ECHSA
CONGENITAL DATABASE

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One can not evaluate what is not measured

"The good news is
outcomes in congenital heart surgery have improved over the last decades."

To make this statement a valid measurement of procedures performed in congenital heart surgery is necessary. But measurement of quality requires comparison of results. For that, three tools are needed together: first, a common nomenclature, second, a simplified electronic registry and third, a reliable method of comparison.

This Newsletter sets the focus on methods of comparison.

Read about all scores in congenital heart surgery, their current usage, and take a look at the hints how to use them.

THOUGHTS ON DATA COLLECTION

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All we surgeons wake up want to save the lives of our patients and/or improve their quality of life. We are also highly competitive and driven people, using data to carry out our work. It is not easy to become a paediatric cardiac surgeon. Many of us are also parents, and well aware of the awful stresses that our patient's families must bear. If any of our children needed surgery, we would read the literature, make a few phone calls and discover who was best at fixing the relevant problem… and then persuade them to undertake the care.

Where do we go for our information, how accurate and complete is it, is it diagnosis- or procedure-related, and is the same information freely available and understandable to our patients? Towards the end of the 20th Century, a revolution had taken place in our speciality, both in techniques available and the analysis of results. Neonatal surgery had advanced, CPB was safer, ICU a different animal, and data analysis courtesy of Kirklin, Blackstone, and Barratt-Boyes increasingly well understood.

But the data were largely derived from specialist studies in specialist hospitals, and focused on specific questions of interest. There was and is nothing wrong with that, of course; all research is done that way, and will continue so to be. Surgeons all over the world acted on those publications, and were expected to deliver the same standard of results, whatever their experience, facilities or teams. There was little, if any, registry data accumulating the data from every centre, and from every patient. Such data could be used for influencing health policy, managing resources and expectations and for basic benchmarking. We all want to be the best!

These thoughts lay behind the establishment of the ECHSA and STS registries, which have had such an important impact in understanding the issues facing our field. The evolution of both has improved coding, exposed health inequalities,

and aided political debate. But issues of accuracy, relevance and consequence remain.

Let me consider some of them.

1. Procedure or diagnosis?

Our registries are procedure-based, set up partly to see how good we are at certain operations, particularly whichever is fashionable of done in large quantity. But is that right? Should we not have gone for diagnosis-based registries? After all, surgery is just an event (or several events) in the course of a disease. Is it not better to see what happens to the baby with TGA over life, with the switch as just part of the care? Or PA-VSD MAPCAs. One day a tablet might turn out to be more effective than surgery! Life course recording of outcome should be our target, not just mortality after (a) surgery. The challenge is how to record both pathway and outcome over life. In the interim, both should be attempted.

2. Data Accuracy & Completeness

In the modern era, healthcare is an information economy. Diagnoses and procedures translate into codes and we share information digitally. Our diagnostic tools (CT, MRI, etc) are recorded digitally and analysed mathematically. We rely on the data to treat individual patients and to make decisions. Yet we are poor at merging those data and finding ways to secure the stored result. We still require manual processes, and the cost of data handling is often underestimated and not borne by the health system. Any analysis of registry information requires both accurate and complete data. Yet we persist in supporting voluntary data supply to registries. I feel strongly that health systems should support data management, perhaps by a levy on each patient, and that data submission should be compulsory, and in the future, automated.

3. Consequence

There is little point in collecting data unless it is used for something. Registry management is very hard work, and it is easy for it to become work in its own right, losing a sense of context. The point of sharing information is to learn and get better. To strive for excellence. Accordingly, registries need to have strategies and structures in place to be able to act on their findings, good or bad. At its most extreme, bad units should be closed, and good units expanded. Life is of course not like that; performance changes over time, and circumstances are not uniform. But what we should do is what the English health service has done for CHD surgery data, which is to make data submission, accuracy, and completeness mandatory, and to implement a scheme by which the professional societies, the health service, and statisticians will visit a unit whose results fall outside the 95th confidence limit of national performance and make suggestions for change, going beyond suggestions if necessary! The effect has been to raise standards everywhere, and to minimise variation between centres.

A few years ago, Michael Porter suggested that the value of a treatment (to a patient) was the outcome of that treatment (over life) divided by the cost (societal and personal) over life. Health policy is made from a deep understanding of value utilities, and it should be our goal to resolve the Porter value equation. Health systems are increasingly looking at outcome-based financing. We need to get smarter in providing the appropriate and accurate data.

We can all list cases of when individual surgeons or centres feel that they have suffered as a result of data comparisons and press intrusion, but we must remember that we are servants of the public. We have a responsibility to provide them with good care and minimal harm. We have a moral responsibility to be able to prove that accurately, reliably and transparently. In the days of the web and internet literacy, we have no excuse not to. It should be compulsory.

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STAT MORTALITY SCORE AND STAT MORTALITY CATEGORIES

Jeffrey P. Jacobs, MD, Marshall L. Jacobs, MD, and Francois Lacour-Gayet, MD, and Bohdan Maruszewski, MD

Risk stratification is a method of analysis in which the data are divided into relatively homogeneous groups (called strata). The data are analyzed and reported within each stratum. Three methods of risk stratification have been used in The European Congenital Heart Surgeons Association Congenital Heart Surgery Database (ECHSA CHSD) and The Society of Thoracic Surgeons Congenital Heart Surgery Database (STS CHSD):

1. **A**ristotle **B**asic Complexity **L**evels (**ABC Levels**) (1-12, 17)
2. **R**isk **A**djustment for **C**ongenital **H**eart **S**urgery-1 Categories (**RACHS-1 Categories**) (12-14, 17)
3. The **S**ociety of **T**horacic Surgeons (STS) - European **A**ssociation for Cardio-**T**horacic Surgery Congenital Heart Surgery (EACTS) Mortality Categories (**STAT Mortality Categories**) (15-17).

In 2020, the primary method of risk stratification used in ECHSA CHSD and the STS CHSD is the STAT Mortality Categories. Nevertheless, a brief review of the ABC Levels and the RACHS-1 Categories provides useful information and helps contextualize the STAT Mortality Categories. These 3 methods provide 3 different ways of grouping types of pediatric and congenital cardiac operations according to their estimated risk or complexity. The STAT Mortality

Categories uses 5 categories and serve as the main complexity adjustment tool for the ECHSA CHSD and the STS CHSD. The ABC method uses 4 categories. The RACHS-1 method uses 6 categories, but functionally has 5 categories when applied to the ECHSA CHSD and the STS CHSD.

In the STS CHSD Feedback Reports that are distributed to all Participants in the STS CHSD every 6 months, overall mortality rates for both individual Participants and the entire STS CHSD are presented overall using all 3 methods of procedural risk stratification. Additional detailed breakdowns by age group are provided using the STAT Mortality Categories only. This article provides a brief description of ABC Levels and RACHS-1 Categories, followed by a more detailed discussion of the STAT Mortality Categories.

The Aristotle Basic Complexity Levels (ABC Levels)

The ABC Score and the ABC Level were developed by multiple leaders in ECHSA and STS and were introduced into STS CHSD and ECHSA CHSD in 2002. The ABC Score and the ABC Level are measures of procedural complexity that were developed by the EACTS/STS Aristotle Committee and are based on potential for mortality, potential for morbidity, and technical difficulty of the operation. A listing of the ABC Score and the ABC Level values are provided in **Table 1**.

The Risk Adjustment for Congenital Heart Surgery (RACHS-1) Categories

The RACHS-1 Categories were introduced into the STS Congenital Heart Surgery Database Feedback Report 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. RACHS-1 was created using a combination of judgment-based and empirical methodology. A listing of the RACHS-1 Categories and interpretation is provided in **Table 2**.

The STAT Mortality Categories

The STAT Mortality Categories were introduced into STS CHSD and the ECHSA CHSD in 2010. The STAT Mortality Categories are an empirically derived methodology of risk stratification based on the statistical estimation of the risk of mortality from an analysis of objective data from STS CHSD and ECHSA CHSD. A listing of the STAT Mortality Categories is provided in **Table 3**.

For over 20 years, ECHSA and STS have also collaborated to develop tools for risk stratification of patients undergoing pediatric and congenital cardiac surgery. These collaborations started with the development of the Aristotle Complexity Score and matured with the development of the STAT Mortality Score and STAT Mortality Categories. In 2010, the STAT Mortality Score and STAT Mortality Categories were introduced into both STS CHSD and ECHSA CHSD. The STAT Mortality Categories are an empirically derived methodology of risk stratification based on statistical estimation of the risk of mortality from an analysis of objective data from STS CHSD and ECHSA CHSD. The STAT Mortality Score and STAT Mortality Categories were developed based on analysis of 77,294 operations entered in the STS CHSD and ECHSA CHSD (ECHSA CHSD provided 33,360 operations and STS CHSD provided 43,934 operations). Procedure-specific mortality rate estimates were calculated using a Bayesian model that adjusted for small denominators. Operations were sorted by increasing risk and grouped into 5 categories that were designed to minimize within-category variation and maximize between-category variation. Both the Aristotle Complexity Score and the STAT Mortality Score and STAT Mortality Categories represent important collaborative initiatives between ECHSA and STS.

Outcomes other than Mortality

The current version of the STAT Mortality Categories is designed to categorize operations based on the statistical estimation of the risk of mortality prior to discharge from the hospital. Obviously, multiple additional endpoints are important beyond mortality. The STS Morbidity Categories are designed to categorize operations based on the statistical estimation of the risk of morbidity (18). The STS Morbidity Categories will be discussed in detail in another section of this newsletter.

Risk Stratification versus Risk Modelling

STS CHSD Feedback Reports began incorporating strategies of case-mix adjustment with the introduction of risk stratification using the ABC Levels in 2002 and the RACHS-1 Categories in 2006. The ABC Levels and the RACHS-1 Categories were largely based on expert opinion (subjective probability). In 2010, STS CHSD and ECHSA CHSD began using the STAT Mortality Categories. Unlike Aristotle and RACHS-1, the STAT Mortality Categories were derived empirically using actual objective data from STS CHSD and EACTS CHSD.

In 2014, STS CHSD Feedback Reports began incorporating the STS CHSD Mortality Risk Model (19–23). The current version of the STS CHSD Mortality Risk Model adjusts not only for procedure and age group pairings but also for multiple additional patient factors, including age, primary procedure, weight (in neonates and infants), prior cardiothoracic operations, prematurity (in neonates and infants), preoperative factors (including preoperative/ preprocedural mechanical circulatory support [IABP, VAD, ECMO, or CPS], shock persistent at time of surgery, mechanical ventilation to treat cardiorespiratory failure, renal failure requiring dialysis and/or renal dysfunction, and preoperative neurological deficit), chromosomal abnormalities, syndromes, and noncardiac congenital anatomic abnormalities. Importantly, the STS CHSD Mortality Risk Model adjusts for each combination of primary procedure and age group. Coefficients obtained via shrinkage estimation with STAT Mortality Category as an auxiliary variable. Thus, although the STAT Mortality Category is not a variable in the STS CHSD Mortality Risk Model, the STAT Mortality Category does inform the Bayesian modeling (i.e. shrinkage estimation). Also, the STAT Mortality Categories are used as a tool to categorize and display benchmarked outcomes data that has been derived from the STS CHSD Mortality Risk Model.

The Future of Risk Stratification and Risk Modelling for Pediatric and Congenital Cardiac Surgery

Both risk stratification and risk modelling are methods of risk adjustment that are commonly used to facilitate the analysis of pediatric and congenital cardiac surgical outcomes (24-26). All three of the methods or risk stratification discussed in this article have been use in multiple peer reviewed scientific publications generated by ECHSA: ABC Score and Levels [27, 28], RACHS-1 (27, 28), and STAT Mortality Categories (28-30). Under the leadership of Marshall L. Jacobs, MD, the STAT Mortality Categories are being updated. The original STAT Mortality Categories were developed based on the outcomes of operations performed between 2002 and 2007. The update of the STAT Mortality Score will accomplish several objectives: (1) provided empirically derived STAT Mortality Scores and STAT Mortality Categories for operations added to the STS CHSD and ECHSA CHSD since 2007, (2) utilize Operative Mortality as an endpoint instead of Discharge Mortality, and (3) provide empirically derived STAT Mortality Scores and STAT Mortality Categories for operations involving multiple component procedures where the estimated risk of Operative Mortality of the combined procedures is statistically different from the estimated risk of Operative Mortality of the procedure with the highest STAT Mortality Score.

Meanwhile, strategies for risk modelling of pediatric and congenital cardiac surgical outcomes are also becoming increasingly sophisticated. Multi-domain composite models are now available that measure the combined outcomes of Operative Mortality, morbidity, and postoperative length of stay (31, 32). Research is ongoing to develop tools to measure and eventually model longitudinal outcomes; and finally, strategies are being explored to classify operations not just by the procedure performed but by the combination of the diagnosis and the procedure. One fact that is certain is that all of these advances will benefit from the ongoing collaboration of STS and ECHSA.

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Table 1. The Aristotle Basic Complexity Score (ABC Score) and The Aristotle Basic Complexity Levels (ABC Levels) (October 24, 2014)

Score	Mortality	Morbidity	Difficulty
1 pt	<1%	ICU 0-24H	elementary
2 pt	1-5%	ICU 1D-3D	simple
3 pt	5-10%	ICU 4D-7D	average
4 pt	10-20%	ICU 1W-2W	important
5 pt	> 20%	ICU > 2W	major

Complexity	
1.5 to 5.9	1
6.0 to 7.9	2
8.0 to 9.9	3
10.0 to 15.0	4

Procedures	Total (Basic Score)	Complexity (Basic Level)	Mortality	Morbidity	Difficulty
Pleural drainage procedure	1.5	1	0.5	0.5	0.5
Bronchoscopy	1.5	1	0.5	0.5	0.5
Delayed sternal closure	1.5	1	0.5	0.5	0.5
Mediastinal exploration	1.5	1	0.5	0.5	0.5
Sternotomy wound drainage	1.5	1	0.5	0.5	0.5
Intra-aortic balloon pump (IABP) insertion	2.0	1	0.5	1.0	0.5
Explantation of pacing system	2.5	1	1.0	1.0	0.5
PFO, Primary closure	3.0	1	1.0	1.0	1.0
ASD repair, Primary closure	3.0	1	1.0	1.0	1.0
ASD repair, Patch	3.0	1	1.0	1.0	1.0
ASD partial closure	3.0	1	1.0	1.0	1.0
Atrial fenestration closure	3.0	1	1.0	1.0	1.0
Pericardial drainage procedure	3.0	1	1.0	1.0	1.0
PDA closure, Surgical	3.0	1	1.0	1.0	1.0
Pacemaker implantation, Permanent	3.0	1	1.0	1.0	1.0
Pacemaker procedure	3.0	1	1.0	1.0	1.0
Shunt, Ligation and takedown	3.5	1	1.5	1.0	1.0
ASD, Common atrium (Single atrium), Septation	3.8	1	1.0	1.0	1.8
AVC (AVSD) repair, Partial (incomplete) (PAVSD)	4.0	1	1.0	1.0	2.0
Coronary artery fistula ligation	4.0	1	1.0	2.0	1.0
Aortopexy	4.0	1	1.5	1.5	1.0
ICD (AICD) implantation	4.0	1	1.5	1.0	1.5
ICD (AICD) (automatic implantable cardioverter defibrillator) procedure	4.0	1	1.5	1.0	1.5
Hybrid Approach, Transcardiac balloon dilation	4.0	1	1.5	1	1.5
Ligation, Thoracic duct	4.0	1	1.0	2.0	1.0
Diaphragm plication	4.0	1	1.0	2.0	1.0
ECMO decannulation	4.0	1	2.0	1.0	1.0
ASD creation/enlargement	5.0	1	2.0	2.0	1.0

