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Abstract

This article presents 21 “Quality Measures for Congenital and Pediatric Cardiac Surgery” that were developed and approved by the Society of Thoracic Surgeons (STS) and endorsed by the Congenital Heart Surgeons’ Society (CHSS). These Quality Measures are organized according to Donabedian’s Triad of Structure, Process, and Outcome. It is hoped that these quality measures can aid in congenital and pediatric cardiac surgical quality assessment and quality improvement initiatives.

Keywords

database, outcomes, quality assessment, quality improvement

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Table 1. Members of the STS Task Force to Develop Quality Measures for Pediatric and Congenital Cardiac Surgery

1. Jeffrey Phillip Jacobs, MD = Chair
2. Erle H. Austin III, MD
3. Emile A. Bacha, MD
4. Pedro J. del Nido, MD
5. Charles D. Fraser Jr, MD
6. Jennifer Christel Hirsch, MD
7. Marshall Lewis Jacobs, MD
8. David L.S. Morales, MD
9. Kamal K. Pourmoghadam, MD
10. Christo I. Tchervenkov, MD
11. James S. Tweddell, MD
12. Jeffrey B. Rich, MD
13. Frederick L. Grover, MD

Background

Ongoing efforts directed at quality assessment and quality improvement in the field of pediatric and congenital cardiac disease¹⁻³ coincide with maturation and expansion of registry databases.⁴⁻⁹ Analysis of these large repositories of data is fundamental to the assessment of outcomes from congenital and pediatric cardiac surgery at a multi-institutional level. It is apparent that substantial variability in the outcomes of pediatric and congenital cardiac surgery still exists.¹⁰ One aspect of overall quality improvement is the reduction in variability of outcomes across centers, and this improvement may be facilitated by adoption of measures and practices that are efficacious and widely applicable. The development and validation of “measures of quality” or “indicators of quality” is an essential step in this process and can facilitate the transformation of our outcome databases into platforms to assess and improve quality. These “quality measures” or “quality indicators” can then become a tool to facilitate multi-institutional quality improvement initiatives.

Quality Measures for Pediatric and Congenital Cardiac Surgery

The Society of Thoracic Surgeons (STS) designated a “Task Force to develop Quality Measures for Pediatric and Congenital Cardiac Surgery” in 2007 under the leadership of STS President John E. Mayer, MD. Members of this STS Task Force are listed in Table 1. This Task Force proposed a list of “Quality Measures for Congenital and Pediatric Cardiac Surgery.” The proposal was developed and approved unanimously by the STS Task Force to develop Quality Measures for Pediatric and Congenital Cardiac Surgery. The proposal was then reviewed and approved by the five STS Committees listed in Table 2, with final approval by the STS Executive Committee. The original set of “Quality Measures for Congenital and Pediatric Cardiac Surgery” that were proposed in 2007 have been updated and refined by members of the “Task Force to develop Quality Measures for Pediatric and Congenital Cardiac Surgery” to ensure consistency with the current version of the STS Congenital Heart Surgery Database.¹¹

Table 2. Committees From Society of Thoracic Surgeons (STS) and Congenital Heart Surgeons’ Society (CHSS)

- Committees of the Society of Thoracic Surgeons that approved the 2007 Proposed STS “Quality Measures for Congenital and Pediatric Cardiac Surgery”
1. The STS Task Force to develop Quality Measures for Pediatric and Congenital Cardiac Surgery
 2. The STS Congenital Heart Surgery Database Task Force
 3. The STS National Database Work Force
 4. The STS Council on Quality, Research & Patient Safety
 5. The Society of Thoracic Surgeons (STS) Executive Committee
- Committees of the Congenital Heart Surgeons’ Society (CHSS) that approved the Quality Measures for Congenital and Pediatric Cardiac Surgery
1. CHSS Committee on Quality Improvement and Outcomes
 2. CHSS Council

The Congenital Heart Surgeons’ Society (CHSS), in 2011, under the leadership of CHSS President Erle H. Austin III, MD, established a Committee on Quality Improvement and Outcomes, which has the following duties: (1) to create and facilitate multi-institutional initiatives to assess and improve the quality of care delivered to patients with congenital and pediatric heart disease, (2) to establish and maintain a CHSS-based resource for the evaluation of programmatic quality for programs caring for patients with congenital and pediatric congenital heart disease, and (3) to oversee the relationship and linkage of the CHSS to other databases in order to achieve the above objectives and simultaneously further the research mission of the CHSS.

In 2011, the CHSS endorsed the most recent version of the Quality Measures for Congenital and Pediatric Cardiac Surgery that were developed and approved by STS. These Quality Measures for Congenital and Pediatric Cardiac Surgery were unanimously endorsed by the two CHSS Committees listed in Table 2.

The Quality Measures for Congenital and Pediatric Cardiac Surgery that were developed and approved by STS and endorsed by CHSS are listed in Table 3 and described in detail in Table 4. Consensus definitions of the morbidities described in Tables 3 and 4 are provided in Table 5.^{5,11}

Discussion

At the present time, the evidence supporting the individual Quality Measures for Congenital and Pediatric Cardiac Surgery that are presented in Tables 3 and 4 ranges from consensus of the opinion of experts to published data from analysis of large multi-institutional data sets.¹² Additional data to support these proposed quality measures will be gathered by the STS Congenital Heart Surgery Database. A Quality Module of the STS Congenital Heart Surgery Database is currently under development in order to achieve this objective.

These Quality Measures are harmonized with several ongoing congenital and pediatric cardiac surgical quality and outcomes initiatives.

