three databases the models that would analyze the morbidity based on the morbidity scores.

DR JACOBS

Thank you Carl and Bohdan. Bohdan, your question is extremely important. Prior to answering this question, I would like to thank both you and Carl Backer for your very kind words. I would also like to acknowledge my friend and partner Gus Mavroudis who founded the STS Congenital Heart Surgery Database (STS CHSD). Gus founded the STS CHSD, Chaired the STS CHSD, and passed the leadership of the STS CHSD on to me in 2006. Both Marshall Jacobs and Gus Mavroudis have Chaired the STS CHSD prior to me. If not for the leadership and vision of Gus and Marshall, we simply would not have the STS CHSD. I have had the pleasure of Chairing the STS CHSD, from January 2006 through January 2014. As of this 2014 annual meeting of STS, I am passing the Chairmanship of the STS CHSD on to Marshall Jacobs. Marshall will return as Chair of the STS CHSD, after the 8 years that I had as Chair of the STS CHSD when I was following in the footsteps of Gus and Marshall. Marshall Jacobs and Gus Mavroudis have been my friends and mentors in this activity, and I am massively thankful to them and appreciative of their support over the years. Other important friends and mentors in these initiatives have included Fred Grover, Dave Shahian, Fred Edwards, and Rich Prager, as well as Martin Elliott, Francois Lacour Gayet, Christo Tchervenkov, and Bill Gaynor.

During the time that I Chaired the STS CHSD, and during the time that Gus and Marshall did, one of our most valuable activities was our collaboration with Bohdan, Giovanni Stellin, and our colleagues from the European Association for Cardio Thoracic Surgery (EACTS) and the European Congenital Heart Surgeons Association (ECHSA), as well as

with Hiromi Kur osawa and Arata Murakami, MD, of The Japan Congenital Cardiovascular Surgery Database (JCCVSD). Clearly, Bohdan, you are absolutely correct about the value of this collaboration. We place tremendously high value on this collaboration with our international colleagues. We have done important research together. This collaboration has been enjoyable, fun, and educational a true highlight of my professional life.

Bohdan, your question is a very important question. My presentation today discussed strategies to measure risk adjusted mortality. Our goal was to determine the best way to report risk stratified mortality using STAT Mortality Categories and augmenting these STAT Mortality Categories with preoperative patient characteristics, including noncardiac abnormalities, genetic abnormalities, syndromes, and the results of this study, patient specific preoperative “status” factors (such as preoperative mechanical circulatory support and preoperative renal dysfunction, among many others).

Certainly, risk adjusted mortality is only part of the picture, and really the next step is to also be able to report risk adjusted morbidity. Marshall Jacobs has recently published a great paper about the STAT Morbidity Categories, which is a tool to analyze risk adjusted morbidity associated with pediatric and congenital heart surgery based on major postoperative complications and postoperative length of stay. Both major postoperative complications and postoperative length of stay were used because these variables provide related but not redundant information about morbidity. I believe an important next step is to incorporate analyses based on the STAT Morbidity Categories into the STS and the EACTS congenital heart surgery databases. In the future, we will be able to report risk stratified morbidity using STAT Morbidity Categories. We should then be able to augment these STAT Morbidity Categories with patient specific variables, using a strategy similar to the strategy that we presented today for reporting risk stratified mortality.

DR PAUL KIRSHBOM (New Haven, CT)

Great presentation, Jeff. I really enjoyed it. I wonder if you could give us a sense of the scale of the contributions of the different portions of the risk model. I mean, the STAT category, for example, might explain 70% of the variability in mortality. What do the genetics and other preoperative factors add? What’s the relative scale of the model contributors?

DR JACOBS

Thanks Paul. That is a great question that probably cannot be answered in the time that I have left at this podium. However, your question is the subject of an abstract that we are submitting to present at the 2014 annual meeting of The Southern Thoracic Surgical Association. Hopefully, at the 2014 annual meeting of The Southern Thoracic Surgical Association, we will present (and then publish in *The Annals of Thoracic Surgery*) the details of a new risk model, which will be based on this presentation as well as the question you just asked: “What’s the relative scale of the model contributors?” How much should be contributed by the STAT Mortality Categories versus prematurity versus noncardiac congenital anatomic abnormalities versus chromosomal abnormalities versus syndromes versus preoperative factors. All of these variables are going to be factored into the new risk model, the details of which will be the subject of a second presentation and paper.

DR BACKER

So Jeff, how is this going to affect the U.S. News & World Report analysis that is generated by the STS? That report is something that everyone is now focused on.

DR JACOBS

Yes, Carl, the U.S. News & World Report Children's Hospital Rankings are of intense interest. Therefore, your question is a great question. I think U.S. News & World Report has been reasonably and encouragingly responsive to work done by the STS CHSD. The leaders of the U.S. News survey have made great efforts to mold their survey to what has been done by STS. Therefore, we currently report to U.S. News & World Report mortality stratified by the STAT Mortality Categories. Previously, we reported mortality stratified by the RACHS 1 Categories, when STS was primarily using RACHS 1 and Aristotle. When STS evolved and transitioned to the primary use of the STAT Mortality Categories, U.S. News followed that lead and also evolved and transitioned to the use of the STAT Mortality Categories.