Atrial septal fenestration	5.0	1	2.0	2.0	1.0
AVC (AVSD) repair, Intermediate (transitional)	5.0	1	1.5	1.5	2.0
PAPVC repair	5.0	1	2.0	1.0	2.0
Lung biopsy	5.0	1	1.5	2.0	1.5
Ligation, Pulmonary artery	5.0	1	1.5	2.0	1.5
Decortication	5.0	1	1.0	1.0	3.0
ASD repair, Patch + PAPVC repair	5.0	1	2.0	1.0	2.0
PAPVC Repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	5.0	1	1.0	2.0	2.0
ECMO cannulation	5.0	1	2.0	1.0	2.0
Pectus repair	5.3	1	2.0	1.0	2.3
Aortic stenosis, Supravalvar, Repair	5.5	1	1.5	2.0	2.0
Valvuloplasty, Pulmonic	5.6	1	1.8	1.8	2.0
VSD repair, Primary closure	6.0	2	2.0	2.0	2.0
VSD repair, Patch	6.0	2	2.0	2.0	2.0
AP window repair	6.0	2	2.0	2.0	2.0
Valve replacement, Truncal valve	6.0	2	2.0	2.0	2.0
Cor triatriatum repair	6.0	2	2.0	2.0	2.0
Valve excision, Tricuspid (without replacement)	6.0	2	2.0	2.0	2.0
PA, reconstruction (plasty), Main (trunk)	6.0	2	2.0	2.0	2.0
Pericardiectomy	6.0	2	2.0	2.0	2.0
Coarctation repair, End to end	6.0	2	2.0	2.0	2.0
Coarctation repair, Subclavian flap	6.0	2	2.0	2.0	2.0
Coarctation repair, Patch aortoplasty	6.0	2	2.0	2.0	2.0
Vascular ring repair	6.0	2	2.0	2.0	2.0
PA banding (PAB)	6.0	2	2.0	2.0	2.0
PA debanding	6.0	2	2.0	2.0	2.0
ECMO procedure	6.0	2	2.0	3.0	1.0
Aortic stenosis, Subvalvar, Repair	6.3	2	2.0	1.8	2.5
Shunt, Systemic to pulmonary, Modified Blalock–Taussig shunt (MBTS)	6.3	2	2.0	2.0	2.3
RVOT procedure	6.5	2	2.0	2.0	2.5
Valve replacement, Pulmonic (PVR)	6.5	2	2.0	2.0	2.5
Shunt, Systemic to pulmonary, Central (From aorta or to main pulmonary artery)	6.8	2	2.0	2.0	2.8
Shunt, Systemic to pulmonary, Central (shunt from aorta), Central shunt with an end-to-side connection between the transected main pulmonary artery and the side of the ascending aorta (i.e. Mee shunt)	7.0	2	3	2	2
Valvuloplasty, Truncal valve	7.0	2	2.0	2.0	3.0
Anomalous systemic venous connection repair	7.0	2	2.0	2.0	3.0
Occlusion MAPCA(s)	7.0	2	2.0	2.0	3.0
Valvuloplasty, Tricuspid	7.0	2	2.0	2.0	3.0
DCRV repair	7.0	2	2.0	2.0	3.0
Valve replacement, Aortic (AVR), Mechanical	7.0	2	2.0	2.0	3.0
Valve replacement, Aortic (AVR), Bioprosthetic	7.0	2	2.0	2.0	3.0
Atrial baffle procedure, Mustard or Senning revision	7.0	2	2.0	2.0	3.0
Aortic arch repair	7.0	2	2.0	2.0	3.0

Kawashima operation (superior cavopulmonary connection in setting of interrupted IVC with azygous continuation)	7.0	2	2.5	2	2.5
Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)	7.0	2	2.5	2.0	2.5
Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)	7.0	2	2.5	2.0	2.5
Hepatic vein to azygous vein connection, Interposition Graft	7.0	2	2.5	2	2.5
Hepatic vein to azygous vein connection, Direct	7.0	2	2.5	2	2.5
Right/left heart assist device procedure	7.0	2	2.0	3.0	2.0
Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA)	7.0	2	1.5	1.5	4.0
VAD implantation	7.0	2	2.0	3.0	2.0
VAD explantation	7.0	2	2.0	3.0	2.0
Hybrid Approach, Transcardiac transcatheter device Placement	7.0	2	1.5	1.5	4
Intravascular stent removal	7.5	2	3	2	2.5
Ventricular septal fenestration	7.5	2	3.0	2.0	2.5
TOF repair, Ventriculotomy, Non-transanular patch	7.5	2	2.5	2.0	3.0
Valve replacement, Tricuspid (TVR)	7.5	2	2.5	2.0	3.0
Conduit placement, RV to PA	7.5	2	2.5	2.0	3.0
Sinus of Valsalva, Aneurysm repair	7.5	2	2.5	2.0	3.0
Valve replacement, Mitral (MVR)	7.5	2	2.5	2.0	3.0
Coronary artery bypass	7.5	2	2.5	2.0	3.0
Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)	7.5	2	2.5	2.0	3.0
Conduit placement, Other	7.5	2	2.5	2.0	3.0
Hybrid Approach "Stage 1", Application of RPA and LPA bands	7.5	2	2.5	2.5	2.5
Atrial baffle procedure (non-Mustard, non-Senning)	7.8	2	2.8	2.0	3.0
PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)	7.8	2	2.8	2.0	3.0
Coarctation repair, Interposition graft	7.8	2	2.8	2.0	3.0
PAPVC, Scimitar, Repair	8.0	3	3.0	2.0	3.0
Systemic venous stenosis repair	8.0	3	3.0	2.0	3.0
TOF repair, No ventriculotomy	8.0	3	3.0	2.0	3.0
TOF repair, Ventriculotomy, Transanular patch	8.0	3	3.0	2.0	3.0
TOF repair, RV-PA conduit	8.0	3	3.0	2.0	3.0
Conduit reoperation	8.0	3	3.0	2.0	3.0
Conduit placement, LV to PA	8.0	3	3.0	2.0	3.0
Valvuloplasty, Aortic	8.0	3	3.0	2.0	3.0
Aortic root replacement	8.0	3	2.5	2.0	3.5
Valvuloplasty, Mitral	8.0	3	3.0	2.0	3.0
Mitral stenosis, Supravalvar mitral ring repair	8.0	3	3.0	2.0	3.0
Coarctation repair, End to end, Extended	8.0	3	3.0	2.0	3.0
Arrhythmia surgery - atrial, Surgical ablation	8.0	3	3.0	2.0	3.0
Arrhythmia surgery - ventricular, Surgical ablation	8.0	3	3.0	2.0	3.0
Hemifontan	8.0	3	3.0	2.0	3.0

Aneurysm, Ventricular, Right, Repair	8.0	3	3.0	2.0	3.0
Aneurysm, Pulmonary artery, Repair	8.0	3	3.0	2.0	3.0
Cardiac tumor resection	8.0	3	3.0	2.0	3.0
Pulmonary embolectomy	8.0	3	3.0	3.0	2.0
Pulmonary embolectomy, Acute pulmonary embolus	8.0	3	3.0	3.0	2.0
Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS	8.0	3	2.0	2.0	4.0
Valvuloplasty converted to valve replacement in the same operation, Pulmonic	8.0	3	2.5	2.5	3.0
LV to aorta tunnel repair	8.3	3	3.0	2.3	3.0
Valve replacement, Aortic (AVR), Homograft	8.5	3	3.0	2.0	3.5
Aortic root replacement, Valve sparing	8.5	3	2.0	2.0	4.5
Senning	8.5	3	3.0	2.5	3.0
PA, reconstruction (plasty), Branch, Peripheral (at or beyond the hilar bifurcation)	8.8	3	2.8	2.5	3.5
Unifocalization MAPCA(s), Unilateral pulmonary Unifocalization	8.8	3	2.8	2.5	3.5
Aortic root replacement, Mechanical	8.8	3	3.3	2.0	3.5
Aortic aneurysm repair	8.8	3	3.0	2.8	3.0
VSD, Multiple, Repair	9.0	3	3.0	2.5	3.5
VSD creation/enlargement	9.0	3	3.0	3.0	3.0
AVC (AVSD) repair, Complete (CAVSD)	9.0	3	3.0	3.0	3.0
Pulmonary artery origin from ascending aorta (hemitruncus) repair	9.0	3	3.0	3.0	3.0
TAPVC repair	9.0	3	3.0	3.0	3.0
Pulmonary atresia - VSD (including TOF, PA) repair	9.0	3	3.0	3.0	3.0
Valve closure, Tricuspid (exclusion, univentricular approach)	9.0	3	4.0	3.0	2.0
1 1/2 ventricular repair	9.0	3	3.0	3.0	3.0
Fontan, Atrio-pulmonary connection	9.0	3	3.0	3.0	3.0
Fontan, Atrio-ventricular connection	9.0	3	3.0	3.0	3.0
Fontan, TCPC, Lateral tunnel, Fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, Lateral tunnel, Non-fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, External conduit, Fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, External conduit, Non-fenestrated	9.0	3	3.0	3.0	3.0
Fontan, TCPC, Intra/extracardiac conduit, Fenestrated	9.	3	3.0	3.0	3.0
Fontan, TCPC, Intra/extracardiac conduit, Nonfenestrated	9.	3	3.0	3.0	3.0
Congenitally corrected TGA repair, VSD closure	9.0	3	3.0	3.0	3.0
Mustard	9.0	3	3.0	3.0	3.0
Pulmonary artery sling repair	9.0	3	3.0	3.0	3.0
Aneurysm, Ventricular, Left, Repair	9.0	3	3.0	2.5	3.5
Conduit placement, Ventricle to aorta	9.0	3	3.0	3.0	3.0
Pulmonary embolectomy, Chronic pulmonary embolus	9.0	3	3.0	3.0	3.0
Valvuloplasty converted to valve replacement in the same operation, Truncal valve	9.0	3	2.5	3.0	3.5
Valvuloplasty, Common atrioventricular valve	9.0	3	3.5	2.5	3.0
TOF - Absent pulmonary valve repair	9.3	3	3.0	3.0	3.3
Transplant, Heart	9.3	3	3.0	3.3	3.0

Aortic root replacement, Bioprosthetic	9.5	3	3.5	2.0	4.0
Aortic root replacement, Homograft	9.5	3	3.5	2.0	4.0
Pulmonary atresia - VSD - MAPCA repair, Status post prior complete unifocalization (includes VSD closure + RV to PA connection [with or without conduit])	9.5	3	3	3	3.5
Damus–Kaye–Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction)	9.5	3	3.0	3.0	3.5
Valvuloplasty converted to valve replacement in same operation, Tricuspid	9.5	3	3.0	2.5	4.0
Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty	9.5	3	3.0	3.0	3.5
Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Incomplete unifocalization (not all usable MAPCA[s] are incorporated)	9.5	3	3	3	3.5
Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Complete unifocalization (all usable MAPCA[s] are incorporated)	10.0	4	3.5	3	3.5
Ebstein's repair	10.0	4	3.0	3.0	4.0
Arterial switch operation (ASO)	10.0	4	3.5	3.0	3.5
Rastelli	10.0	4	3.0	3.0	4.0
Coarctation repair + VSD repair	10.0	4	2.5	3.5	4.0
Aortic arch repair + VSD repair	10.0	4	3.0	3.0	4.0
Anomalous origin of coronary artery from pulmonary artery repair	10.0	4	3.0	3.0	4.0
Superior cavopulmonary anastomosis(es) + PA reconstruction	10.0	4	3.5	3.0	3.5
Hybrid Approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair	10.0	4	2.5	3.5	4.0
Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) + application of RPA and LPA bands	10.0	4	3.0	3.0	4.0
Valve replacement, Common atrioventricular valve	10.0	4	3.5	3.5	3.0
Ross procedure	10.3	4	4.0	2.3	4.0
DORV, Intraventricular tunnel repair	10.3	4	3.3	3.0	4.0
Valvuloplasty converted to valve replacement in the same operation, Aortic	10.3	4	3.5	2.5	4.3
Ventricular septation	10.5	4	3.5	3.5	3.5
Valvuloplasty converted to valve replacement in the same operation, Mitral	10.5	4	4.0	2.5	4.0
Interrupted aortic arch repair	10.8	4	3.8	3.0	4.0
Truncus arteriosus repair	11.0	4	4.0	3.0	4.0
TOF - AVC (AVSD) repair	11.0	4	4.0	3.0	4.0
Pulmonary atresia - VSD - MAPCA repair	11.0	4	4.0	3.0	4.0
Unifocalization MAPCA(s)	11.0	4	4.0	3.0	4.0
Konno procedure	11.0	4	4.0	3.0	4.0
Congenitally corrected TGA repair, Atrial switch and Rastelli	11.0	4	4.0	3.0	4.0
Congenitally corrected TGA repair, VSD closure and LV to PA conduit	11.0	4	4.0	3.0	4.0
Arterial switch operation (ASO) and VSD repair	11.0	4	4.0	3.0	4.0
REV	11.0	4	4.0	3.0	4.0

DOLV repair	11.0	4	4.0	3.0	4.0
Aortic dissection repair	11.0	4	4.0	3.0	4.0
TAPVC repair + Shunt - Systemic to pulmonary	11.0	4	4.0	3.5	3.5
Pulmonary atresia - VSD - MAPCA repair, Status post prior incomplete unifocalization (includes completion of pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	11.0	4	4	3.5	3.5
Pulmonary atresia - VSD - MAPCA repair, Complete single stage repair (1-stage that includes bilateral pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	11.5	4	4.5	3.5	3.5
Arterial switch procedure + Aortic arch repair	11.5	4	4.0	3.5	4.0
Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve	11.5	4	4.5	3.0	4.0
Fontan + Atrioventricular valvuloplasty	11.5	4	4.0	3.5	4.0
Pulmonary venous stenosis repair	12.0	4	4.0	4.0	4.0
Partial left ventriculectomy (LV volume reduction surgery) (Batista)	12.0	4	4.0	4.0	4.0
Transplant, Lung(s)	12.0	4	4.0	4.0	4.0
Aortic root translocation over left ventricle (Including Nikaidoh procedure)	12.0	4	3.0	4.0	5.0
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross procedure	12.0	4	4.0	3.5	4.5
Ross–Konno procedure	12.5	4	4.5	3.0	5.0
Fontan revision or conversion (Re-do Fontan)	12.5	4	4.0	4.0	4.5
Arterial switch procedure and VSD repair + Aortic arch repair	13.0	4	4.5	4.0	4.5
Hybrid Approach “Stage 2”, Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)	13.0	4	4.0	4.5	4.5
Transplant, Heart and lung(s)	13.3	4	4.0	5.0	4.3
Congenitally corrected TGA repair, Atrial Switch and ASO (Double switch)	13.8	4	5.0	3.8	5.0
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross-Konno procedure	14.0	4	4.5	4.5	5.0
Conduit insertion right ventricle to pulmonary artery + Intraventricular tunnel left ventricle to neoaorta + Arch reconstruction (Rastelli and Norwood type arch reconstruction) (Yasui)	14.5	4	5	4.5	5
Norwood procedure	14.5	4	5.0	4.5	5.0
HLHS biventricular repair	15.0	4	5.0	5.0	5.0
Truncus + Interrupted aortic arch repair (IAA) repair	15.0	4	5.0	5.0	5.0