Table 3. Quality Measures for Congenital and Pediatric Cardiac Surgery

1. Participation in a National Database for Pediatric and Congenital Heart Surgery
2. Multidisciplinary rounds involving multiple members of the health care team
3. Availability of institutional pediatric extracorporeal life support (ECLS) program
4. Surgical volume for pediatric and congenital heart surgery: total programmatic volume and programmatic volume stratified by the Five STS-EACTS Mortality Categories
5. Surgical volume for eight pediatric and congenital heart benchmark operations
6. Multidisciplinary preoperative planning conference to plan pediatric and congenital heart surgery operations
7. Regularly Scheduled Quality Assurance and Quality Improvement Cardiac Care Conference, to occur no less frequently than once every two months
8. Availability of intraoperative transesophageal echocardiography (TEE) and epicardial echocardiography
9. Timing of antibiotic administration for pediatric and congenital cardiac surgery patients
10. Selection of appropriate prophylactic antibiotics for pediatric and congenital cardiac surgery patients
11. Use of an expanded preprocedural and postprocedural "time-out"
12. Occurrence of new postoperative renal failure requiring dialysis
13. Occurrence of new postoperative neurological deficit persisting at discharge
14. Occurrence of arrhythmia necessitating permanent pacemaker insertion
15. Occurrence of paralyzed diaphragm (possible phrenic nerve injury)
16. Occurrence of need for postoperative mechanical circulatory support (IABP, VAD, ECMO, or CPS)
17. Occurrence of unplanned reoperation and/or unplanned interventional cardiovascular catheterization procedure
18. Operative mortality stratified by the Five STS-EACTS Mortality Categories
19. Operative mortality for eight benchmark operations
20. Index cardiac operations free of mortality and major complication
21. Operative survivors free of major complication

Abbreviations: STS, Society of Thoracic Surgeons; EACTS, European Association for Cardio-Thoracic Surgery; IABP, intra-aortic balloon pump; VAD, ventricular assist device; ECMO, extracorporeal membrane oxygenation; CPS, cardiopulmonary support system.

1. The Quality Measures for Congenital and Pediatric Cardiac Surgery are harmonized with all nomenclature, standards, and rules currently used by the STS and the European Association for Cardio-Thoracic Surgery (EACTS) in the STS Congenital Heart Surgery Database and the EACTS Congenital Heart Surgery Database.^{11,13,14}
2. Both STS and EACTS developed and published the STS-EACTS Congenital Heart Surgery Mortality Score and STS-EACTS Congenital Heart Surgery Mortality Categories.¹² A similar initiative to develop a Congenital Heart Surgery Morbidity Score and Congenital Heart Surgery Morbidity Categories is nearing completion. The measures of morbidity in these Quality Measures for Congenital and Pediatric Cardiac Surgery are harmonized with the measures of morbidity in the proposed Congenital Heart Surgery Morbidity Score and Congenital Heart Surgery Morbidity Categories.
3. The Quality Measures for Congenital and Pediatric Cardiac Surgery are harmonized with recent analyses performed with the STS Congenital Heart Surgery Database that examine "Variation in Outcomes for Benchmark Operations".¹⁰
4. The Quality Measures for Congenital and Pediatric Cardiac Surgery are harmonized with ongoing analyses performed with the STS Congenital Heart Surgery Database that examine "Failure to Rescue," which is the concept of measuring survival versus nonsurvival following complications as a potential measure of performance.¹⁵⁻¹⁷

Efforts are already underway to gather data to assess these quality measures in the following domains: reliability, validity,

importance, scientific acceptability, usability, and feasibility. Questions to be answered include a determination of the relationship of structure measures and process measures to outcome, the assessment as to whether this relationship is one of "cause and effect" or simply "association," and an analysis of possible unintended consequences of any of these measures.

Eventually, efforts to measure and improve the quality of care of patients with congenital and/or pediatric cardiac disease must also span temporal, geographical, and subspecialty boundaries.^{2,9} As such, development of additional measures of quality should include longitudinal follow-up with longitudinal assessment of quality, global collaboration, and multidisciplinary involvement.

Conclusions

This article presents 21 Quality Measures for Congenital and Pediatric Cardiac Surgery that were developed and approved by STS and endorsed by CHSS. These quality measures are organized according to Donabedian's Triad of Structure, Process, and Outcome. It is hoped that these quality measures can aid in congenital and pediatric cardiac surgical quality assessment and quality improvement initiatives.

Declaration of Conflicting Interests

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Table 4. Quality Measures for Congenital and Pediatric Cardiac Surgery

1. Participation in a **National Database** for Pediatric and Congenital Heart Surgery
2. **Multidisciplinary rounds** involving multiple members of the healthcare team
3. Availability of Institutional **Pediatric ECLS (Extracorporeal Life Support) Program**
4. **Surgical volume** for Pediatric and Congenital Heart Surgery: Total Programmatic Volume and Programmatic Volume Stratified by the **Five STS-EACTS Mortality Categories**
5. **Surgical Volume** for **Eight Pediatric and Congenital Heart Benchmark Operations**
6. Multidisciplinary **preoperative planning conference** to plan pediatric and congenital heart surgery operations
7. Regularly Scheduled **Quality Assurance and Quality Improvement Cardiac Care Conference**, to occur no less frequently than once every two months
8. Availability of **intraoperative transesophageal echocardiography (TEE)** and epicardial echocardiography
9. **Timing of Antibiotic Administration** for Pediatric and Congenital Cardiac Surgery Patients
10. Selection of **Appropriate Prophylactic Antibiotics** for Pediatric and Congenital Cardiac Surgery Patients
11. Use of an **expanded pre-procedural and post-procedural “time-out”**
12. Occurrence of new post-operative **renal failure** requiring dialysis
13. Occurrence of new post-operative **neurological deficit** persisting at discharge
14. Occurrence of arrhythmia necessitating **permanent pacemaker** insertion
15. Occurrence of **paralyzed diaphragm** (possible phrenic nerve injury)
16. Occurrence of need for **postoperative mechanical circulatory support** (IABP, VAD, ECMO, or CPS)
17. Occurrence of **unplanned reoperation** and/or unplanned interventional cardiovascular catheterization procedure
18. **Operative Mortality** Stratified by the Five STS-EACTS Mortality Categories
19. **Operative Mortality** for Eight Benchmark Operations
20. Index Cardiac **Operations Free of Mortality and Major Complication**
21. Operative **Survivors Free of Major Complication**

