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Invited Editorial

Perfusion Variables in the 2010 Update of the Society of Thoracic Surgeons Congenital Heart Surgery Database

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An estimated 19,000 congenital and pediatric cardiac surgical procedures are conducted annually in the United States (1). Patients undergoing these procedures are at risk for further morbidity and mortality secondary to the surgery. Although the risks attributed to the preoperative characteristics of the patient and the procedure have been well documented (2–4), much of this research has neglected the impact of discrete intra-operative processes of care on either mitigating or increasing this risk. Meanwhile, there is growing evidence from work in and outside of congenital heart surgery that there is a relationship between variability in care and morbidity and outcomes following surgery (5–7). Unfortunately, variability in practice patterns across surgical centers is not carefully measured.

In 2005, the Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, under the leadership of Dr. Jeffrey Jacobs, was established with the goal of providing infrastructure to facilitate collaboration between health care providers interested in the outcome of treatments provided to patients with congenital heart disease, with the ultimate aim of improving the quality of care delivered to these patients (8). To accomplish this goal, the Multi-Societal Database Committee spans geographical and subspecialty boundaries to involve experts from all disciplines and regions of the world. This collaboration is designed to increase our understanding regarding variations in practice and their consequences.

In an effort to better understand the association between perfusion practice and the outcomes of pediatric and congenital heart surgery patients, the Pediatric Committee of the International Consortium for Evidence-Based Perfusion (ICEBP, *http://www.bestpracticeperfusion.org/*)[1] was invited in 2009 by Jeffrey P. Jacobs, MD, Chair of the Society of Thoracic Surgeons Congenital Heart Surgery Database Taskforce and also Chair of the Multi-Societal Database Committee for Pediatric and Congenital Heart Disease, to assist in the refinement and development of perfusion-related fields for the Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHSD). The ICEBP was asked to:

(1) study and refine the three extant fields in the STS-CHSD (version 2.50) related to perfusion (cardiopulmonary bypass time, aortic cross-clamp time, and deep hypothermic circulatory arrest time), and
(2) propose new fields (and their corresponding definitions) related to perfusion practice for the planned 2010 upgrade of the STS-CHSD.

To accomplish these tasks, the Pediatric Committee of the ICEBP, in collaboration with the Pediatric Committee of the American Society of ExtraCorporeal Technology (http://www.amsect.org), used teleconferences, wiki-based communication software, and e-mail to discuss the definitions of the variable fields for cardiopulmonary bypass time (CPBT), cross-clamp time (CCT), and circulatory arrest time (CAT) found in the present version of the

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[1]The ICEBP is a partnership and collaboration between perfusion societies, medical societies, clinicians, and industry whose mission is to improve continuously the delivery of care and outcomes for our patients. The ICEBP currently comprises 17 perfusion societies spanning Australia and New Zealand, Asia, Europe, and North America.

STS-CHSD (version 2.50). Three smaller subcommittees were organized to develop new fields and definitions focused on three topics:

(1) strategies of circulatory arrest and cerebral perfusion,
(2) strategies of myocardial protection, and
(3) techniques to minimize hemodilution and allogeneic blood transfusions.

Definitions were given consideration with regard to specificity to approximate unequivocal implementation within participating international institutions. Each subcommittee proposed the new fields and definitions to the larger pediatric committee. Subsequently, each field and definition was debated until consensus was achieved. Our recommendations were then submitted to the STS-CHSD Taskforce for final review, discussion, and selection.

The definitions for CPBT, CCT, and CAT were revised and can be found in Table 1 along with their version 2.50 counterpart. Table 2 contains the new variables proposed (and whether the STS-CHSD Taskforce selected them for inclusion) and the complete manuscript that was published in the World Journal for Pediatric and Congenital Heart Surgery can be accessed online for free.[2] In summary, 23 new perfusion-related variables (out of 53 submitted) were selected for inclusion: 14 fields (out of 18 submitted) focused on circulatory arrest and cerebral perfusion, six fields (out of 15 submitted) focused on myocardial protection, and three fields (out of 20 submitted) focused on hemodilution and allogeneic blood transfusions.

The STS Congenital Heart Surgery Database Taskforce, in partnership with the ICEBP, has made substantial changes to the STS-CHSD concerning the fields of data related to the practice of perfusion. Revision of current variables and definitions within the STS-CHSD will minimize ambiguity while improving the accuracy and reliability of the data collected by participating institutions. The creation of new variables (with precise definitions) that are focused on perfusion-specific strategies will, in the very least, identify trends in processes of care. However, the real value of these data could be their utility for identifying best practices, developing clinical practice guidelines, and subsequently validating those guidelines. It is our collective belief that the measurement and study of discrete intra-operative processes of care (and the results of that care) will ultimately improve the outcomes of patients undergoing pediatric and congenital cardiac surgery.