Interventional cardiology or not eligible (intentionally excluded from Aristotle) procedures:
ASD repair, Device
VSD repair, Device
PDA closure, Device
ASD creation, Balloon septostomy (BAS) (Rashkind)
ASD creation, Blade septostomy
Balloon dilation
Stent placement
Device closure
RF ablation
Coil embolization
Pulmonary AV fistula repair/occlusion
TGA, Other procedures (Kawashima, LV-PA conduit, other)
Cardiovascular catherization procedure, Therapeutic
Echocardiography procedure, Sedated transesophageal echocardiogram
Echocardiography procedure, Sedated transthoracic echocardiogram
Non-cardiovascular, non-thoracic procedure on cardiac patient with cardiac anesthesia
Radiology procedure on cardiac patient, Cardiac Computerized Axial Tomography (CT Scan)
Radiology procedure on cardiac patient, Cardiac Magnetic Resonance Imaging (MRI)
Radiology procedure on cardiac patient, Diagnostic radiology
Radiology procedure on cardiac patient, Non-Cardiac Computerized Tomography (CT) on cardiac patient
Radiology procedure on cardiac patient, Non-Cardiac Magnetic Resonance Imaging (MRI) on cardiac patient
Radiology procedure on cardiac patient, Therapeutic radiology
Cardiovascular catherization procedure, Diagnostic
Cardiovascular catherization procedure, Diagnostic, Hemodynamic data obtained
Cardiovascular catherization procedure, Diagnostic, Angiographic data obtained
Cardiovascular catherization procedure, Diagnostic, Transluminal test occlusion
Cardiovascular catherization procedure, Diagnostic, Hemodynamic alteration
Cardiovascular catherization procedure, Diagnostic, Electrophysiology alteration
Cardiovascular catherization procedure, Therapeutic, Septostomy
Cardiovascular catherization procedure, Therapeutic, Balloon valvotomy
Cardiovascular catherization procedure, Therapeutic, Stent re-dilation
Cardiovascular catherization procedure, Therapeutic, Perforation (establishing interchamber and/or intervessel communication)
Cardiovascular catherization procedure, Therapeutic, Transcatheter Fontan completion
Cardiovascular catherization procedure, Therapeutic, Transcatheter implantation of valve
Cardiovascular catherization procedure, Therapeutic Adjunctive therapy
Cardiovascular electophysiological catheterization procedure
Cardiovascular electophysiological catheterization procedure, Therapeutic ablation

Other miscellaneous, not scored:
(Either too vague or not a primary procedure)
Atrial baffle procedure, NOS
VSD repair, NOS
Valve surgery, Other, Tricuspid
Valve surgery, Other, Pulmonic
Valve surgery, Other, Mitral
Valve surgery, Other, Aortic
Tracheal procedure
TOF repair, NOS
Thoracotomy, Other
Thoracic and/or mediastinal procedure, Other
TGA, Other procedures (Nikaidoh, Kawashima, LV-PA conduit, other)
Shunt, Systemic to pulmonary, Other
Shunt, Systemic to pulmonary, NOS
Pleural procedure, Other
Peripheral vascular procedure, Other
Pericardial procedure, Other
PDA closure, NOS
Palliation, Other
PA, reconstruction (plasty), NOS
Other
Organ procurement
Miscellaneous procedure, Other
Mediastinal procedure
Fontan, TCPC, Lateral tunnel, NOS
Fontan, Other
Fontan, NOS
Esophageal procedure
DORV repair, NOS
Diaphragm procedure, Other
Coronary artery procedure, Other
Congenitally corrected TGA repair, Other

Congenitally corrected TGA repair, NOS
Conduit placement, NOS
Coarctation repair, Other
Coarctation repair, NOS
Cardiotomy, Other
Cardiac procedure, Other
AVC (AVSD) repair, NOS
ASD repair, NOS
Arrhythmia surgery, NOS
Other annular enlargement procedure
Fontan, TCPC, External conduit, NOS
VATS (video assisted thoracoscopic surgery)
Minimally invasive procedure
Bypass for non-cardiac lesion
Valve replacement, Aortic

Table 2: The Risk Adjustment for Congenital Heart Surgery (RACHS-1) Categories (October 24, 2014)

Procedure	RACHS-1 Category
Aortopexy	1
ASD partial closure	1
ASD repair, Patch	1
ASD repair, Patch + PAPVC repair	1
ASD repair, Primary closure	1
Atrial fenestration closure	1
PAPVC repair	1
PAPVC Repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	1
PAPVC, Scimitar, Repair	1
PFO, Primary closure	1
Aneurysm, Ventricular, Right, Repair	2
Aortic stenosis, Subvalvar, Repair	2
AP window repair	2
ASD, Common atrium (single atrium), Septation	2
AVC (AVSD) repair, Partial (Incomplete) (PAVSD)	2
Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)	2
Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)	2
Coronary artery fistula ligation	2
DCRV repair	2
Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)	2
Hemifontan	2
Kawashima operation (superior cavopulmonary connection in setting of interrupted IVC with azygous continuation)	2
Ligation, Pulmonary artery	2
PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)	2
PA, reconstruction (plasty), Branch, Peripheral (at or beyond the hilar bifurcation)	2
PA, reconstruction (plasty), Main (trunk)	2
PA, reconstruction (plasty), NOS	2
Pulmonary artery sling repair	2
RVOT procedure	2
Sinus of Valsalva, Aneurysm repair	2
Superior cavopulmonary anastomosis(es) + PA reconstruction	2
TOF repair, No ventriculotomy	2
TOF repair, Ventriculotomy, Nontransanular patch	2
TOF repair, Ventriculotomy, Transanular patch	2
Valve replacement, Pulmonic (PVR)	2
Valve surgery, Other, Pulmonic	2
Valvuloplasty converted to valve replacement in the same operation, Pulmonic	2
Valvuloplasty, Pulmonic	2
Vascular ring repair	2
VSD repair, Patch	2
VSD repair, Primary closure	2
VSD, Multiple, Repair	2
Aortic aneurysm repair	3
Aortic arch repair + VSD repair	3
Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS	3
Aortic stenosis, Supravalvar, Repair	3
Arterial switch operation (ASO)	3
Atrial baffle procedure (non-Mustard, non-Senning)	3
Atrial baffle procedure, Mustard or Senning revision	3
Atrial baffle procedure, NOS	3
Atrial baffle procedure, NOS	3
AVC (AVSD) repair, Complete (CAVSD)	3
AVC (AVSD) repair, Intermediate (Transitional)	3
Cardiac tumor resection	3
Coarctation repair + VSD repair	3
Conduit placement, LV to PA	3
Conduit placement, RV to PA	3
Cor triatriatum repair	3
DORV repair, NOS	3
DORV, Intraventricular tunnel repair	3
Fontan + Atrioventricular valvuloplasty	3
Fontan, Atrio-pulmonary connection	3
Fontan, Atrio-ventricular connection	3
Fontan, NOS	3
Fontan, Other	3
Fontan, TCPC, External conduit, Fenestrated	3
Fontan, TCPC, External conduit, Nonfenestrated	3
Fontan, TCPC, External conduit, NOS	3
Fontan, TCPC, Intra/extracardiac conduit, Nonfenestrated	3
Fontan, TCPC, Intra/extracardiac conduit, Fenestrated	3
Fontan, TCPC, Lateral tunnel, Fenestrated	3
Fontan, TCPC, Lateral tunnel, Nonfenestrated	3
Fontan, TCPC, Lateral tunnel, NOS	3
Hybrid Approach “Stage 1”, Application of RPA and LPA bands	3
Hybrid Approach “Stage 1”, Stent placement in arterial duct (PDA) + application of RPA and LPA bands	3
Mustard	3
PA banding (PAB)	3
Pulmonary artery origin from ascending aorta (hemitruncus) repair	3
Pulmonary atresia - VSD - MAPCA repair	3
Pulmonary atresia - VSD - MAPCA repair, Complete single stage repair (1-stage that includes bilateral pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	3
Pulmonary atresia - VSD - MAPCA repair, Status post prior complete unifocalization (includes VSD closure + RV to PA connection [with or without conduit])	3
Pulmonary atresia - VSD - MAPCA repair, Status post prior incomplete unifocalization (includes completion of pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	3

Pulmonary atresia - VSD (including TOF, PA) repair	3
Ross procedure	3
Senning	3
Shunt, Systemic to pulmonary, Central (from aorta or to main pulmonary artery)	3
Shunt, Systemic to pulmonary, Central (shunt from aorta), Central shunt with an end-to-side connection between the transected main pulmonary artery and the side of the ascending aorta (i.e. Mee shunt)	3
Shunt, Systemic to pulmonary, Modified Blalock-Taussig Shunt (MBTS)	3
Shunt, Systemic to pulmonary, NOS	3
Shunt, Systemic to pulmonary, Other	3
Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty	3
Valve closure, Semilunar	3
Valve excision, Tricuspid (without replacement)	3
Valve replacement, Aortic (AVR)	3
Valve replacement, Aortic (AVR), Bioprosthetic	3
Valve replacement, Aortic (AVR), Homograft	3
Valve replacement, Aortic (AVR), Mechanical	3
Valve replacement, Mitral (MVR)	3
Valve replacement, Tricuspid (TVR)	3
Valve surgery, Other, Aortic	3
Valve surgery, Other, Mitral	3
Valve surgery, Other, Tricuspid	3
Valvuloplasty converted to valve replacement in same operation, Tricuspid	3
Valvuloplasty converted to valve replacement in the same operation, Aortic	3
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross procedure	3
Valvuloplasty converted to valve replacement in the same operation, Mitral	3
Valvuloplasty, Mitral	3
Valvuloplasty, Tricuspid	3
Aortic arch repair	4
Arterial switch operation (ASO) and VSD repair	4
ASD creation/enlargement	4
Conduit insertion right ventricle to pulmonary artery + Intraventricular tunnel left ventricle to neoaorta + Arch reconstruction (Rastelli and Norwood type arch reconstruction) (Yasui)	4
Congenitally corrected TGA repair, Atrial switch and ASO (double switch)	4
Interrupted aortic arch repair	4
Konno procedure	4
Rastelli	4
Truncus arteriosus repair	4
Unifocalization MAPCA(s)	4
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross-Konno procedure	4
VSD creation/enlargement	4
Truncus + Interrupted aortic arch repair (IAA) repair	5
Damus-Kaye-Stansel procedure (DKS) (creation of AP anastomosis without arch reconstruction)	6
Hybrid Approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)	6
Norwood procedure	6
Coarctation repair, End to end	1 if > 30d, 2 if <= 30d
Coarctation repair, End to end, Extended	1 if > 30d, 2 if <= 30d
Coarctation repair, Interposition graft	1 if > 30d, 2 if <= 30d
Coarctation repair, NOS	1 if > 30d, 2 if <= 30d

Coarctation repair, Other	1 if > 30d, 2 if <= 30d
Coarctation repair, Patch aortoplasty	1 if > 30d, 2 if <= 30d
Coarctation repair, Subclavian flap	1 if > 30d, 2 if <= 30d
PDA closure, Surgical	1 if > 30d, not eligible if <= 30d
TAPVC repair	2 if > 30d, 4 if <= 30d
Valvuloplasty, Aortic	2 if > 30d, 4 if <= 30d
Ebstein's repair	3 if > 30d, 5 if <= 30d
TAPVC repair + Shunt - Systemic to pulmonary	3 if age >30 days, 4 if age <=30 days

Other, Not Categorized (Eligible, but not assigned a category)

1 1/2 ventricular repair
Aneurysm, Pulmonary artery, Repair
Aneurysm, Ventricular, Left, Repair
Anomalous origin of coronary artery from pulmonary artery repair
Anomalous systemic venous connection repair
Aortic root replacement
Aortic root replacement, Bioprosthetic
Aortic root replacement, Homograft
Aortic root replacement, Mechanical
Aortic root replacement, Valve sparing
Aortic root translocation over left ventricle (Including Nikaidoh procedure)
Arterial switch procedure + Aortic arch repair
Arterial switch procedure and VSD repair + Aortic arch repair
Atrial septal fenestration
AVC (AVSD) repair, NOS
Conduit placement, NOS
Conduit placement, Other
Conduit placement, Ventricle to aorta
Conduit reoperation
Congenitally corrected TGA repair, Atrial switch and Rastelli
Congenitally corrected TGA repair, NOS
Congenitally corrected TGA repair, Other
Congenitally corrected TGA repair, VSD closure
Congenitally corrected TGA repair, VSD closure and LV to PA conduit
Coronary artery bypass
Coronary artery procedure, Other
DOLV repair
Fontan revision or conversion (Re-do Fontan)
HLHS biventricular repair
Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA)
Hybrid Approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair
LV to aorta tunnel repair
Mitral stenosis, Supravalvar mitral ring repair
Occlusion MAPCA(s)
Other annular enlargement procedure
PA debanding
Partial left ventriculectomy (LV volume reduction surgery) (Batista)
Pulmonary AV fistula repair/occlusion
Pulmonary embolectomy
Pulmonary embolectomy, Acute pulmonary embolus
Pulmonary embolectomy, Chronic pulmonary embolus
Pulmonary venous stenosis repair
REV
Ross-Konno procedure
Shunt, Ligation and takedown
Systemic venous stenosis repair
TGA, Other procedures (Kawashima, LV-PA conduit, other)
TGA, Other procedures (Nikaidoh, Kawashima, LV-PA conduit, other)
TOF - AVC (AVSD) repair
TOF - Absent pulmonary valve repair
TOF repair, NOS
TOF repair, RV-PA conduit
Valve closure, Tricuspid (exclusion, univentricular approach)
Valve excision, Pulmonary (without replacement)
Valve replacement, Common atrioventricular valve
Valve replacement, Truncal valve
Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve
Valvuloplasty converted to valve replacement in the same operation, Truncal valve

Valvuloplasty, Common atrioventricular valve
Valvuloplasty, Truncal valve
Ventricular septal fenestration
Ventricular septation
Hepatic vein to azygous vein connection, Direct
Hepatic vein to azygous vein connection, Interposition Graft
Hybrid Approach, Transcardiac balloon dilation
Hybrid Approach, Transcardiac transcatheter device Placement
Intravascular stent removal
Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Complete unifocalization (all usable MAPCA[s] are incorporated)
Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Incomplete unifocalization (not all usable MAPCA[s] are incorporated)
Unifocalization MAPCA(s), Unilateral pulmonary Unifocalization

Other, Not Eligible (Intentionally excluded from RACHS-1)
Aortic dissection repair
Arrhythmia surgery - atrial, Surgical Ablation
Arrhythmia surgery - ventricular, Surgical Ablation
Arrhythmia surgery, NOS
ASD creation, Balloon septostomy (BAS) (Rashkind)
ASD creation, Blade septostomy
ASD repair, Device
ASD repair, NOS
Balloon dilation
Bronchoscopy
Bypass for noncardiac lesion
Cardiac procedure, Other
Cardiotomy, Other
Cardiovascular catherization procedure, Diagnostic
Cardiovascular catherization procedure, Diagnostic, Angiographic data obtained
Cardiovascular catherization procedure, Diagnostic, Electrophysiology alteration
Cardiovascular catherization procedure, Diagnostic, Hemodynamic alteration
Cardiovascular catherization procedure, Diagnostic, Hemodynamic data obtained
Cardiovascular catherization procedure, Diagnostic, Transluminal test occlusion
Cardiovascular catherization procedure, Therapeutic
Cardiovascular catherization procedure, Therapeutic Adjunctive therapy
Cardiovascular catherization procedure, Therapeutic, Balloon valvotomy
Cardiovascular catherization procedure, Therapeutic, Perforation (establishing interchamber and/or intervessel communication)
Cardiovascular catherization procedure, Therapeutic, Septostomy
Cardiovascular catherization procedure, Therapeutic, Stent re-dilation
Cardiovascular catherization procedure, Therapeutic, Transcatheter Fontan completion
Cardiovascular catherization procedure, Therapeutic, Transcatheter implantation of valve
Cardiovascular electophysiological catheterization procedure
Cardiovascular electophysiological catheterization procedure, Therapeutic ablation
Coil embolization
Decortication
Delayed sternal closure
Device closure
Diaphragm plication
Diaphragm procedure, Other
Echocardiography procedure, Sedated transesophageal echocardiogram
Echocardiography procedure, Sedated transthoracic echocardiogram
ECMO cannulation
ECMO decannulation
ECMO procedure
Esophageal procedure
Explantation of pacing system
ICD (AICD) ([automatic] implantable cardioverter defibrillator) procedure
ICD (AICD) implantation
Intraaortic balloon pump (IABP) insertion
Ligation, Thoracic duct
Lung biopsy
Lung procedure, Other
Mediastinal exploration
Mediastinal procedure
Minimally invasive procedure
Miscellaneous procedure, Other
Non-cardiovascular, non-thoracic procedure on cardiac patient with cardiac anesthesia
Organ procurement
Other procedure
Pacemaker implantation, Permanent
Pacemaker procedure