Definitions of Quality Measures for Congenital and Pediatric Cardiac Surgery

Number	Type	Title of Indicator	Description
1	S-1	Structure	Participation in a National Database for Pediatric and Congenital Heart Surgery
			Participation in at least one multi-center, standardized data collection and feedback program that provides regularly scheduled reports of the individual center’s data relative to national multicenter aggregates and uses process and outcome measures.
2	S-2	Structure	Multidisciplinary rounds involving multiple members of the healthcare team
			Occurrence of daily multidisciplinary rounds on pediatric and congenital cardiac surgery patients involving multiple members of the healthcare team, with recommended participation including but not limited to: cardiac surgery, cardiology, critical care, primary caregiver, family, nurses, pharmacist, and respiratory therapist. Involvement of the family is encouraged.
3	S-3	Structure	Availability of Institutional Pediatric ECLS (Extracorporeal Life Support) Program
			Availability of an institutional pediatric Extracorporeal Life Support (ECLS) Program for pediatric and congenital cardiac surgery patients. Measure is satisfied by availability of ECMO equipment and support staff, but applies as well to Ventricular Assist Devices (including extracorporeal, paracorporeal, and implantable).
4	S-4	Structure	Surgical volume for Pediatric and Congenital Heart Surgery: Total Programmatic Volume and Programmatic Volume Stratified by the Five STS-EACTS Mortality Categories
			Surgical Volume for Pediatric and Congenital Heart Surgery STS version 2.5: All Index Cardiac Operations (A Cardiac Operation is defined as an operation of Operation Type “CPB” or “No CPB Cardiovascular”.) STS version 3.0: Same Surgical volume for pediatric and congenital heart surgery stratified by the five STS-EACTS Mortality Categories, a multi-institutional validated complexity stratification tool See <i>J Thorac Cardiovasc Surg</i> 2009;138:1139-1153. O’Brien et al. An empirically based tool for analyzing mortality associated with congenital heart surgery. Table 1, pp 1141-1146.
5	S-5	Structure	Surgical Volume for Eight Pediatric and Congenital Heart Benchmark Operations
			Surgical Volume for Eight Benchmark Pediatric and Congenital Heart Operations: These 8 Eight Benchmark Pediatric and Congenital Heart Operations are tracked when they are the Primary Procedure of an Index Cardiac Operation. (A Cardiac Operation is defined as an operation of Operation Type “CPB” or “No CPB Cardiovascular”.)

(continued)

Table 4. (continued)

Number	Type	Title of Indicator	Description
			Procedure type Abbreviation STS–CHSDB Diagnostic and Procedural Inclusionary and Exclusionary Criteria
1.	VSD Repair	VSD	<p>Procedural Inclusionary Criteria: 100 = VSD repair, Primary closure 110 = VSD repair, Patch 120 = VSD repair, Device*</p> <p>*(Please note that this measure is applicable when one or more septal occluder devices are implanted in the course of a surgical operation for which the Primary Procedure of an Index Cardiac Operation is VSD repair. [A Cardiac Operation is defined as an operation of Operation Type “CPB” or “No CPB Cardiovascular”.] A VSD device that is placed as a purely transcatheter technique and not as a component of a cardiac operation is classified as an Interventional Cardiology Procedure and is not tracked as part of this measure.)</p> <p>Diagnostic Inclusionary Criteria: 71 = VSD, Type 1 (Subarterial) (Supracristal) (Conal septal defect) (Infundibular) 73 = VSD, Type 2 (Perimembranous) (Paramembranous) (Conoventricular) 75 = VSD, Type 3 (Inlet) (AV canal type) 77 = VSD, Type 4 (Muscular) 79 = VSD, Type: Gerbode type (LV-RA communication)</p> <p>Diagnostic Exclusionary Criteria: 80 = VSD, Multiple</p>
2.	TOF Repair	TOF	<p>Procedural Inclusionary Criteria: 350 = TOF repair, No ventriculotomy 360 = TOF repair, Ventriculotomy, Nontransannular patch 370 = TOF repair, Ventriculotomy, Transannular patch 380 = TOF repair, RV-PA conduit</p> <p>Diagnostic Inclusionary Criteria: 290 = TOF 2140 = TOF, Pulmonary stenosis</p> <p>Diagnostic Exclusionary Criteria 300 = TOF, AVC (AVSD) 310 = TOF, Absent pulmonary valve 320 = Pulmonary atresia 330 = Pulmonary atresia, IVS 340 = Pulmonary atresia, VSD (Including TOF, PA) 350 = Pulmonary atresia, VSD-MAPCA (pseudotruncus) 360 = MAPCA(s) (major aortopulmonary collateral[s]) (without PA-VSD)</p>
3.	Complete AV Canal Repair	AVC	<p>Procedural Inclusionary Criteria 170 = AVC (AVSD) repair, Complete (CAVSD)</p> <p>Diagnostic Inclusionary Criteria: 100 = AVC (AVSD), Complete (CAVSD)</p> <p>Diagnostic Exclusionary Criteria: 110 = AVC (AVSD), Intermediate (transitional) 120 = AVC (AVSD), Partial (incomplete) (PAVSD) (ASD, primum) 300 = TOF, AVC (AVSD)</p>

(continued)

Table 4. (continued)