My hope is that after STS begins to report STAT stratified outcomes adjusted for preoperative patient characteristics, then U.S. News will follow our lead as well and also move to the new and improved STS risk model. So I believe that the changes that we make in the STS CHSD will be incorporated in the U.S. News & World Report Children's Hospital Rankings. This belief is supported by evidence from history where U.S. News & World Report has incorporated previous changes and upgrades in the STS CHSD.

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Table 1**Inclusionary and Exclusionary Criteria Applied to Obtain Study Cohort**

Inclusionary and Exclusionary Rules Applied	Records Excluded	Remaining Records	No. of Patients	No. of Participants
Start with all operation in STS-CHSD through January 1, 2013	...	256,854	168,776	111
1. Exclude PDA closure in 2.5 kg or less and exclude organ procurement	12,140	244,714	157,078	111
2. Include only cardiac operations	43,330	201,384	143,362	111
3. Include only index operation of a hospitalization	28,935	172,449	143,253	111
4. Include neonates, infants, children, adults	17	172,432	143,240	111
5. Include surgery year 2010, 2011, or 2012	119,960	52,472	47,352	104
6. Include data version 3.0 only	0	52,472	47,352	104
7. Include only demographic data collected with version 3.0	8,379	44,093	39,658	104
8. Include operations with STAT Mortality Score	1,348	42,745	38,685	104
9. Exclude operation with missing mortality data	1,919	40,826	36,924	104
10. Exclude STS database participants with >10% missing mortality rate (after above steps)	4,916	35,910	32,437	93
11. Exclude STS database participants with >10% missing rate of preoperative factors, noncardiac congenital anatomic abnormalities, chromosomal abnormalities, syndromes, prematurity (neonates and infants), or number of prior cardiothoracic operations (after above steps)	10,434	25,476	23,019	72

CHSD = Congenital Heart Surgery Database;

PDA = patent ductus arteriosus;

STAT = The Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery;

STS = The Society of Thoracic Surgeons.

Table 2

Prevalence of Common Preoperative Factors and Their Associated Discharge Mortality

Potential Preoperative Risk Factors	Neonates (n = 5,630) Mortality Rate ^a (p Value)	Infants (n = 9,500) Mortality Rate ^a (p Value)	Children (n = 8,742) Mortality Rate ^a (p Value)	Adults (n = 1,604) Mortality Rate ^a (p Value)
Overall mortality rate	9.88%	2.91%	0.92%	1.93%
Preoperative/preprocedural mechanical circulatory support ^b	20/37 = 54.1% (<0.0001)	12/49 = 24.5% (<0.0001)	13/48 = 27.1% (<0.0001)	0/4 = 0.0% (0.9999)
Shock, persistent at time of surgery	42/125 = 33.6% (<0.0001)	9/47 = 19.2% (<0.0001)	9/29 = 31.0% (<0.0001)	1/4 = 25.0% (0.0752)
Renal dysfunction	31/119 = 26.1% (<0.0001)	17/79 = 21.5% (<0.0001)	6/53 = 11.3% (<0.0001)	2/26 = 7.7% (0.0882)
Mechanical ventilation to treat cardiorespiratory failure	271/1792 = 15.1% (<0.0001)	83/723 = 11.5% (<0.0001)	21/146 = 14.4% (<0.0001)	3/12 = 25.0% (0.0013)
Gastrostomy present	3/18 = 16.7% (0.4132)	41/654 = 6.3% (<0.0001)	13/364 = 3.6% (<0.0001)	0/5 = 0.0% (0.9999)
Shock, resolved at time of surgery	63/421 = 15.0% (0.0006)	10/179 = 5.6% (0.0407)	8/59 = 13.6% (<0.0001)	1/7 = 14.3% (0.1279)
Coagulation disorder, hypocoagulable state secondary to medication	5/11 = 45.5% (0.0026)	5/44 = 11.4% (0.0086)	2/50 = 4.0% (0.0764)	1/36 = 2.8% (0.5086)
Hypothyroidism	6/23 = 26.1% (0.0211)	9/190 = 4.7% (0.1258)	4/113 = 3.5% (0.0197)	2/66 = 3.0% (0.3674)
Preoperative neurologic deficit	10/47 = 21.3% (0.022)	12/155 = 7.7% (0.0018)	8/246 = 3.3% (0.0018)	4/47 = 8.5% (0.0114)
Preoperative complete atrioventricular block	10/50 = 20.0% (0.0276)	2/47 = 4.3% (0.3984)	5/161 = 3.1% (0.0158)	0/57 = 0.0% (0.6247)
Stroke, CVA, or intracranial hemorrhage grade >2 during lifetime	7/41 = 17.1% (0.1179)	10/100 = 10.0% (0.0006)	4/102 = 3.9% (0.014)	2/45 = 4.4% (0.2152)
Seizure during lifetime	7/51 = 13.7% (0.3426)	9/187 = 4.8% (0.1204)	10/291 = 3.4% (0.0003)	3/48 = 6.3% (0.0629)

CVA = cerebrovascular accident.

^aNumber of deaths divided by number with factor (n/n) equals mortality rate.^bSuch as intraaortic balloon pump, ventricular assist device, extracorporeal membrane oxygenation, or cardiopulmonary support.