Palliation, Other
PDA closure, Device
PDA closure, NOS
Pectus repair
Pericardial drainage procedure
Pericardial procedure, Other
Pericardiectomy
Peripheral vascular procedure, Other
Pleural drainage procedure
Pleural procedure, Other
Radiology procedure on cardiac patient, Cardiac Computerized Axial Tomography (CT Scan)
Radiology procedure on cardiac patient, Cardiac Magnetic Resonance Imaging (MRI)
Radiology procedure on cardiac patient, Diagnostic radiology
Radiology procedure on cardiac patient, Non-Cardiac Computerized Tomography (CT) on cardiac patient
Radiology procedure on cardiac patient, Non-Cardiac Magnetic Resonance Imaging (MRI) on cardiac patient
Radiology procedure on cardiac patient, Therapeutic radiology
RF ablation
Right/left heart assist device procedure
Stent placement
Sternotomy wound drainage
Thoracic and/or mediastinal procedure, Other
Thoracotomy, Other
Tracheal procedure
Transplant, Heart
Transplant, Heart and lung
Transplant, lung(s)
VAD explantation
VAD implantation
VATS (video-assisted thoracoscopic surgery)
VSD repair, Device
VSD repair, NOS

Table 3: The Society of Thoracic Surgeons - European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories (STAT Mortality Categories) (November 27, 2016)

Data version 3.22 Procedure	Procedure	STAT Mortality Score	STAT Mortality Category
30	ASD repair, Patch	0.1	1
190	AVC (AVSD) repair, Partial (Incomplete) (PAVSD)	0.1	1
10	PFO, Primary closure	0.2	1
20	ASD repair, Primary closure	0.2	1
110	VSD repair, Patch	0.2	1
570	DCRV repair	0.2	1
780	Aortic stenosis, Subvalvar, Repair	0.2	1
1210	Coarctation repair, End to end	0.2	1
1360	Vascular ring repair	0.2	1
1470	ICD (AICD) implantation	0.2	1
1480	ICD (AICD) ([automatic] implantable cardioverter defibrillator) procedure	0.2	1
**2110	ASD Repair, Patch + PAPCV Repair	0.2	1
100	VSD repair, Primary closure	0.3	1
180	AVC (AVSD) repair, Intermediate (Transitional)	0.3	1
260	PAPVC repair	0.3	1
350	TOF repair, No ventriculotomy	0.3	1
360	TOF repair, Ventriculotomy, Nontransanular patch	0.3	1
580	Conduit reoperation	0.3	1
600	Valve replacement, Pulmonic (PVR)	0.3	1
680	Valve replacement, Aortic (AVR), Mechanical	0.3	1
690	Valve replacement, Aortic (AVR), Bioprosthetic	0.3	1
810	Sinus of Valsalva, Aneurysm repair	0.3	1

970	Fontan, TCPC, Lateral tunnel, Fenestrated	0.3	1
1250	Coarctation repair, Interposition graft	0.3	1
1460	Pacemaker procedure	0.3	1
1680	Glenn (Unidirectional cavopulmonary anastomosis) (Unidirectional Glenn)	0.3	1
*2120	PAPVC Repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	0.3	1
520	1 1/2 ventricular repair	0.4	2
530	PA, Reconstruction (Plasty), Main (Trunk)	0.4	2
660	Valvuloplasty, Aortic	0.4	2
740	Ross procedure	0.4	2
820	LV to aorta tunnel repair	0.4	2
830	Valvuloplasty, Mitral	0.4	2
950	Fontan, Atrio-pulmonary connection	0.4	2
1330	PDA closure, Surgical	0.4	2
1365	Aortopexy	0.4	2
1450	Pacemaker implantation, Permanent	0.4	2
1500	Arrhythmia surgery - ventricular, Surgical Ablation	0.4	2
1690	Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (Bilateral bidirectional Glenn)	0.4	2
***2130	Superior Cavopulmonary anastomosis(es) + PA reconstruction	0.4	2
210	AP window repair	0.5	2
370	TOF repair, Ventriculotomy, Transanular patch	0.5	2
510	RVOT procedure	0.5	2
590	Valvuloplasty, Pulmonic	0.5	2
620	Conduit placement, LV to PA	0.5	2
715	Aortic root replacement, Bioprosthetic	0.5	2
720	Aortic root replacement, Mechanical	0.5	2
790	Aortic stenosis, Supravalvar, Repair	0.5	2
930	Pericardiectomy	0.5	2
1070	Congenitally corrected TGA repair, VSD closure	0.5	2
1220	Coarctation repair, End to end, Extended	0.5	2
1291	Anomalous origin of coronary artery from pulmonary artery repair	0.5	2
1380	Aortic aneurysm repair	0.5	2
1670	Bidirectional cavopulmonary anastomosis (BDCPA) (Bidirectional Glenn)	0.5	2
1730	Aneurysm, Ventricular, Left, Repair	0.5	2
1772	Conduit placement, Other	0.5	2
****2760	Hybrid Approach, Transcardiac balloon dilation	0.5	2
*2350	Explantation of pacing system	0.5	2
50	ASD, Common atrium (Single atrium), Septation	0.6	2
220	Pulmonary artery origin from ascending aorta (Hemitruncus) repair	0.6	2
270	PAPVC, Scimitar, Repair	0.6	2
735	Aortic root replacement, Valve sparing	0.6	2
840	Mitral stenosis, Supravalvar mitral ring repair	0.6	2
1000	Fontan, TCPC, External conduit, Fenestrated	0.6	2
1010	Fontan, TCPC, External conduit, Nonfenestrated	0.6	2
1290	Coronary artery fistula ligation	0.6	2
1790	Ligation, Pulmonary artery	0.6	2
****2770	Hybrid Approach, Transcardiac transcatheter device Placement	0.6	2
****2780	Fontan, TCPC, Intra/extracardiac conduit, Fenestrated	0.6	2
****2790	Fontan, TCPC, Intra/extracardiac conduit, Nonfenestrated	0.6	2
****3160	Kawashima operation (superior cavopulmonary connection in setting of interrupted IVC with azygous continuation)	0.6	2

****3180	Intravascular stent removal	0.6	2
*1305	Anomalous aortic origin of coronary artery from aorta (AAOCA) repair	0.6	2
*2100	Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS	0.6	2
*2270	Valvuloplasty converted to valve replacement in the same operation, Pulmonic	0.6	2
*****3310	Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Fenestrated	0.6	2
*****3320	Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Nonfenestrated	0.6	2
85	Atrial fenestration closure	0.7	2
130	VSD, Multiple, Repair	0.7	2
250	Valve replacement, Truncal valve	0.7	2
290	Cor triatriatum repair	0.7	2
310	Atrial baffle procedure (Non-Mustard, Non-Senning)	0.7	2
340	Systemic venous stenosis repair	0.7	2
380	TOF repair, RV-PA conduit	0.7	2
460	Valvuloplasty, Tricuspid	0.7	2
470	Valve replacement, Tricuspid (TVR)	0.7	2
550	PA, Reconstruction (Plasty), Branch, Peripheral (At or beyond the hilar bifurcation)	0.7	2
910	Partial left ventriculectomy (LV volume reduction surgery) (Batista)	0.7	2
980	Fontan, TCPC, Lateral tunnel, Nonfenestrated	0.7	2
1230	Coarctation repair, Subclavian flap	0.7	2
1490	Arrhythmia surgery - atrial, Surgical Ablation	0.7	2
****3140	Hepatic vein to azygous vein connection, Direct	0.7	2
****3150	Hepatic vein to azygous vein connection, Interposition Graft	0.7	2
*2240	Valvuloplasty converted to valve replacement in the same operation, Aortic	0.7	2
*****3210	Removal of transcatheter delivered device from blood vessel	0.7	2
150	Ventricular septal fenestration	0.8	3
170	AVC (AVSD) repair, Complete (CAVSD)	0.8	3
240	Valvuloplasty, Truncal valve	0.8	3
330	Anomalous systemic venous connection repair	0.8	3
450	Occlusion MAPCA(s)	0.8	3
540	PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)	0.8	3
750	Konno procedure	0.8	3
1110	Arterial switch operation (ASO)	0.8	3
1240	Coarctation repair, Patch aortoplasty	0.8	3
1410	Transplant, Lung(s)	0.8	3
1630	Shunt, Ligation and takedown	0.8	3
1700	Hemifontan	0.8	3
1720	Aneurysm, Ventricular, Right, Repair	0.8	3
1740	Aneurysm, Pulmonary artery, Repair	0.8	3
**1275	Coarctation repair + VSD repair	0.8	3
*2280	Valvuloplasty converted to valve replacement in same operation, Tricuspid	0.8	3
*****3220	Removal of transcatheter delivered device from heart	0.8	3
70	ASD partial closure	0.9	3
960	Fontan, Atrio-ventricular connection	0.9	3
1150	Rastelli	0.9	3
1774	Conduit placement, Ventricle to aorta	0.9	3
1802	Pulmonary embolectomy, Acute pulmonary embolus	0.9	3
700	Valve replacement, Aortic (AVR), Homograft	1	3
*2290	Valvuloplasty converted to valve replacement in the same operation, Truncal valve	1	3
420	Pulmonary atresia - VSD (including TOF, PA) repair	1.1	3
1140	Mustard	1.1	3

1160	REV	1.1	3
1370	Pulmonary artery sling repair	1.1	3
610	Conduit placement, RV to PA	1.2	3
1800	Pulmonary embolectomy	1.2	3
*2310	Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross procedure	1.2	3
*2340	Fontan + Atrioventricular valvuloplasty	1.2	3
*****1145	Atrial baffle procedure, Mustard or Senning revision	1.2	3
850	Valve replacement, Mitral (MVR)	1.3	4
920	Pericardial drainage procedure	1.3	4
****2750	Unifocalization MAPCA(s), Unilateral pulmonary Unifocalization	1.3	4
*2260	Valvuloplasty converted to valve replacement in the same operation, Mitral	1.3	4
*2300	Valvuloplasty, Common atrioventricular valve	1.3	4
890	Transplant, Heart	1.4	4
1025	Fontan revision or conversion (Re-do Fontan)	1.4	4
1180	DORV, Intraventricular tunnel repair	1.4	4
1200	DOLV repair	1.4	4
1280	Aortic arch repair	1.4	4
1650	PA debanding	1.4	4
1760	Cardiac tumor resection	1.4	4
**1120	Arterial switch operation (ASO) and VSD repair	1.4	4
**1123	Arterial switch procedure + Aortic arch repair	1.4	4
*2330	Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty	1.4	4
400	TOF - Absent pulmonary valve repair	1.5	4
490	Valve excision, Tricuspid (Without replacement)	1.5	4
1300	Coronary artery bypass	1.5	4
1590	Shunt, Systemic to pulmonary, Modified Blalock-Taussig shunt (MBTS)	1.5	4
****2740	Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Incomplete unifocalization (not all usable MAPCA[s] are incorporated)	1.5	4
*****3200	PA band adjustment	1.5	4
390	TOF - AVC (AVSD) repair	1.6	4
465	Ebstein's repair	1.6	4
760	Ross-Konno procedure	1.6	4
1130	Senning	1.6	4
****2730	Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Complete unifocalization (all usable MAPCA[s] are incorporated)	1.6	4
****3130	Shunt, Systemic to pulmonary, Central (shunt from aorta), Central shunt with an end-to-side connection between the transected main pulmonary artery and the side of the ascending aorta (i.e. Mee shunt)	1.6	4
430	Pulmonary atresia - VSD - MAPCA repair	1.7	4
440	Unifocalization MAPCA(s)	1.7	4
730	Aortic root replacement, Homograft	1.7	4
1080	Congenitally corrected TGA repair, VSD closure and LV to PA conduit	1.7	4
1390	Aortic dissection repair	1.7	4
1640	PA banding (PAB)	1.7	4
****2710	Pulmonary atresia - VSD - MAPCA repair, Status post prior complete unifocalization (includes VSD closure + RV to PA connection [with or without conduit])	1.7	4
**1285	Aortic arch repair + VSD repair	1.7	4
140	VSD creation/enlargement	1.8	4
280	TAPVC repair	1.9	4
880	HLHS biventricular repair	1.9	4
*2230	Valve replacement, Common atrioventricular valve	1.9	4
*2250	Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular	1.9	4

*2320	Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross-Konno procedure	1.9	4
300	Pulmonary venous stenosis repair	2	4
*****3230	Shunt, Systemic to pulmonary, Potts – Smith type (descending aorta to pulmonary artery)	2	4
1320	Interrupted aortic arch repair	2.1	4
1600	Shunt, Systemic to pulmonary, Central (From aorta or to main pulmonary artery)	2.1	4
****2720	Pulmonary atresia - VSD - MAPCA repair, Status post prior incomplete unifocalization (includes completion of pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	2.1	4
****2700	Pulmonary atresia - VSD - MAPCA repair, Complete single stage repair (1-stage that includes bilateral pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	2.3	4
230	Truncus arteriosus repair	2.4	4
**1125	Arterial switch procedure and VSD repair + Aortic arch repair	2.4	4
*2190	Aortic root translocation over left ventricle (Including Nikaidoh procedure)	2.4	4
*2210	TGA, Other procedures (Kawashima, LV-PA conduit, other)	2.4	4
60	ASD creation/enlargement	2.5	4
*2170	Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA)	2.5	4
80	Atrial septal fenestration	2.6	4
480	Valve closure, Tricuspid (Exclusion, Univentricular approach)	2.6	4
*2160	Hybrid Approach "Stage 1", Application of RPA and LPA bands	2.6	4
1660	Damus-Kaye-Stansel procedure (DKS) (Creation of AP anastomosis without arch reconstruction)	2.9	5
*2200	TAPVC repair + Shunt - Systemic to pulmonary	3	5
*2180	Hybrid Approach "Stage 1", Stent placement in arterial duct (PDA) + application of RPA and	3.1	5
900	Transplant, Heart and lung	3.2	5
1060	Congenitally corrected TGA repair, Atrial switch and Rastelli	3.2	5
1050	Congenitally corrected TGA repair, Atrial switch and ASO (Double switch)	3.4	5
****2755	Conduit insertion right ventricle to pulmonary artery + Intraventricular tunnel left ventricle to neoaorta + Arch reconstruction (Rastelli and Norwood type arch reconstruction) (Yasui)	3.6	5
*2150	Hybrid approach "Stage 2", Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair	3.6	5
870	Norwood procedure	4	5
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)	4.1	5
**2220	Truncus + IAA Repair	5	5

*Indicates that this Procedure, Score, and Category were not included in the original JTCVS publication[6] but were subsequently assigned as part of the upgrade to version 3.0. The original list of procedure codes was based on Version 2.5 of the STS Congenital Heart Surgery Database. These additional procedures represent the list of new procedure codes that were added to The STS Congenital Heart Surgery Database in 2010 as part of the upgrade to version 3.0, and have also been incorporated into The EACTS Congenital Heart Surgery Database, and The Japan Congenital Cardiovascular Surgery Database (JCCVSD). To assign scores to these new procedures, a panel of highly experienced congenital heart surgeons from programs representing a variety of programmatic volume categories were surveyed and asked to provide an STS-EACTS Mortality Score for 26 procedures that were new to version 3.0, using the scores in the Table of the JTCVS article[6] as a guide. The mean of the scores from these ten surgeons was then used to assign the STS-EACTS Mortality Score and STS-EACTS Mortality Category for these 26 new procedures. (When the highest and lowest scores were discarded, the scores were essentially the same. [9/23 scores did not change, 13/23 scores change by only 0.1, and 1/23 scores change by 0.2]).