Number	Type	Title of Indicator	Description
	Procedure type	Abbreviation	STS–CHSDB Diagnostic and Procedural Inclusionary and Exclusionary Criteria
4.	Arterial Switch	ASO	<p>Procedural Inclusionary Criteria: 1110 = Arterial switch operation (ASO)</p> <p>Procedural Exclusionary Criteria: 1120 = Arterial switch operation (ASO) and VSD repair 1123 = Arterial switch procedure + Aortic arch repair 1125 = Arterial switch procedure and VSD repair + Aortic arch repair 1050 = Congenitally corrected TGA repair, Atrial switch and ASO (double switch)</p>
5.	Arterial Switch +VSD repair	ASO+VSD	<p>Procedural Inclusionary Criteria: 1120 = Arterial switch operation (ASO) and VSD repair</p> <p>Procedural Exclusionary Criteria: 1110 = Arterial switch operation (ASO) 1123 = Arterial switch procedure + Aortic arch repair 1125 = Arterial switch procedure and VSD repair + Aortic arch repair 1050 = Congenitally corrected TGA repair, Atrial switch and ASO (double switch)</p>
6.	Fontan	Fontan	<p>Procedural Inclusionary Criteria: 950 = Fontan, Atrio-pulmonary connection 960 = Fontan, Atrio-ventricular connection 970 = Fontan, TCPC, Lateral tunnel, Fenestrated 980 = Fontan, TCPC, Lateral tunnel, Nonfenestrated 1000 = Fontan, TCPC, External conduit, Fenestrated 1010 = Fontan, TCPC, External conduit, Nonfenestrated 1030 = Fontan, Other 2340 = Fontan + Atrioventricular valvuloplasty</p> <p>Procedural Exclusionary Criteria: Exclude patients age \geq 7 years 1025 = Fontan revision or conversion (Re-do Fontan)</p>
7.	Truncus Repair	Truncus	<p>Procedural Inclusionary Criteria: Primary procedure must be: 230 = Truncus arteriosus repair</p> <p>Procedural Exclusionary Criteria: Exclude any operation if any of the component procedures is: 240 = Valvuloplasty, Truncal valve 2290 = Valvuloplasty converted to valve replacement in the same operation, Truncal valve 250 = Valve replacement, Truncal valve 2220 = Truncus + Interrupted aortic arch repair (IAA) repair</p>
8.	Norwood	Norwood	<p>Procedural Inclusionary Criteria: 870 = Norwood procedure</p>

Table 4. (continued)

Number	Type	Title of Indicator	Description	
6	P-1	Process	Multidisciplinary preoperative planning conference to plan pediatric and congenital heart surgery operations	<p>Occurrence of a pre-operative multidisciplinary planning conference to plan pediatric and congenital heart surgery cases. This conference will involve multiple members of the healthcare team, with recommended participation including but not limited to: cardiology, cardiac surgery, anesthesia, and critical care.</p> <p>This measure will be coded on a per operation basis. Reporting of compliance will be as a fraction of all Cardiac Operations. A Cardiac Operation is defined as an operation of Operation Type "CPB" or "No CPB Cardiovascular".</p>
7	P-2	Process	Regularly Scheduled Quality Assurance and Quality Improvement Cardiac Care Conference, to occur no less frequently than once every two months	<p>Occurrence of a regularly scheduled Quality Assurance and Quality Improvement Cardiac Care Conference to discuss care provided to patients who have undergone pediatric and congenital cardiac surgery operations, including reporting and discussion of all major complications and mortalities, and discussion of opportunities for improvement. A "Quality Assurance and Quality Improvement Conference" is also known as a "Mortality and Morbidity Conference" (M and M Conference).</p> <p>Reporting of compliance will be by reporting the date of occurrence. Annual compliance of 100% equals no fewer than six conferences per year.</p>
8	P-3	Process	Availability of intraoperative transesophageal echocardiography (TEE) and epicardial echocardiography	<p>Availability of intraoperative transesophageal echocardiography (TEE) and appropriate physician and sonographer support for pediatric and congenital cardiac operations. Epicardial echocardiography and appropriate physician and sonographer support should be readily available for those patients in whom TEE is contraindicated or less informative. Availability means presence and availability of equipment and staff.</p> <p>This measure will be coded on a per operation basis. Reporting of compliance will be as the fraction of all Cardiac Operations with availability (as opposed to use) of TEE and/or epicardial echocardiography. (A Cardiac Operation is defined as an operation of Operation Type "CPB" or "No CPB Cardiovascular".)</p>
9	P-4	Process	Timing of Antibiotic Administration for Pediatric and Congenital Cardiac Surgery Patients	<p>Measure is satisfied for each Cardiac Operation, when there is documentation that the patient has received prophylactic antibiotics within the hour immediately preceding surgical incision (two hours if receiving vancomycin). (A Cardiac Operation is defined as an operation of operation type "CPB" or "No CPB Cardiovascular".)</p>
10	P-5	Process	Selection of Appropriate Prophylactic Antibiotics for Pediatric and Congenital Cardiac Surgery Patients	<p>Measure is satisfied for each Cardiac Operation, when there is documentation that the patient received appropriate prophylactic antibiotics as recommended for the operation. (A Cardiac Operation is defined as an operation of operation type "CPB" or "No CPB Cardiovascular".)</p>
11	P-6	Process	Use of an expanded pre-procedural and post-procedural "time-out"	<p>Measure is satisfied for each Cardiac Operation when there is documentation of performance and completion of an expanded pre-procedural and post-procedural "time-out" that includes the following four elements (A Cardiac Operation is defined as an operation of operation type "CPB" or "No CPB Cardiovascular".):</p> <ol style="list-style-type: none"> 1. The conventional pre-procedural "time-out", which includes identification of patient, operative site, procedure, and history of any allergies. 2. A pre-procedural briefing (checklist) wherein the surgeon shares with all members of the operating room team the essential elements of the operative plan; including diagnosis, planned procedure, outline of essentials of anesthesia and bypass strategies, antibiotic prophylaxis, availability of blood products, anticipated or planned implants or device applications, and anticipated challenges. 3. A post-procedural debriefing (checklist) wherein the surgeon succinctly reviews with all members of the operating room team the essential elements of the operative plan, identifying both the successful components and the opportunities for improvement. This debriefing should take <i>place prior to the patient leaving the operating room or its equivalent</i>, and may be followed by a more in-depth dialogue involving team members at a later time. (The actual debriefing in the operating room is intentionally and importantly brief, in recognition of the fact that periods of transition may be times of instability or vulnerability for the patient.)