**Indicates a combined procedure (made up of two or more component procedures).

***Indicates a combined procedure and also a procedure for which the Score and Category were not part of the original JTCVS publication[6] and were assigned later as described above.

****Indicates that this Procedure, Score, and Category were not included in the original JTCVS publication [6] but were subsequently assigned as part of the upgrade to version 3.22. The original list of procedure codes was based on Version 2.5 of the STS Congenital Heart Surgery Database. These additional procedures represent the list of new procedure codes that were added to The STS Congenital Heart Surgery Database in 2014 as part of the upgrade to version 3.22, and have also been incorporated into The EACTS Congenital Heart Surgery Database, and The Japan Congenital Cardiovascular Surgery Database (JCCVSD). To assign scores to these new procedures, a panel of highly experienced congenital heart surgeons from programs representing a variety of programmatic volume categories were surveyed and asked to provide an STS-EACTS Mortality Score for 16 procedures that were new to version 3.22, using the STAT scores provided in the STS Congenital Heart Surgery Database Spring 2014 Feedback Report as a guide. The mean of the scores from these seventeen surgeons was then used to assign the STS-EACTS Mortality Score and STS-EACTS Mortality Category for these 16 new procedures. (When the high and low scores were discarded, the STAT Scores were essentially the same. [12/16 scores did not change and 4/16 scores change by only 0.1]; meanwhile, when the high and low scores were discarded, the STAT Categories were all unchanged.)

*****Indicates that this Procedure, Score, and Category were not included in the original JTCVS publication[6] but were subsequently assigned as part of the upgrade to version 3.3. The original list of procedure codes was based on Version 2.5 of the STS Congenital Heart Surgery Database. These additional procedures represent the list of new procedure codes that were added to The STS Congenital Heart Surgery Database in 2016 as part of the upgrade to version 3.3, and have also been incorporated into The EACTS Congenital Heart Surgery Database, and The Japan Congenital Cardiovascular Surgery Database (JCCVSD). To assign scores to these new procedures, a panel of highly experienced congenital heart surgeons from programs representing a variety of programmatic volume categories were surveyed and asked to provide an STS-EACTS Mortality Score for 7 procedures that were new to version 3.3, using the STAT scores provided in the STS Congenital Heart Surgery Database Spring 2016 Feedback Report as a guide. The mean of the scores from these seventeen surgeons was then used to assign the STS-EACTS Mortality Score and STS-EACTS Mortality Category for these 7 new procedures. (When the high and low scores were discarded, the STAT Scores were essentially the same.)

DEVELOPMENT AND USE OF AN EMPIRICALLY DERIVED MORBIDITY METRIC FOR CONGENITAL HEART SURGERY

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In comparison to acquired heart disease in adults, which includes ischemic heart disease, valvar heart disease and disorders affecting the aorta, congenital heart disease encompasses a broad spectrum of anomalies encompassing hundreds of distinct diagnoses and clinical entities. The armamentarium of congenital heart surgeons includes well over a hundred types of operative interventions, which ultimately are performed in a multitude of combinations. The goals of outcomes assessment and quality improvement are well served by the application of reliable metrics that reflect the differences in surgical case mix that exist across centers, and within a given center across periods of time. At any given center, the complexity of the patients seen and the operations performed in any given year is unlikely to be the same as the complexity of those managed during the preceding year, or in the following year, or at another center. Reporting of raw, unadjusted mortality data is misleading, as it fails to consider the
influence of high-risk patients and complex procedures. Early efforts to characterize case mix based on the estimated mortality risk of the operations performed were based largely on expert opinion.

When a large body of data had been collected through national and international registries, the leaders of congenital heart surgery database efforts in North America and in Europe collaborated to develop an empirically based tool for analyzing mortality associated with congenital heart surgery. Formulation of the STS–EACTS Congenital Heart Surgery Mortality Scores and Categories,1 now widely known as STAT Mortality Scores and Categories, became a possibility as a result of the use of a uniform set of data elements, standardized nomenclature and definitions, and systems for data verification.

But, even within the context of outcomes that can be measured within the temporal confines of a given episode of care, the description of outcomes and the formulation of inferences concerning performance and quality of case that are based exclusively on mortality versus survival is a very incomplete approach to a more complex challenge. It is fortunate that we have reached a point where more than 95% of patients who undergo surgical operations for congenital heart disease survive to hospital discharge and beyond. Therefore, it is clear that accounting not only for survival, but for other end points as well, is essential to measuring and understanding outcomes, and ultimately to measuring the effectiveness or “quality” of therapeutic approaches and of patient care. Nonfatal events, such as stroke and renal failure, are major determinants of hospital cost and of patients' health status after surgery. In addition, post-procedure length of hospital stay provides useful direct information about resource use and indirect proxy information about a patient's condition. It became apparent that the principles used in the development of the STAT Mortality metrics could be adapted for the development of an empirically-based Morbidity metric. The development of the STAT Morbidity Score and Categories was based on these objectives:

- to develop a morbidity metric that accounts for the occurrence of complications that have a significant and durable impact on the patient's health and also accounts for utilization of health care resources;
- to estimate the average amount of patient morbidity by procedure type;
- to convert these procedure-specific morbidity estimates into a scale ranging from 0.1 to 5.0 (that range having been chosen specifically for consistency with the STS-EACTS Mortality Score) to group procedures with similar estimated morbidity risk into 5 relatively homogeneous categories that are designed to minimize within-category variation and to serve as a stratification variable that can be used to describe and adjust for case mix when analyzing outcomes and comparing institutions.

Using data from 62,851 operations entered in the STS-CHS database in 2002 through 2008, procedural morbidity risk was estimated using a Bayesian model that adjusted for small denominators. Morbidity was quantified for each procedure on the basis of the proportion of patients experiencing major complications and of the average postoperative length of stay (PLOS) as a measure of resource utilization. Major complication was defined as the occurrence of any one or more of six specific complications (**Table 1**). These complications represent definitive outcomes that can be ascertained reliably and that are likely to have significant and durable impact on patient health.

Table 1. Major Complications: STS Congenital Heart Surgery Database

Complication Description (STS Congenital Heart Surgery Database code*)	Number (%) of Events**	Mortality N (%)
Postoperative acute renal failure requiring temporary or permanent dialysis (220 or 230)	705 (1.1%)	396 (56.2%)
Postoperative neurological deficit persisting at discharge (320)	500 (0.8%)	152 (30.4%)
Postoperative AV block requiring permanent pacemaker (60)	593 (0.9%)	28 (4.7%)
Postoperative mechanical circulatory support (IABP, VAD, ECMO or CPS) (40)	1110 (1.8%)	617 (55.6%)
Phrenic nerve injury/paralyzed diaphragm (300)	578 (0.9%)	35 (6.1%)
Unplanned reoperation. (20 or 240)	2942 (4.7%)	636 (21.6%)
Major Complication (defined as any one or more of the above)	5059 (8.0%)	1187 (23.5%)

*Complication codes in the STS Congenital Heart Surgery Database Data Collection Form, Version 2.50 [ref. STS Congenital Heart Surgery Database Version 2.50 Data Collection Form Annotated "(Updated 7/10/2006)".

[http://www.sts.org/sites/default/files/documents/pdf/DataCollectionForm250_07102006_Annotated.pdf]. Accessed March 18, 2014.]. ** Denominator is 62851 operations.
IABP= intra-aortic balloon pump, VAD= ventricular assist device, ECMO= extra-corporeal membrane oxygenation, CPS= cardiopulmonary support (Adapted from: Jacobs ML et al., An empirically based tool for analyzing morbidity associated with operations for congenital heart disease. J Thorac Cardiovasc Surg, 2013; 145:1046-57)

Table 2. Summary of STS Congenital Heart Surgery Morbidity Categories

	1	2	3	4	5
Number of procedures	36	43	36	21	4
Aggregate average postoperative length of stay (days)	6.3	11.3	15.2	22.3	34.0
Rate of major complications	3.2%	6.5%	11.9%	15.2%	30.0%

(Adapted from: Jacobs ML et al., An empirically based tool for analyzing morbidity associated with operations for congenital heart disease. J Thorac Cardiovasc Surg, 2013; 145:1046-57)

Importantly, a given operative procedure does not necessarily fall into the same category with respect to statistically estimated risk of morbidity as it does with respect to mortality. Morbidity Categories were the same as the Mortality Categories for only about one half of the 140 procedures (**Table 3**) supporting the need for a separate morbidity metric to compliment the STAT Mortality metric. While there is undoubtedly a complex relationship between morbidity and mortality, it is likewise clear that descriptive data regarding the likelihood of occurrence of morbidity and of mortality are not redundant. Hence, the consideration of both metrics helps to maximally inform any measure that is intended to describe case mix and facilitate reporting of risk-adjusted outcomes.

In a manner that is analogous to the use of the STAT Mortality metrics, the STAT Morbidity Scores and Categories have been widely used in outcomes research as a measure of case mix and/or a means of adjustment for procedural risk in investigations where the primary focus is on outcomes other than mortality. Examples include an investigation of occurrence of cardiac arrest and associated outcomes following in-hospital cardiac arrest after pediatric cardiac surgery operations,3 and a study of delayed sternal closure in infant heart surgery, which investigated potential associations between duration of sternum left open (SLO) and rate of infection complications, and evaluated the hypothesis that location of sternal closure may mitigate infection risk.4
Most recently, the principle elements of the STAT Morbidity Scores and Categories have been incorporated in the development of a Congenital Heart Surgery Composite Quality Metric.5,6 The composite measure is comprised of two domains: (1) a mortality domain (based on operative mortality), and (2) a morbidity domain (which encompasses the six major complications included in the STAT Morbidity metric plus cardiac arrest, as well as postoperative length of stay). Potential advantages of a composite, or multi-domain quality metric include the more comprehensive view of quality as compared with mortality alone and the potential for improvements in discrimination of hospital performance as a consequence of increasing the number of end points. It is anticipated that the new Congenital Heart Surgery Composite Quality Metric will be incorporated in the outcomes reporting of the STS-CHSD and potentially those of the ECHSA Database as well.

Table 3. Association between STS Congenital Heart Surgery Morbidity Categories and STAT Mortality Categories.

		Mortality Categories				
		1	**2**	**3**	**4**	**5**
Morbidity Categories	**1**	21	13	1	1	0
	2	5	26	10	2	0
	3	0	12	10	13	1
	4	0	0	3	15	3
	5	0	0	0	2	2

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RISK-ADJUSTMENT FOR CONGENITAL HEART SURGERY (RACHS-1)

Kathy Jenkins MD, MPH, and Kimberlee Gauvreau, DSc

Building off prior efforts to create a useful analytical framework for the diverse caseload operated on by pediatric cardiac surgeons (1,2), the Risk-Adjustment for Congenital Heart Surgery method (RACHS-1) was developed in 2002 using US federal funding to adjust for risk for in-hospital mortality after congenital heart surgery. Under the guidance of an expert panel and using a modified Delphi process, procedures for repair of congenital heart defects were grouped into six risk categories (3). Decisions about the placement of procedures into appropriate risk groups and about which additional clinical factors should be included were based on the judgment of the panel informed by data from two sources: administrative data from three states that approximated a diverse population-based sample, and the carefully curated data from the Pediatric Cardiac Care Consortium, a large multi-institutional quality improvement collaborative. Patients <18 years of age undergoing congenital heart operations mapped to a risk group were eligible, and the final model, including procedural risk group, age, prematurity and presence of a non-cardiac anomaly showed reasonable discrimination and calibration in both datasets.

RACHS was incorporated into reports from the Society for Thoracic Surgeons for a period of time (4), and more recently has been used to account for case mix differences in the International Quality Improvement Collaborative for Congenital Heart Disease Improving Care in Low and Middle Income Countries (5). RACHS was adapted by the Agency for Healthcare Research and Quality (AHRQ) for use as a pediatric quality indicator (PDI) using administrative data (www.qualityindicators.ahrq.gov/Modules/pdi_resources.aspx) and later harmonized with the original methodology as part of the ongoing National Quality Forum approval process. (6) Both the full RACHS model and the RACHS risk groups have been used extensively for research and quality improvement.

RACHS has multiple advantages that have led to its widespread use, most importantly incorporation of nearly all common types of congenital heart surgery, flexible adaptation to multiple data sources and coding systems, and parsimonious incorporation of only a few clinical factors that are typically well-captured by clinicians. RACHS is easy to understand and can be flexibly applied to allow current benchmarking with appropriate peer comparisons, or to allow a single center to track its own performance over time using a consistent external standard. RACHS can only be applied to eligible cases <18 years that are matched to a risk group (typically 85-95% of cases <18 years of age). The methodology was developed to account for short term in-hospital risk for groups of cases, and was not designed to account for different procedural strategies with short term versus long term risk tradeoffs, to predict risk accurately for individual cases, or to account for outcomes other than in-hospital mortality. RACHS risk category 5 contains fewer procedures than the other categories, and in smaller datasets is often combined with category 6 for display and analysis. Also, new procedures may not be assigned to a risk group. RACHS was developed with the assumption that variation in risk for specific procedures, such as pulmonary artery size for repair of Tetralogy of Fallot, are evenly distributed among centers, and the method will be limited in applications where this is not the case. Although RACHS can be used with administrative data, limitations in diagnostic and procedural information can further reduce discrimination.

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THE ARISTOTLE SCORE IN PERSPECTIVE

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In 2020, the STAT mortality score (1) is considered the most reliable system to predict mortality, due to the considerable amount of real data accumulated in the STS and EACTS/ECHSA congenital heart surgery database (CHSD). Historically, in the early 2000, the Aristotle Score (2) and the RACHS-1 (3) scores were created. Both methods were strictly based on expert opinion. They proved both to be efficient to predict mortality and were rapidly introduced in the STS and EACTS/ECHSA CHSD. This allowed a rapid growth of the US and European congenital databases who could receive data, because the centers were not anymore concerned to be judged only on their mortality. Finally, in 2009, enough data were present in the congenital databases, and the STS committee could develop the STAT Mortality (1) and Morbidity (4) Scores based only on true real data harvested by the STS and EACTS.

Predictability and Performance are two different entities. Assessing Performance of centers is the “Holy Grail” of evaluation of quality of care. It is particularly challenging in Congenital Heart Surgery (CHS) because there are around ten times more surgical procedures than in adult cardiac surgery, with important variation of complexity within the same procedure. The attempt made by the STS CHSD to copy the adult system of Performance in using the one to three stars model has failed. Since 2020, the 3 stars graphic system was removed from the STS CHSD (5). The Congenital Heart Surgeons Society (CHSS) is developing, along with other sister scientific societies, a new model of evaluation of Performance in CHS. It is clearly the right time for the Europeans Pediatric Cardiac Surgeons and the ECHSA to contribute to this new model.