Table 4. (continued)

Number	Type	Title of Indicator	Description
12	O-1	Outcome	<p>Occurrence of new post-operative renal failure requiring dialysis</p> <p>4. A briefing and execution of a hand-off protocol (checklist) at the time of transfer (arrival) to the Intensive Care Unit at the end of the operation, involving the anesthesiologist, surgeon, physician staff of the Intensive Care Unit (including critical care and cardiology) and nursing.</p> <p>For each surgical admission (Index Cardiac Operation) code whether the complication occurred during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer (A Cardiac Operation is defined as an operation of operation type “CPB” or “No CPB Cardiovascular”.):</p> <p>STS version 2.5: 220 = Acute renal failure requiring temporary dialysis 230 = Acute renal failure requiring permanent dialysis</p> <p>STS version 3.0: 230 = Renal failure - acute renal failure, Acute renal failure requiring dialysis at the time of hospital discharge 223 = Renal failure - acute renal failure, Acute renal failure requiring temporary dialysis with the need for dialysis not present at hospital discharge 224 = Renal failure - acute renal failure, Acute renal failure requiring temporary hemofiltration with the need for dialysis not present at hospital discharge</p> <p>Please note: Unless a patient requires dialysis prior to surgery, renal failure that requires dialysis after surgery constitutes an operative complication, despite the fact that pre-operative diminished renal perfusion may have contributed to the development of this complication.</p> <p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified by the STS Congenital Heart Surgery Morbidity Categories instead of the STS Congenital Heart Surgery Mortality Categories.)</p>
13	O-2	Outcome	<p>Occurrence of new post-operative neurological deficit persisting at discharge</p> <p>For each surgical admission (Index Cardiac Operation) code whether the complication occurred during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer (A Cardiac Operation is defined as an operation of operation type “CPB” or “No CPB Cardiovascular”.):</p> <p>320 = Neurological deficit, Neurological deficit persisting at discharge</p> <p>This measure tracks “new post-operative neurological deficits” that (1) occur during the time interval beginning at admission to operating room and ending at the time of hospital discharge and (2) persist at discharge.</p> <p>Such new post-operative neurological deficits may or may not be related to a stroke. If the new post-operative neurological deficit is the result of a stroke (that occurs during the time interval beginning at admission to operating room and ending at the time of hospital discharge) and the neurological deficit persists at discharge, then the following two complications should both be selected:</p> <p>320 = Neurological deficit, Neurological deficit persisting at discharge 420 = Stroke</p> <p>Thus, this complication (320 = Neurological deficit, Neurological deficit persisting at discharge) should be coded in situations where a patient has a stroke (during the time interval beginning at admission to operating room and ending at the time of hospital discharge) and the neurological deficit persists at discharge.</p> <p>This measure does not include a neurologic deficit (which may or may not be related to a stroke) that does not persist at discharge.</p>

(continued)

Table 4. (continued)

Number	Type	Title of Indicator	Description
14	O-3	Outcome	<p>Occurrence of arrhythmia necessitating permanent pacemaker insertion</p> <p>Please note that this complication (320 = Neurological deficit, Neurological deficit persisting at discharge) should be coded even in the situation where the patient has a neurological deficit that is present prior to admission to operating room and this neurological deficit worsens (or a new neurological deficit develops) during the time interval beginning at admission to operating room and ending at the time of hospital discharge.</p> <p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified by the STS Congenital Heart Surgery Morbidity Categories instead of the STS Congenital Heart Surgery Mortality Categories.)</p> <p>For each surgical admission (Index Cardiac Operation) code whether the complication occurred during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer (A Cardiac Operation is defined as an operation of operation type "CPB" or "No CPB Cardiovascular".):</p> <p>STS version 2.5: 60 = Postoperative AV block requiring permanent pacemaker</p> <p>STS version 3.0: 74 = Arrhythmia necessitating pacemaker, Permanent pacemaker</p> <p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified by the STS Congenital Heart Surgery Morbidity Categories instead of the STS Congenital Heart Surgery Mortality Categories.)</p>
15	O-4	Outcome	<p>Occurrence of paralyzed diaphragm (possible phrenic nerve injury)</p> <p>For each surgical admission (Index Cardiac Operation) code whether the complication occurred during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer (A Cardiac Operation is defined as an operation of operation type "CPB" or "No CPB Cardiovascular".):</p> <p>STS version 2.5: 300 = Phrenic nerve injury/paralyzed diaphragm</p> <p>STS version 3.0: 300 = Paralyzed diaphragm (possible phrenic nerve injury)</p> <p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified by the STS Congenital Heart Surgery Morbidity Categories instead of the STS Congenital Heart Surgery Mortality Categories.)</p>
16	O-5	Outcome	<p>Occurrence of need for Postoperative mechanical circulatory support (IABP, VAD, ECMO, or CPS)</p> <p>For each surgical admission (Index Cardiac Operation) code whether the complication occurred during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer (A Cardiac Operation is defined as an operation of operation type "CPB" or "No CPB Cardiovascular".):</p> <p>STS version 2.5: 40 = Postoperative mechanical circulatory support (IABP, VAD, ECMO, or CPS)</p> <p>STS version 3.0: 40 = Postoperative/Postprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS)</p> <p>Please note that this complication should be coded even in the situation where the patient had preoperative mechanical circulatory support if the patient has mechanical circulatory support postoperatively at any time until 30 days post-operatively or the time of hospital discharge, whichever is longer.</p>