STAT, RACHS-1 (5) are good predictors of mortality but they don’t deal with Performance. The Aristotle Score is different with two new concepts (2). First, it is based on the idea that the complexity is a constant for any patient in any geographical area. Second, Performance is a relation between complexity and outcomes that is given by the equation: Performance = Complexity x Survival. There are two levels of the score: the Basic Aristotle Score (BAS) calculated only on procedure; the STAT score could replace it. The second level is the Comprehensive Aristotle Score (CAS) that is calculated on the patient and includes two components: - the patient dependent complexity factors (pre-operative conditions) and - the procedure dependent complexity factors (an arterial switch with intra-mural coronary artery is more complex than simple coronary). The CAS has shown a better predictability than the STAT and RACHS-1 scores (6). The Comprehensive score is available on the Aristotle website (7). It has been used with many centers and is very efficient to assess the complex patients: the ones at risk for mortality.

All together, at the time when a new system of performance is to be envisioned, an updated and simplified Aristotle Score could be useful. The new system may consider including: -a comprehensive evaluation of outcomes calculated on a limited number of benchmark procedures, - a center volume (8) index - a mortality and a morbidity performance, - and others.

Finally, an ECHSA/EACTS think-tank, gathering experts and stakeholders in evaluation of quality of care in congenital heart surgery would be welcome.

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THE PARTIAL RISK ADJUSTMENT IN SURGERY (PRAIS) MODEL FOR PAEDIATRIC CARDIAC SURGERY

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Background

It is challenging to adjust for risk in paediatric cardiac surgery because the patient population is very diverse in terms of the procedures they have and their diagnoses and co-morbidities, amongst other things. In the past, risk stratification tools were largely consensus-based, for example the Aristotle Basic Complexity Levels1 and Risk Adjustment for Congenital Heart Surgery-1 categories.2 However, the establishment of multi-institutional databases for paediatric heart surgery and consequent accumulation of standardised data on case-mix and outcomes has enabled empirical risk models to be developed, such as the Partial Risk Adjustment in Surgery (PRAiS) model for paediatric cardiac surgery in the UK and the STS score used in the USA.3

The motivation for developing PRAiS was to create a model that could adjust for case-mix during routine monitoring of 30-day survival after paediatric cardiac surgery in the UK. From the outset, the focus in developing the model was on practical implementation rather than technical statistical performance alone. It was developed using data from the National Congenital Heart Disease Audit (previously the Central Cardiac Audit Database). The aim was to augment procedural information with information on cardiac diagnosis, comorbidities and other factors available in the NCHDA dataset.

The original model (PRAiS 1) was developed using 10 years of data (2000-2010),4 and then recalibrated using more recent data (2009-2012) because of improved raw survival rates. The model was then comprehensively updated in 2016 (PRAiS 2), revisiting all the risk factors with extensive input from an expert panel of clinicians and data experts. The current PRAiS 2 model includes 15 procedural, 11 diagnostic, and 4 comorbidity groupings, and nonlinear functions of age and weight. It showed excellent performance (validation set AUC of 0.86 and calibration slope and intercept of 1.01 and 0.11 respectively).5

Benefits and disadvantages of the score

At the time of developing PRAiS, the UK was one of only three countries with mandatory data submission for national audit: all hospitals in the UK have been mandated since 2000 to submit information to NCHDA, so the database is very mature. The data are also validated and subject to a quality assurance process, with all units undergoing annual inspection, so the data completeness and quality were very high for many data-fields. However, there are still inevitable

problems in using an audit database to develop a risk model and then using that model for audit. For example, despite concerns about the quality of recorded comorbidity information, it was included in the original model as a simple “yes/no” field because of its clinical relevance and because it was hoped that its inclusion would drive up standards of data completeness and quality. Indeed, significant improvements did occur and the richer comorbidity data enabled the revised model (PRAiS 2) to have four separate yes/no indicators of comorbidity (“Congenital comorbidity”, “Acquired comorbidity”, “Severity of Illness indicator” and “Additional cardiac risk factor”[6]).

Despite the relatively good performance of PRAiS in predicting 30-day survival, it is important to remember that no risk model can completely account for risk, hence the term ‘partial’ in the model’s name. Inevitably some factors associated with risk are not captured in the databased and so will not be accounted for at all, and others are not fully accounted for. When using PRAiS within a single centre for its intended use of in-house monitoring of short-term outcomes to support quality improvement, the prevalence of factors not accounted for is likely to be relatively stable, and the local clinical team would be aware of and understand any medium to long term changes. However, it is important when comparing PRAiS-adjusted survival outcomes between hospitals to recognise that case-mix relating to factors not accounted for in the model may differ. So, although partial risk-adjustment makes for fairer comparisons, it does not make comparisons fair.

Where and how the score is currently used

The PRAiS risk score has been incorporated in easy-to-use Excel software that allows hospitals to generate VLAD-charts of their risk adjusted 30-day survival outcomes to support local quality improvement processes (see example VLAD chart generated using the PRAiS software below). All hospitals who perform children’s heart surgery in

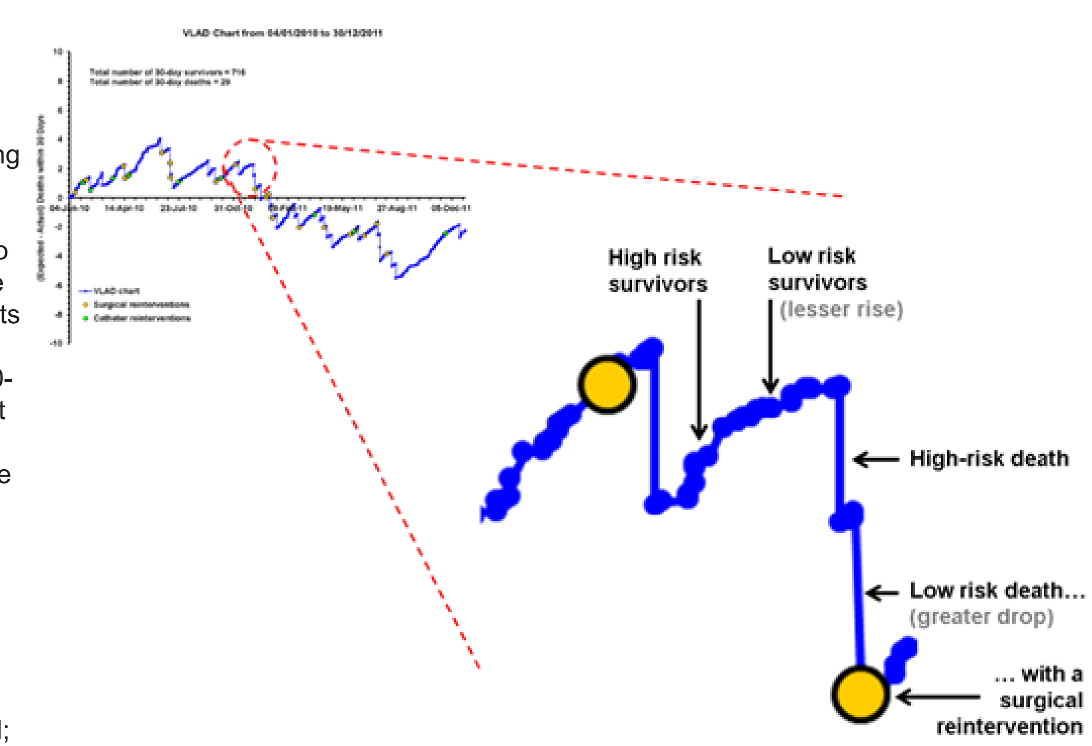

Figure 1. Example of Variable Life Adjusted Display (VLAD) Chart (reproduced from 10). The software generates VLAD charts using PRAiS to provide a visual representation of actual 30-day survival compared to the survival expected by the model. Each point represents an episode of care (the first procedure for a child in a 30-day care period). If a patient survives the procedure and is still alive 30 days later, the VLAD plot goes up. If the patient dies before 30 days, the VLAD plot goes down. The vertical axis is the total number of (predicted minus actual) deaths. When this is positive there have been fewer deaths than predicted; when this is negative there have been more deaths than predicted. A run of survivors will cause the VLAD plot to go up and a run of deaths will cause it to go down. The estimated risk of death for a patient is small and this means that the VLAD will rise much more slowly for a run of survivors than it will fall for a run of deaths.

the UK have adopted the PRAiS software and its use is mandated by the Care Quality Commission. NCHDA adopted PRAiS1 in 2013 and PRAiS2 in 2016, within two weeks of the model being finalised, so it underpins national public reporting of 30-day mortality following paediatric cardiac surgery. NCHDA's survival data are used by journalists, politicians, and the public to make difficult judgements about whether heart surgery is 'safe', so to improve public understanding and interpretation of these statistics, a group of academics, charities, parents and members of the public co-developed a new public web resource to explain how PRAiS is used by national audit.[7] The website (http://childrensheartsurgery.info/) launched in June 2016 to great acclaim and with endorsement from the Lancet and BMJ.[8,9]

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HOW TO CODE

Claudia Herbst, MD

To apply scores appropriately on database reports, a few rules on coding during the database entry need to be followed.

A lead principle is, that the Primary Procedure for a given operation is the one with the highest STAT mortality score. This is followed by concomitant procedures in descending order.

Concomitant procedures are secondary procedures. Each case can have only one primary procedure. If there are two procedures performed with similar STAT mortality score, it is the database user's choice to select the one with higher priority in this specific case. The primary procedure will determine the procedure of interest for subsequent database reports. See the list of procedures with STAT mortality scores in **Appendix 1.**

For several procedures, you will find a combined procedure code; this is preferable to be used instead of separate coding. You can see the list of combined procedures in **Appendix 2.**

Exceptions to the above stated rule:

If a multiple procedure operation includes as a component procedure any of the following procedures (Table 1), then that procedure will be designated as a **Primary Procedure.**

Table 1. Designated Primary Procedures

Procedure Group	Procedure
TOF Repair	TOF – AVC (AVSD) repair
	TOF repair, No ventriculotomy
	TOF repair, Ventriculotomy, Nontransanular patch
	TOF repair, Ventriculotomy, Transanular patch
	TOF repair, RV-PA conduit
	TOF – Absent pulmonary valve repair
Pulmonary atresia repair	Pulmonary atresia – VSD (incl. TOF, PA) repair
	Pulmonary atresia – VSD – MAPCA (pseudotruncus) repair
AVC complete, repair	AVC (AVSD) repair, complete (CAVSD)
Glenn / HemiFontan	Bidirectional cavopulmonary anastomosis (BDCPA) (bidirectional Glenn)
	Glenn (unidirectional cavopulmonary anastomosis) (unidirectional Glenn)
	Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (bilateral bidirectional Glenn)
	HemiFontan
	Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty
	Superior Cavopulmonary anastomosis(es) + PA reconstruction

Procedure Group	Procedure
Fontan	Fontan, Atrio-pulmonary connection
	Fontan, Atrio-ventricular connection
	Fontan, TCPC, Lateral tunnel, Fenestrated
	Fontan, TCPC, Lateral tunnel, Nonfenestrated
	Fontan, TCPC, External conduit, Fenestrated
	Fontan, TCPC, External conduit, Nonfenestrated
	Fontan, Other
	Fontan + Atrioventricular valvuloplasty
	Fontan revision or conversion (Re-do Fontan)
Arterial Switch Operation	Arterial switch operation (ASO)
	Arterial switch procedure + Aortic arch repair
	Arterial switch operation (ASO) and VSD repair
	Arterial switch procedure and VSD repair + Aortic arch repair
Truncus arteriosus repair	Truncus arteriosus repair
	Truncus + Interrupted aortic arch repair (IAA) repair
Norwood Procedure	Norwood Procedure
Ebstein's Repair	Ebstein's Repair
	ECHSA Congenital Database, Version 7.4.8

Exceptions to the above stated rules:

If an operation includes:

Glenn/HemiFontan procedure and either DKS or Aortic Arch Repair - the Primary Procedure will be determined to be the pertinent one of the latter ones;

Glenn/HemiFontan procedure also includes DKS and Aortic Arch Repair - the Primary Procedure will be determined to DKS;

VSD repair and Valvuloplasty, Tricuspid, then VSD repair will be coded as Primary Procedure. Regardless of technique of VSD repair (Patch, Primary closure, Device, Multiple)

Transplant is always a Primary Procedure. Including Transplant, Heart, Transplant, Heart and Lung, Transplant, Lung(s)

The following procedures will be Primary Procedure if performed as a single procedure. If one of the following procedures is a component of a multiple component operation, they will not be primary procedure.

PDA closure, Surgical
Shunt, Ligation and takedown
PA debanding
ASD Partial closure
ASD creation/enlargement
Atrial Septal Fenestration

Appendix 1: STAT Mortality Score and Categories (STAT 2009)

Procedure	STAT Mortality Score	STAT Mortality Category
ASD repair, Patch	0.1	1
AVC (AVSD) repair, Partial (Incomplete) (PAVSD)	0.1	1
PFO, Primary closure	0.2	1
ASD repair, Primary closure	0.2	1
VSD repair, Patch	0.2	1
DCRV repair	0.2	1
Aortic stenosis, Subvalvar, Repair	0.2	1
Coarctation repair, End to end	0.2	1
Vascular ring repair	0.2	1
ICD (AICD) implantation	0.2	1
ICD (AICD) ([automatic] implantable cardioverter defibrillator) procedure	0.2	1
ASD Repair, Patch + PAPCV Repair	0.2	1
VSD repair, Primary closure	0.3	1
AVC (AVSD) repair, Intermediate (Transitional)	0.3	1
PAPVC repair	0.3	1
TOF repair, No ventriculotomy	0.3	1
TOF repair, Ventriculotomy, Nontransanular patch	0.3	1
Conduit reoperation	0.3	1
Valve replacement, Pulmonic (PVR)	0.3	1
Valve replacement, Aortic (AVR), Mechanical	0.3	1
Valve replacement, Aortic (AVR), Bioprosthetic	0.3	1
Sinus of Valsalva, Aneurysm repair	0.3	1

Fontan, TCPC, Lateral tunnel, Fenestrated	0.3	1
Coarctation repair, Interposition graft	0.3	1
Pacemaker procedure	0.3	1
Glenn (Unidirectional cavopulmonary anastomosis) (Unidirectional Glenn)	0.3	1
PAPVC Repair, Baffle redirection to left atrium with systemic vein translocation (Warden) (SVC sewn to right atrial appendage)	0.3	1
1 1/2 ventricular repair	0.4	2
PA, Reconstruction (Plasty), Main (Trunk)	0.4	2
Valvuloplasty, Aortic	0.4	2
Ross procedure	0.4	2
LV to aorta tunnel repair	0.4	2
Valvuloplasty, Mitral	0.4	2
Fontan, Atrio-pulmonary connection	0.4	2
PDA closure, Surgical	0.4	2
Aortopexy	0.4	2
Pacemaker implantation, Permanent	0.4	2
Arrhythmia surgery - ventricular, Surgical Ablation	0.4	2
Bilateral bidirectional cavopulmonary anastomosis (BBDCPA) (Bilateral bidirectional Glenn)	0.4	2
Superior Cavopulmonary anastomosis(es) + PA reconstruction	0.4	2
AP window repair	0.5	2
TOF repair, Ventriculotomy, Transanular patch	0.5	2
RVOT procedure	0.5	2
Valvuloplasty, Pulmonic	0.5	2
Conduit placement, LV to PA	0.5	2
Aortic root replacement, Bioprosthetic	0.5	2
Aortic root replacement, Mechanical	0.5	2
Aortic stenosis, Supravalvar, Repair	0.5	2
Pericardiectomy	0.5	2
Congenitally corrected TGA repair, VSD closure	0.5	2
Coarctation repair, End to end, Extended	0.5	2
Anomalous origin of coronary artery from pulmonary artery repair	0.5	2
Aortic aneurysm repair	0.5	2
Bidirectional cavopulmonary anastomosis (BDCPA) (Bidirectional Glenn)	0.5	2
Aneurysm, Ventricular, Left, Repair	0.5	2
Conduit placement, Other	0.5	2
Hybrid Approach, Transcardiac balloon dilation	0.5	2
Explantation of pacing system	0.5	2
ASD, Common atrium (Single atrium), Septation	0.6	2
Pulmonary artery origin from ascending aorta (Hemitruncus) repair	0.6	2
PAPVC, Scimitar, Repair	0.6	2
Aortic root replacement, Valve sparing	0.6	2

Mitral stenosis, Supravalvar mitral ring repair	0.6	2
Fontan, TCPC, External conduit, Fenestrated	0.6	2
Fontan, TCPC, External conduit, Nonfenestrated	0.6	2
Coronary artery fistula ligation	0.6	2
Ligation, Pulmonary artery	0.6	2
Hybrid Approach, Transcardiac transcatheter device Placement	0.6	2
Fontan, TCPC, Intra/extracardiac conduit, Fenestrated	0.6	2
Fontan, TCPC, Intra/extracardiac conduit, Nonfenestrated	0.6	2
Kawashima operation (superior cavopulmonary connection in setting of interrupted IVC with azygous continuation)	0.6	2
Intravascular stent removal	0.6	2
Anomalous aortic origin of coronary artery from aorta (AAOCA) repair	0.6	2
Aortic stenosis, Subvalvar, Repair, With myectomy for IHSS	0.6	2
Valvuloplasty converted to valve replacement in the same operation, Pulmonic	0.6	2
Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Fenestrated	0.6	2
Fontan, TCPC, External conduit, hepatic veins to pulmonary artery, Nonfenestrated	0.6	2
Atrial fenestration closure	0.7	2
VSD, Multiple, Repair	0.7	2
Valve replacement, Truncal valve	0.7	2
Cor triatriatum repair	0.7	2
Atrial baffle procedure (Non-Mustard, Non-Senning)	0.7	2
Systemic venous stenosis repair	0.7	2
TOF repair, RV-PA conduit	0.7	2
Valvuloplasty, Tricuspid	0.7	2
Valve replacement, Tricuspid (TVR)	0.7	2
PA, Reconstruction (Plasty), Branch, Peripheral (At or beyond the hilar bifurcation)	0.7	2
Partial left ventriculectomy (LV volume reduction surgery) (Batista)	0.7	2
Fontan, TCPC, Lateral tunnel, Nonfenestrated	0.7	2
Coarctation repair, Subclavian flap	0.7	2
Arrhythmia surgery - atrial, Surgical Ablation	0.7	2
Hepatic vein to azygous vein connection, Direct	0.7	2
Hepatic vein to azygous vein connection, Interposition Graft	0.7	2
Valvuloplasty converted to valve replacement in the same operation, Aortic	0.7	2
Removal of transcatheter delivered device from blood vessel	0.7	2
Ventricular septal fenestration	0.8	3
AVC (AVSD) repair, Complete (CAVSD)	0.8	3
Valvuloplasty, Truncal valve	0.8	3
Anomalous systemic venous connection repair	0.8	3

Occlusion MAPCA(s)	0.8	3
PA, reconstruction (plasty), Branch, Central (within the hilar bifurcation)	0.8	3
Konno procedure	0.8	3
Arterial switch operation (ASO)	0.8	3
Coarctation repair, Patch aortoplasty	0.8	3
Transplant, Lung(s)	0.8	3
Shunt, Ligation and takedown	0.8	3
Hemifontan	0.8	3
Aneurysm, Ventricular, Right, Repair	0.8	3
Aneurysm, Pulmonary artery, Repair	0.8	3
Coarctation repair + VSD repair	0.8	3
Valvuloplasty converted to valve replacement in same operation, Tricuspid	0.8	3
Removal of transcatheter delivered device from heart	0.8	3
ASD partial closure	0.9	3
Fontan, Atrio-ventricular connection	0.9	3
Rastelli	0.9	3
Conduit placement, Ventricle to aorta	0.9	3
Pulmonary embolectomy, Acute pulmonary embolus	0.9	3
Valve replacement, Aortic (AVR), Homograft	1	3
Valvuloplasty converted to valve replacement in the same operation, Truncal valve	1	3
Pulmonary atresia - VSD (including TOF, PA) repair	1.1	3
Mustard	1.1	3
REV	1.1	3
Pulmonary artery sling repair	1.1	3
Conduit placement, RV to PA	1.2	3
Pulmonary embolectomy	1.2	3
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross procedure	1.2	3
Fontan + Atrioventricular valvuloplasty	1.2	3
Atrial baffle procedure, Mustard or Senning revision	1.2	3
Valve replacement, Mitral (MVR)	1.3	4
Pericardial drainage procedure	1.3	4
Unifocalization MAPCA(s), Unilateral pulmonary Unifocalization	1.3	4
Valvuloplasty converted to valve replacement in the same operation, Mitral	1.3	4
Valvuloplasty, Common atrioventricular valve	1.3	4
Transplant, Heart	1.4	4
Fontan revision or conversion (Re-do Fontan)	1.4	4
DORV, Intraventricular tunnel repair	1.4	4
DOLV repair	1.4	4
Aortic arch repair	1.4	4

PA debanding	1.4	4
Cardiac tumor resection	1.4	4
Arterial switch operation (ASO) and VSD repair	1.4	4
Arterial switch procedure + Aortic arch repair	1.4	4
Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty	1.4	4
TOF - Absent pulmonary valve repair	1.5	4
Valve excision, Tricuspid (Without replacement)	1.5	4
Coronary artery bypass	1.5	4
Shunt, Systemic to pulmonary, Modified Blalock-Taussig shunt (MBTS)	1.5	4
Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Incomplete unifocalization (not all usable MAPCA[s] are incorporated)	1.5	4
PA band adjustment	1.5	4
TOF - AVC (AVSD) repair	1.6	4
Ebstein's repair	1.6	4
Ross-Konno procedure	1.6	4
Senning	1.6	4
Unifocalization MAPCA(s), Bilateral pulmonary unifocalization - Complete unifocalization (all usable MAPCA[s] are incorporated)	1.6	4
Shunt, Systemic to pulmonary, Central (shunt from aorta), Central shunt with an end-to-side connection between the transected main pulmonary artery and the side of the ascending aorta (i.e. Mee shunt)	1.6	4
Pulmonary atresia - VSD - MAPCA repair	1.7	4
Unifocalization MAPCA(s)	1.7	4
Aortic root replacement, Homograft	1.7	4
Congenitally corrected TGA repair, VSD closure and LV to PA conduit	1.7	4
Aortic dissection repair	1.7	4
PA banding (PAB)	1.7	4
Pulmonary atresia - VSD - MAPCA repair, Status post prior complete unifocalization (includes VSD closure + RV to PA connection [with or without conduit])	1.7	4
Aortic arch repair + VSD repair	1.7	4
VSD creation/enlargement	1.8	4
TAPVC repair	1.9	4
HLHS biventricular repair	1.9	4
Valve replacement, Common atrioventricular valve	1.9	4
Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular	1.9	4
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross-Konno procedure	1.9	4
Pulmonary venous stenosis repair	2	4
Shunt, Systemic to pulmonary, Potts – Smith type (descending aorta to pulmonary artery)	2	4
Interrupted aortic arch repair	2.1	4

Shunt, Systemic to pulmonary, Central (From aorta or to main pulmonary artery)	2.1	4
Pulmonary atresia - VSD - MAPCA repair, Status post prior incomplete unifocalization (includes completion of pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	2.1	4
Pulmonary atresia - VSD - MAPCA repair, Complete single stage repair (1-stage that includes bilateral pulmonary unifocalization + VSD closure + RV to PA connection [with or without conduit])	2.3	4
Truncus arteriosus repair	2.4	4
Arterial switch procedure and VSD repair + Aortic arch repair	2.4	4
Aortic root translocation over left ventricle (Including Nikaidoh procedure)	2.4	4
TGA, Other procedures (Kawashima, LV-PA conduit, other)	2.4	4
ASD creation/enlargement	2.5	4
Hybrid Approach “Stage 1”, Stent placement in arterial duct (PDA)	2.5	4
Atrial septal fenestration	2.6	4
Valve closure, Tricuspid (Exclusion, Univentricular approach)	2.6	4
Hybrid Approach “Stage 1”, Application of RPA and LPA bands	2.6	4
Damus-Kaye-Stansel procedure (DKS) (Creation of AP anastomosis without arch reconstruction)	2.9	5
TAPVC repair + Shunt - Systemic to pulmonary	3	5
Hybrid Approach “Stage 1”, Stent placement in arterial duct (PDA) + application of RPA and	3.1	5
Transplant, Heart and lung	3.2	5
Congenitally corrected TGA repair, Atrial switch and Rastelli	3.2	5
Congenitally corrected TGA repair, Atrial switch and ASO (Double switch)	3.4	5
Conduit insertion right ventricle to pulmonary artery + Intraventricular tunnel left ventricle to neoaorta + Arch reconstruction (Rastelli and Norwood type arch reconstruction) (Yasui)	3.6	5
Hybrid approach “Stage 2”, Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair	3.6	5
Norwood procedure	4	5
Hybrid approach “Stage 2”, Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)	4.1	5
Truncus + IAA Repair	5	5

Appendix 2: Combined Procedure Codes

ASD repair, Patch + PAPVC repair
Aortic arch repair + VSD repair
Arterial switch operation (ASO) and VSD repair
Arterial switch procedure + Aortic arch repair
Arterial switch procedure and VSD repair + Aortic arch repair
Coarctation repair + VSD repair
Congenitally corrected TGA repair, Atrial switch and ASO (double switch)
Congenitally corrected TGA repair, Atrial switch and Rastelli
Congenitally corrected TGA repair, VSD closure
Congenitally corrected TGA repair, VSD closure and LV to PA conduit
Fontan + Atrioventricular valvuloplasty
Hybrid Approach “Stage 1”, Stent placement in arterial duct (PDA) + application of RPA & LPA bands
Hybrid approach “Stage 2”, Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Aortic arch repair (Norwood [Stage 1] + Superior Cavopulmonary anastomosis(es) + PA Debanding)
Hybrid approach “Stage 2”, Aortopulmonary amalgamation + Superior Cavopulmonary anastomosis(es) + PA Debanding + Without aortic arch repair
Ross-Konno procedure
Superior Cavopulmonary anastomosis(es) + PA reconstruction
Superior cavopulmonary anastomosis(es) (Glenn or HemiFontan) + Atrioventricular valvuloplasty
TAPVC repair + Shunt - systemic-to-pulmonary
TOF repair, RV-PA conduit
Truncus + Interrupted aortic arch repair (IAA) repair
Valvuloplasty converted to valve replacement in the same operation, Aortic
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross procedure
Valvuloplasty converted to valve replacement in the same operation, Aortic - with Ross-Konno procedure
Valvuloplasty converted to valve replacement in the same operation, Common atrioventricular valve
Valvuloplasty converted to valve replacement in the same operation, Mitral
Valvuloplasty converted to valve replacement in the same operation, Pulmonic
Valvuloplasty converted to valve replacement in the same operation, Tricuspid
Valvuloplasty converted to valve replacement in the same operation, Truncal valve

DATABASE STUDIES

Recently published ECHSA CHSD studies

Pediatric Cardiac Surgical Patterns of Practice and Outcomes in Europe and China: An Analysis of the European Congenital Heart Surgeons Association Congenital Heart Surgery Database.
Claudia Herbst, Haibo Zhang, Renjie Hu, Jürgen Hörer, Masamichi Ono, Vladimiro Vida, Tjark Ebels, Andrzej Kansy, Jeffrey P. Jacobs, Zdzislaw Tobota and Bohdan Maruszewski.
Congenital Heart Disease. Accepted: 23 September 2020. CHD, 2021, vol.16, no.1. DOI: 10.32604/CHD.2020.012982.

Pediatric Cardiac Surgical Patterns of Practice and Outcomes in Japan and Europe: An Analysis of the European Congenital Heart Surgeons Association (ECHSA) Congenital Heart Surgery Database and the Japan Cardiovascular Surgery Database.
Jürgen Hörer, MD, Yasutaka Hirata, MD, PhD, Hisateru Tachimori, PhD, Masamichi Ono, MD, Vladimiro Vida, MD, Claudia Herbst, MD, Andrzej Kansy, MD, PhD, Jeffrey P. Jacobs, MD, Zdzislaw Tobota, MD, Kisaburo Sakamoto, MD, Tjark Ebels, MD, PhD and Bohdan Maruszewski, MD, PhD.
The World Journal for Pediatric and Congenital Heart Surgery (WJPCHS). Accepted for Publication 26-Dec-2020. In Press.

Outcomes from the European Congenital Heart Surgeons Association Database
Triglia LT, Guariento A, Zanotto L, Zanotto L, Cattapan C, Hu R, Zhang H, Herbst C, Hörer J, Sarris G, Ebels T, Maruszewski B, Tobota Z, Blitzer D, Lorenzoni G, Bottigliengo D, Gregori D, Padalino M, Di Salvo G, Vida VL.
Anomalous left coronary artery from pulmonary artery repair. J Card Surg. 2021 Mar 2. doi: 10.1111/jocs.15448. Epub ahead of print. PMID: 33651393.

SOURCE DATA VERIFICATION

Zdzislaw Tobota, MD and Bohdan Maruszewski, MD, PhD

Introduction

The purpose of the source data verification (SDV) is to ensure that reported data are accurate, complete, and verifiable from source documents and the conduct of the data collection (e.g. the coding of diagnoses, procedures and complication) is in compliance with the recommendations.

According to Good Clinical Practice recommendations:

“Centralized monitoring processes provide additional monitoring capabilities that can complement and reduce the extent and/or frequency of on-site monitoring and help distinguish between reliable data and potentially unreliable data. Review, that may include statistical analyses, of accumulating data from centralized monitoring can be used to:
a) identify missing data, inconsistent data, data outliers, unexpected lack of variability and protocol deviations.

b) examine data trends such as the range, consistency, and variability of data within and across sites.
c) evaluate for systematic or significant errors in data collection and reporting at a site or across sites; or potential data manipulation or data integrity problems.
d) analyze site characteristics and performance metrics.
e) select sites and/or processes for targeted on-site monitoring.”

Source Data Verification Program in ECHSA Congenital Database

Following the EACTS Council directives and internationally admitted rules of data verification the EACTS Congenital Database management has created and applied in 2004 the stepwise protocol for control of the data completeness and accuracy. At that time the database has been co-managed by ECHSA and EACTS and had the name of the EACTS Congenital Database.

Each year since 2005 we verify the data in 4 (first year of the program activity) to 9 centers (mean 7,6). During the verification visit, which consist usually of 2 working days, the data of previous year(s) are being verified. In two days ca. 400 procedures can be verified. The possible number of verified procedures is mostly determined by the type of the source documents; paper documents, computerized hospital system, the data exported from hospital system etc. In the centers with small annual volume of procedures 2 or 3 years is verified during one visit. All together during 16 years the data of 122 annual volumes of procedures in 23 different centers has been verified, in many of them several times.