Table 4. (continued)

Number	Type	Title of Indicator	Description
17	O-6	Outcome	<p>Occurrence of unplanned reoperation and/or unplanned interventional cardiovascular catheterization procedure</p> <p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified by the STS Congenital Heart Surgery Morbidity Categories instead of the STS Congenital Heart Surgery Mortality Categories.)</p> <p>For each surgical admission (Index Cardiac Operation) code whether the complication occurred during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer (A Cardiac Operation is defined as an operation of operation type “CPB” or “No CPB Cardiovascular”.):</p> <p>STS version 2.5: 20 = Reoperation during this admission (unplanned reoperation) 240 = Bleeding requiring reoperation</p> <p>STS version 3.0: 22 = Unplanned cardiac reoperation during the postoperative or postprocedural time period 24 = Unplanned interventional cardiovascular catheterization procedure during the postoperative or postprocedural time period 26 = Unplanned non-cardiac reoperation during the postoperative or postprocedural time period 240 = Bleeding, Requiring reoperation</p> <p><i>n.b. does not include delayed sternal closure</i></p> <p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified by the STS Congenital Heart Surgery Morbidity Categories instead of the STS Congenital Heart Surgery Mortality Categories.)</p> <p>This measure counts all patients who require any additional unplanned cardiac or non-cardiac operation and/or interventional cardiovascular catheterization procedure occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention. A cardiac operation is defined as any operation that is of the Operation Type of “CPB” or “No CPB Cardiovascular”. The following operations will always be coded as “Planned Reoperation”: (1) Delayed Sternal Closure, (2) ECMO Decannulation, (3) VAD Decannulation, (4) Removal of Broviac catheter. The following operations will always be coded as “Unplanned Reoperation”: (1) Reoperation for bleeding, (2) Reoperation for infection, (3) Reoperation for hemodynamic instability, (4) Reoperation for initiation of ECMO or VAD, (5) Reoperation for residual or recurrent lesion.</p>
18	O-7	Outcome	<p>Operative Mortality Stratified by the Five STS-EACTS Mortality Categories</p> <p>Operative mortality stratified by the five STS-EACTS Mortality Categories, a multi-institutional validated complexity stratification tool</p> <p>See <i>J Thorac Cardiovasc Surg</i> 2009;138:1139-1153. O'Brien et al. An empirically based tool for analyzing mortality associated with congenital heart surgery. Table 1, pp 1140-1146.</p>

(continued)

Table 4. (continued)

Number	Type	Title of Indicator	Description
19	0-8	Outcome	Operative Mortality for Eight Benchmark Operations
			Operative Mortality for Eight Benchmark Pediatric and Congenital Heart Operations: These 8 Eight Benchmark Pediatric and Congenital Heart Operations are tracked when they are the Primary Procedure of an Index Cardiac Operation. (A Cardiac Operation is defined as an operation of Operation Type “CPB” or “No CPB Cardiovascular”.) (These 8 Eight Benchmark Pediatric and Congenital Heart Operations are listed and described in this table in Measure Number S-5.)
20	O-9	Outcome	Index Cardiac Operations Free of Mortality and Major Complication
			“Index Cardiac Operations free of mortality and major complication” is defined as the percent of pediatric and congenital heart surgery Index Cardiac Operations free all of the following: (1) Operative mortality, (2) any one or more of the following major complications occurring or diagnosed during the time interval beginning at admission to operating room and ending 30 days post-operatively or at the time of hospital discharge, whichever is longer: a) <i>Renal failure</i> . Acute renal failure requiring temporary or permanent dialysis (220, 230, 223, 224) STS version 2.5: 220 = Acute renal failure requiring temporary dialysis 230 = Acute renal failure requiring permanent dialysis STS version 3.0: 230 = Renal failure - acute renal failure, Acute renal failure requiring dialysis at the time of hospital discharge 223 = Renal failure - acute renal failure, Acute renal failure requiring temporary dialysis with the need for dialysis not present at hospital discharge 224 = Renal failure - acute renal failure, Acute renal failure requiring temporary hemofiltration with the need for dialysis not present at hospital discharge b) <i>Neurological deficit, Neurological deficit persisting at discharge</i> . STS version 2.5: 320 = Postoperative neurological deficit persisting at discharge STS version 3.0: 320 = Neurological deficit, Neurological deficit persisting at discharge c) <i>Arrhythmia necessitating pacemaker, Permanent pacemaker (60, 74)</i> STS version 2.5: 60 = Postoperative AV block requiring permanent pacemaker STS version 3.0: 74 = Arrhythmia necessitating pacemaker, Permanent pacemaker d) <i>ECMO/VAD</i> . Postop mechanical circulatory support (IABP, VAD, ECMO or CPS) (40) STS version 2.5: 40 = Postoperative mechanical circulatory support (IABP, VAD, ECMO, or CPS) STS version 3.0: 40 = Postoperative/Postprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS) e) <i>Paralyzed diaphragm (possible phrenic nerve injury)</i> . STS version 2.5:

Table 4. (continued)