How to apply for data verification

The Congenital Heart Surgery Centre that wants to participate in the SDV program should collect and upload to the ECHSA Congenital Database website the complete set of the data of all operations done in the previous year.

Nowadays, because of the personal data protection law, patients have a right to deny consent for their data collection. The patient should be informed that the data sent to the international database are anonymized. If the patient does not agree anyway, these very few operations can be skipped. Experience has shown that this applies to exceptional cases.

If the annual volume of the procedures is small it is recommended to collect the data of 2 or 3 years, at least 200 – 250 procedures for a verification visit to be efficient.

In matters of including the center in the SDV Program and arranging an appointment, please contact the technical director of the database, Dr. Zdzislaw Tobota - ztobota@ecdb.pl.pl.

The verification process

Source data: Source data are contained in source documents (original records or certified copies) and can be said to be the first place where information is recorded/captured. In practice it can be the paper documents (perfusionist charts, descriptions of operations), access to the Hospital Information System (HIS), or the data exported from HIS e.g. in excel format.

Legal issues: the person who visits the center for data verification has no the rights to access the patients’ data. There are at least two solutions of this problem; back to back method. The visitor works with the verification forms and says the patient id number and only the person from local staff access the source data. This method solves also the language problems, if they occur. Alternatively, the hospital's legal department may prepare a document authorizing temporary access to patient data and requiring the auditor to maintain professional secrecy.

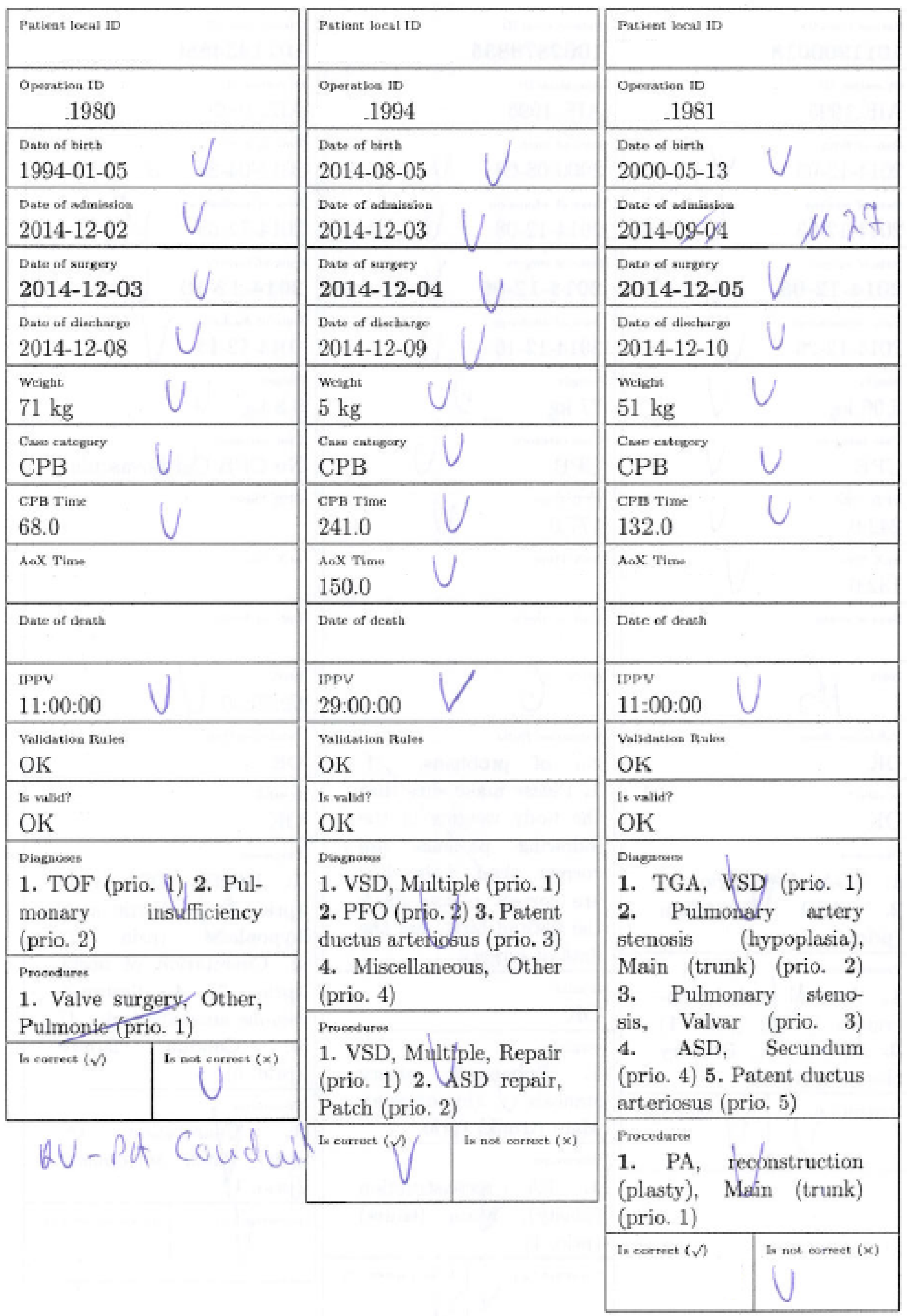
The process: The auditor comes to the center with printed Verification Forms for all operations transferred to the database from agreed years. Then the auditor himself or with the help of a person from the hospital team checks each of the fields subject to verification with the source documents.

The 13 verified fields are as follows:

Patient local ID
Date of birth
Date of admission
Date of operation
Date of discharge
Weight at operation
Case category
CPB Time
AoX clamp time
Date of death
IPPV (if available)
Diagnosis
Procedures

Each item can be marked as correct, is not correct, or data unavailable for verification.

Please see the example of the Verification form, after verification:



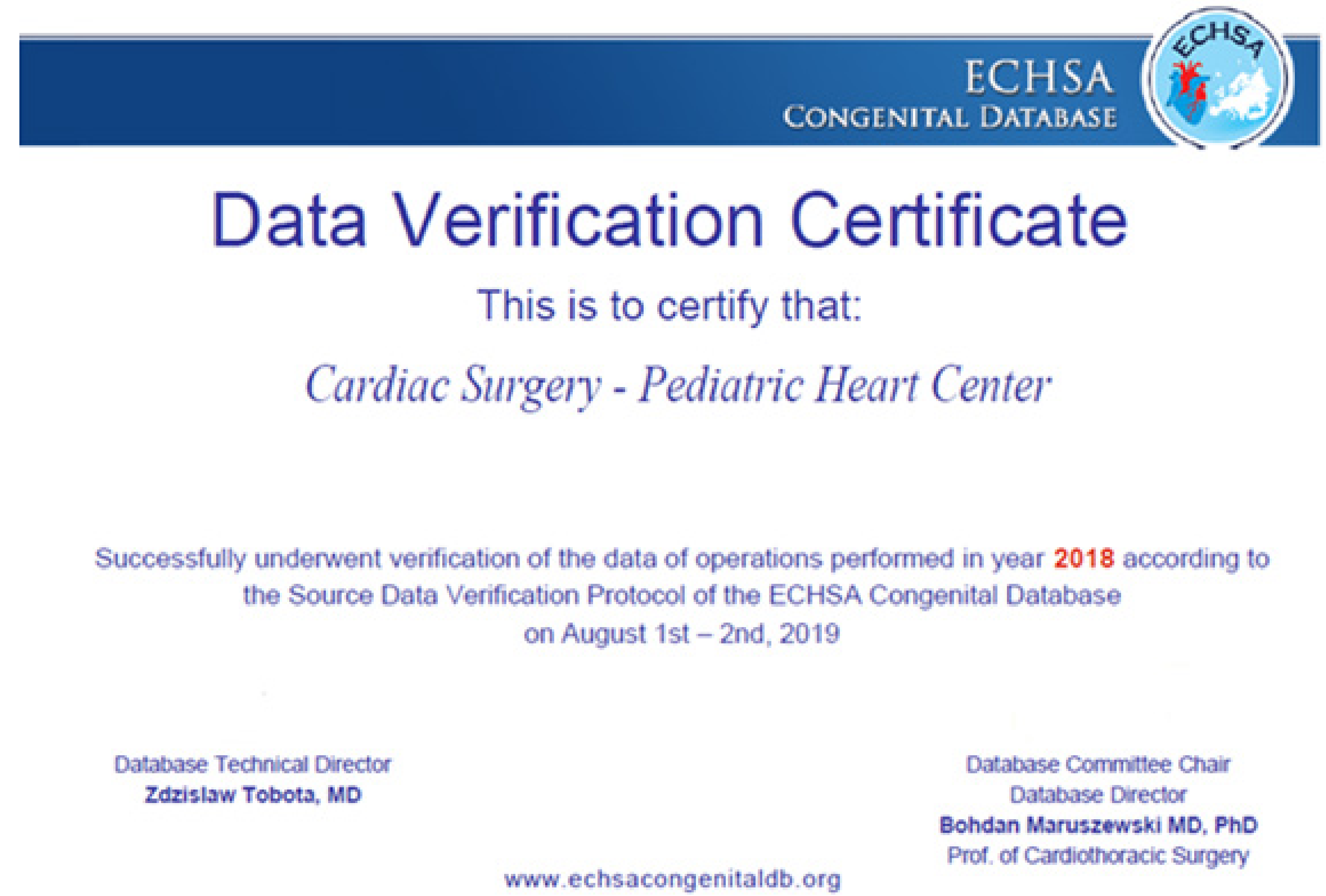
Patient local ID		
Operation ID	1980	
Date of birth	1994-01-05	
Date of admission	2014-12-02	
Date of surgery	2014-12-03	
Date of discharge	2014-12-08	
Weight	71 kg	
Case category	CPB	
CPB Time	68.0	
AoX Time		
Date of death		
IPPV	11:00:00	
Validation Rules	OK	
Is valid?	OK	
Diagnoses	1. TOF (prio. 1) 2. Pulmonary insufficiency (prio. 2)	
Procedures	1. Valve surgery, Other, Pulmonic (prio. 1)	
Is correct (√)	Is not correct (×)	

RV-PA Conduit

Patient local ID		
Operation ID	1994	
Date of birth	2014-08-05	
Date of admission	2014-12-03	
Date of surgery	2014-12-04	
Date of discharge	2014-12-09	
Weight	5 kg	
Case category	CPB	
CPB Time	241.0	
AoX Time	150.0	
Date of death		
IPPV	29:00:00	
Validation Rules	OK	
Is valid?	OK	
Diagnoses	1. VSD, Multiple (prio. 1) 2. PFO (prio. 2) 3. Patent ductus arteriosus (prio. 3) 4. Miscellaneous, Other (prio. 4)	
Procedures	1. VSD, Multiple, Repair (prio. 1) 2. ASD repair, Patch (prio. 2)	
Is correct (√)	Is not correct (×)	

Patient local ID		
Operation ID	1981	
Date of birth	2000-05-13	
Date of admission	2014-09-04	M 27
Date of surgery	2014-12-05	
Date of discharge	2014-12-10	
Weight	51 kg	
Case category	CPB	
CPB Time	132.0	
AoX Time		
Date of death		
IPPV	11:00:00	
Validation Rules	OK	
Is valid?	OK	
Diagnoses	1. TGA, VSD (prio. 1) 2. Pulmonary artery stenosis (hypoplasia), Main (trunk) (prio. 2) 3. Pulmonary stenosis, Valvar (prio. 3) 4. ASD, Secundum (prio. 4) 5. Patent ductus arteriosus (prio. 5)	
Procedures	1. PA, reconstruction (plasty), Main (trunk) (prio. 1)	
Is correct (√)	Is not correct (×)	

The verified Center receives the data verification certificate (in an electronic and printed in a frame version).



ECHSA
CONGENITAL DATABASE

Data Verification Certificate

This is to certify that:

Cardiac Surgery - Pediatric Heart Center

Successfully underwent verification of the data of operations performed in year **2018** according to the Source Data Verification Protocol of the ECHSA Congenital Database on August 1st – 2nd, 2019

Database Technical Director
Zdzislaw Tobota, MD

Database Committee Chair
Database Director
Bohdan Maruszewski MD, PhD
Prof. of Cardiothoracic Surgery

www.echsacongenitaldb.org

At the end of the year after finishing the data verification in the current year, the center receives the data verification summary showing the percentage of own mistakes and comparison to the other verified centers:

ECHSA
CONGENITAL DATABASE

Data verification summary
Dept. of Congenital Heart Surgery / Pediatric Heart Surgery, 2017

		%	% of all verified data of 2017	% of all verified data 2003-2017
The number of all operations before verification:	849			
The number of deleted operations:	0	0,00%	0,03%	0,38%
The number of added operations:	3	0,35%	1,03%	1,14%
The number of all operations after verification:	852			
The number of not verified operations:	3	0,35%	2,62%	1,41%

The number of not verified data in the field "Date of discharge":	31	3,65%	1,14%	0,63%
The number of changes in the field "Weight":	20	2,36%	2,34%	1,81%
The number of not verified data in the field "Weight":	37	4,36%	4,07%	2,72%
The number of changes in the field "Case category name":	58	6,83%	2,41%	1,19%
The number of changes in the field "CPB time":	6	0,71%	1,27%	1,52%
The number of not verified data in the field "CPB time":	6	0,71%	1,10%	0,31%
The number of changes in the field "AOX time":	5	0,59%	1,34%	1,32%
The number of not verified data in the field "AOX time":	5	0,59%	1,48%	0,41%
The number of changes in the field "Diagnoses":	13	1,53%	3,03%	1,73%
The number of priority changes in the field "Diagnoses":	15	1,77%	1,38%	0,88%
The number of changes in the field "Procedures":	10	1,18%	2,24%	1,64%
The number of priority changes in the field "Procedures":	7	0,82%	0,45%	0,28%

Database Technical Director
Zdzislaw Tobota, MD

Database Director
Bohdan Maruszewski MD, PhD
Prof. of Cardiothoracic Surgery

www.echsacongenitaldb.org

The comparative statistics of the data verification results is published on database web site and is updated every year with the new data verification data:

DATA VERIFICATION RESULTS

Data Of 2003 - 2017

ALL PATIENTS

- No of all collected procedures for 2003 - 2017: 257,939
- No of verified procedures: 37,699 (14.62%)

- No of procedures in whole database: 301,074
- No of verified procedures: 37,699 (12.52%)

Verification Results

Procedures	37,105		37,699		
	Before verification		After verification		
	Mean	Std Dev	Mean	Std Dev	p-value
Age (days)	2316.26	4367.37	2303.38	4308.61	0.68
AOX time (min)	63.57	46.47	63.61	46.63	0.93
CPB time (min)	111.39	81.87	111.42	80.37	0.97
IPPV (min)	88.15	282.37	89.59	287.21	0.60
LOS (days)	23.14	418.89	19.26	171.98	0.10
Weight (kg)	19.07	29.43	18.80	23.58	0.18

Verification Results - Mortality

Patients	29,593		29,894		
	Before verification		After verification		
	No of deaths	Mortality (%)	No of deaths	Mortality (%)	p-value
30 days mortality	988	3.34	1032	3.45	0.44
hospital mortality	1087	3.67	1141	3.82	0.36

Costs of data verification
The work of the Auditor is covered by the Database annual budget.
The verified center covers the travel and accommodation (flight ticket and hotel bill) costs of the auditor.

GENERAL INFORMATION

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Questions or Requests regarding the newsletter or the ECHSA-CHSD itself?

Want to enroll your center to the ECHSA-CHSD?

Contact us: dbnewsletter@echsa.org