Number	Type	Title of Indicator	Description
			<p>300 = Phrenic nerve injury/paralyzed diaphragm STS version 3.0: 300 = Paralyzed diaphragm (possible phrenic nerve injury)</p> <p>f) <i>Unplanned reoperation.</i> (20, 22, 26 or 240) STS version 2.5: 20 = Reoperation during this admission (unplanned reoperation) 240 = Bleeding requiring reoperation STS version 3.0: 22 = Unplanned cardiac reoperation during the postoperative or postprocedural time period, exclusive of reoperation for bleeding 24 = Unplanned interventional cardiovascular catheterization procedure during the postoperative or postprocedural time period 26 = Unplanned non-cardiac reoperation during the postoperative or postprocedural time period 240 = Bleeding, Requiring reoperation</p>
21	0-10	Outcome Operative Survivors Free of Major Complication	<p>This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified both by the STS Congenital Heart Surgery Morbidity Categories and the STS Congenital Heart Surgery Mortality Categories.)</p> <p>“Operative survivors free of major complication” is defined as the percent of all surviving (live at discharge and 30 days postoperatively) pediatric and congenital heart surgery index operations free all of the following itemized major complications:</p> <p>a) <i>Renal failure.</i> Acute renal failure requiring temporary or permanent dialysis (220, 230, 223, 224) STS version 2.5: 220 = Acute renal failure requiring temporary dialysis 230 = Acute renal failure requiring permanent dialysis STS version 3.0: 230 = Renal failure - acute renal failure, Acute renal failure requiring dialysis at the time of hospital discharge 223 = Renal failure - acute renal failure, Acute renal failure requiring temporary dialysis with the need for dialysis not present at hospital discharge 224 = Renal failure - acute renal failure, Acute renal failure requiring temporary hemofiltration with the need for dialysis not present at hospital discharge</p> <p>b) <i>Neurological deficit, Neurological deficit persisting at discharge.</i> STS version 2.5: 320 = Postoperative neurological deficit persisting at discharge</p>

(continued)

Table 4. (continued)

Number	Type	Title of Indicator	Description
			STS version 3.0: 320 = Neurological deficit, Neurological deficit persisting at discharge
c)		<i>Arrhythmia necessitating pacemaker, Permanent pacemaker (60, 74)</i>	STS version 2.5: 60 = Postoperative AV block requiring permanent pacemaker STS version 3.0: 74 = Arrhythmia necessitating pacemaker, Permanent pacemaker
d)		<i>ECMO/VAD. Postop mechanical circulatory support (IABP, VAD, ECMO or CPS) (40)</i>	STS version 2.5: 40 = Postoperative mechanical circulatory support (IABP, VAD, ECMO, or CPS) STS version 3.0: 40 = Postoperative/Postprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS)
e)		<i>Paralyzed diaphragm (possible phrenic nerve injury).</i>	STS version 2.5: 300 = Phrenic nerve injury/paralyzed diaphragm STS version 3.0: 300 = Paralyzed diaphragm (possible phrenic nerve injury)
f)		<i>Unplanned reoperation. (20, 22, 26 or 240)</i>	STS version 2.5: 20 = Reoperation during this admission (unplanned reoperation) 240 = Bleeding requiring reoperation STS version 3.0: 22 = Unplanned cardiac reoperation during the postoperative or postprocedural time period, exclusive of reoperation for bleeding 24 = Unplanned interventional cardiovascular catheterization procedure during the postoperative or postprocedural time period 26 = Unplanned non-cardiac reoperation during the postoperative or postprocedural time period 240 = Bleeding, Requiring reoperation
			This measure will be reported as percentage of all Index Cardiac Operations. This measure will also be reported stratified by the 5 STS-EACTS Congenital Heart Surgery Mortality Categories. (STS is developing Congenital Heart Surgery Morbidity Categories. When these STS Congenital Heart Surgery Morbidity Categories are published and available, this metric will be stratified both by the STS Congenital Heart Surgery Morbidity Categories and the STS Congenital Heart Surgery Mortality Categories.)

Abbreviations: STS, Society of Thoracic Surgeons; EACTS, European Association for Cardio-Thoracic Surgery; IABP, intra-aortic balloon pump; VAD, ventricular assist device; ECMO, extracorporeal membrane oxygenation; CPS, cardiopulmonary support system.

Table 5. Consensus definitions of the morbidities

Measure	Organ System	Complication	Definitions
12	Renal	Renal failure - acute renal failure, Acute renal failure requiring dialysis at the time of hospital discharge	Renal failure - acute renal failure (ROOT Definition) + With new postoperative/postprocedural requirement for dialysis, including peritoneal dialysis and/or hemodialysis. Code this complication if the patient requires dialysis at the time of hospital discharge or death in the hospital. (This complication should be chosen only if the dialysis was associated with acute renal failure.) {"Renal failure - acute renal failure" ROOT Definition = Acute renal failure is defined as new onset oliguria with sustained urine output < 0.5 cc/kg/hr for 24 hours and/or a rise in creatinine > 1.5 times upper limits of normal for age (or twice the most recent preoperative/preprocedural values if these are available), with eventual need for dialysis (including peritoneal dialysis and/or hemodialysis) or hemofiltration. Acute renal failure that will be counted as an operative or procedural complication must occur prior to hospital discharge or after hospital discharge but within 30 days of the procedure. (An operative or procedural complication is any complication, regardless of cause, occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention. Operative and procedural complications include both intraoperative/intraprocedural complications and postoperative/postprocedural complications in this time interval.) The complication is to be coded even if the patient required dialysis, but the treatment was not instituted due to patient or family refusal.}
12	Renal	Renal failure - acute renal failure, Acute renal failure requiring temporary dialysis with the need for dialysis not present at hospital discharge	Renal failure - acute renal failure (ROOT Definition) + With new postoperative/postprocedural requirement for temporary dialysis, including peritoneal dialysis and/or hemodialysis. Code this complication if the patient does not require dialysis at the time of hospital discharge or death in the hospital. (This complication should be chosen only if the dialysis was associated with acute renal failure.) {"Renal failure - acute renal failure" ROOT Definition = Acute renal failure is defined as new onset oliguria with sustained urine output < 0.5 cc/kg/hr for 24 hours and/or a rise in creatinine > 1.5 times upper limits of normal for age (or twice the most recent preoperative/preprocedural values if these are available), with eventual need for dialysis (including peritoneal dialysis and/or hemodialysis) or hemofiltration. Acute renal failure that will be counted as an operative or procedural complication must occur prior to hospital discharge or after hospital discharge but within 30 days of the procedure. (An operative or procedural complication is any complication, regardless of cause, occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention. Operative and procedural complications include both intraoperative/intraprocedural complications and postoperative/postprocedural complications in this time interval.) The complication is to be coded even if the patient required dialysis, but the treatment was not instituted due to patient or family refusal.}
12	Renal	Renal failure - acute renal failure, Acute renal failure requiring temporary hemofiltration with the need for dialysis not present at hospital discharge	Renal failure - acute renal failure (ROOT Definition) + With new postoperative/postprocedural requirement for temporary hemofiltration. Code this complication if the patient does not require dialysis at the time of hospital discharge or death in the hospital. (This complication should be chosen only if the hemofiltration was associated with acute renal failure.) {"Renal failure - acute renal failure" ROOT Definition = Acute renal failure is defined as new onset oliguria with sustained urine output < 0.5 cc/kg/hr for 24 hours and/or a rise in creatinine > 1.5 times upper limits of normal for age (or twice the most recent preoperative/preprocedural values if these are available), with eventual need for dialysis (including peritoneal dialysis and/or hemodialysis) or hemofiltration. Acute renal failure that will be counted as an operative or procedural complication must occur prior to hospital discharge or after hospital discharge but within 30 days of the procedure. (An operative or procedural complication is any complication, regardless of cause, occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same

(continued)

Table 5 (continued)

Measure	Organ System	Complication	Definitions
			hospitalization subsequent to the operation or intervention. Operative and procedural complications include both intraoperative/intraprocedural complications and postoperative/postprocedural complications in this time interval.) The complication is to be coded even if the patient required dialysis, but the treatment was not instituted due to patient or family refusal.}
13	Neurologic	Neurological deficit, Neurological deficit persisting at discharge	Newly recognized and/or newly acquired deficit of neurologic function leading to inpatient referral, therapy, or intervention not otherwise practiced for a similar unaffected inpatient, With a persisting neurologic deficit present at hospital discharge. In other words, new (onset intraoperatively or postoperatively - or intraprocedurally or postprocedurally) neurological deficit persisting and present at discharge from hospital.
13	Neurologic	Stroke	“Stroke” ROOT Definition = A stroke is any confirmed neurological deficit of abrupt onset caused by a disturbance in blood flow to the brain, when the neurologic deficit does not resolve within 24 hours.
13	Neurologic	Spinal cord injury, Neurological deficit persisting at discharge	Spinal cord injury (ROOT Definition) + With a persisting neurologic deficit present at hospital discharge. {“Spinal cord injury” ROOT Definition = Newly acquired or newly recognized deficit of spinal cord function indicated by physical exam findings, imaging studies, or both.}
13	Neurologic	Peripheral nerve injury, Neurological deficit persisting at discharge	Peripheral nerve injury (ROOT Definition) + With a persisting neurologic deficit present at hospital discharge. {“Peripheral nerve injury” ROOT Definition = Newly acquired or newly recognized deficit of unilateral or bilateral peripheral nerve function indicated by physical exam findings, imaging studies, or both.}
14	Arrhythmia - Arrhythmia necessitating pacemaker	Arrhythmia necessitating pacemaker, Permanent pacemaker	Implantation and utilization of a permanent pacemaker for treatment of any arrhythmia including heart block (atrioventricular [AV] heart block).
15	Neurologic	Paralyzed diaphragm (possible phrenic nerve injury)	Presence of elevated hemi-diaphragm(s) on chest radiograph in conjunction with evidence of weak, immobile, or paradoxical movement assessed by ultrasound or fluoroscopy.
16	Mechanical support utilization	Postoperative/Postprocedural mechanical circulatory support (IABP, VAD, ECMO, or CPS)	Utilization of postoperative/postprocedural mechanical support, of any type (IABP, VAD, ECMO, or CPS), for resuscitation/CPR or support, during the postoperative/postprocedural time period. Code this complication if it occurs (1) within 30 days after surgery or intervention regardless of the date of hospital discharge, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention.
17	Operative/Procedural	Unplanned cardiac reoperation during the postoperative or postprocedural time period, exclusive of reoperation for bleeding	Any additional unplanned cardiac operation occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention. A cardiac operation is defined as any operation that is of the operation type of “CPB” or “No CPB Cardiovascular”. The following operations will always be coded as “Planned Reoperation”: (1) Delayed Sternal Closure, (2) ECMO Decannulation, (3) VAD Decannulation, (4) Removal of Broviac catheter. The following operations will always be coded as “Unplanned Reoperation”: (1) Reoperation for bleeding, (2) Reoperation for infection, (3) Reoperation for hemodynamic instability, (4) Reoperation for initiation of ECMO or VAD, (5) Reoperation for residual or recurrent lesion.
17	Operative/Procedural	Unplanned interventional cardiovascular catheterization procedure during the postoperative or postprocedural time period	Any unplanned interventional cardiovascular catheterization procedure occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention.
17	Operative/Procedural	Unplanned non-cardiac reoperation during the postoperative or postprocedural time period	Any additional unplanned non-cardiac operation occurring (1) within 30 days after surgery or intervention in or out of the hospital, or (2) after 30 days during the same hospitalization subsequent to the operation or intervention.

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