"Every hospital should follow every patient it treats long enough to determine whether the treatment has been successful, and then to inquire 'if not, why not' with a view to preventing similar failures in the future"- Ernest Amory Codman, 1914.

[2] https://online.sagepub.com/cgi/register?registration=WJPCHS2009

Table 1. Revised fields and definitions.

	Version 2.5 (STS-CHSD)	Version 3.0 (STS-CHSD)
Cardiopulmonary Bypass Time	Indicate the total number of minutes on cardiopulmonary bypass. If more than one run of cardiopulmonary bypass (CPB) required during this surgical procedure, the sum of the bypass runs will equal the total number of CPB minutes.	Indicate the total number of minutes that systemic return is diverted into the cardiopulmonary bypass (CPB) circuit and returned to the systemic system. This time period (Cardiopulmonary Bypass Time) includes all periods of cerebral perfusion and sucker bypass. This time period (Cardiopulmonary Bypass Time) excludes any circulatory arrest and modified ultrafiltration periods. If more than one period of CPB is required during the surgical procedure, the sum of all the CPB periods will equal the total number of CPB minutes. Enter zero if cardiopulmonary bypass technique was not used.
Cross-Clamp Time	Indicate the total number of minutes the aorta is completely cross-clamped during this surgical procedure. Enter zero if no cross-clamp was used.	Indicate the total number of minutes that the coronary circulation is mechanically isolated from systemic circulation, either by an aortic cross-clamp or systemic circulatory arrest. This time period (Cross-Clamp Time) includes all intervals of intermittent or continuous cardioplegia administration. If more than one cross-clamp period is required during this surgical procedure, the sum of the cross-clamp periods is equal to the total number of cross-clamp minutes. Enter zero if the coronary circulation was never mechanically isolated from systemic circulation, either by an aortic cross-clamp or systemic circulatory arrest. For the following two operations: (1) "Transplant, Heart", and (2) "Transplant, Heart and lung", the field "Cross-Clamp Time" will be defined as the cross-clamp time of the donor heart. Therefore, these two operations represent the only operations where the field "Cross-Clamp Time" can be greater than the field "Cardiopulmonary Bypass Time".
Circulatory Arrest Time	Indicate the total number of required circulatory arrest minutes. If more than one period of circulatory arrest required during this surgical procedure, the sum of these periods is equal to the total duration of circulatory arrest. Enter zero if circulatory arrest technique was not used.	Indicate the total number of minutes of complete cessation of blood flow to the patient. This time period (Circulatory Arrest Time) excludes any periods of cerebral perfusion. If more than one period of circulatory arrest is required during this surgical procedure, the sum of these periods is equal to the total duration of circulatory arrest. Enter zero if circulatory arrest technique was not used.

Table 2. New fields and definitions.

Variable Name	Definition	Selected for Inclusion
Circulatory Arrest and Cerebral Perfusion		
Lowest Patient Temperature	Indicate the lowest patient temperature (Celsius) achieved during cardiopulmonary bypass.	Yes
Patient Temperature Monitoring Site	Indicate the patient temperature-monitoring site used during this procedure to determine lowest and highest patient temperature during cardiopulmonary bypass. • Bladder • Esophageal • Nasopharyngeal • Rectal • Tympanic • Other	Yes
Cooling Time	Indicate the number of minutes of active cooling prior to initiation of circulatory arrest or cerebral perfusion. Enter zero if circulatory arrest or cerebral perfusion was not used	Yes
Hematocrit Prior to Circulatory Arrest or Cerebral Perfusion	Indicate the last hematocrit value prior to initiation of circulatory arrest or cerebral perfusion. Enter zero if circulatory arrest or cerebral perfusion was not used.	Yes
Oxygenation	Indicate the oxygenation strategy (Venous pO2) used during the cooling phase of cardiopulmonary bypass prior to initiation of circulatory arrest or cerebral perfusion. Enter zero if circulatory arrest or cerebral perfusion was not used. • <100 mmHg • 101–300 mmHg • >300 mmHg	No
Arterial Blood Gas Management During Cooling	Indicate the arterial blood gas management strategy used during the cooling phase of cardiopulmonary bypass prior to initiation of circulatory arrest or cerebral perfusion. Enter zero if circulatory arrest or cerebral perfusion was not used. • Alpha STAT • pH STAT • pH STAT cooling/Alpha STAT rewarming • Other combination	Yes
Cerebral Perfusion Time	Indicate the total number of minutes cerebral perfusion was performed. This would include antegrade or retrograde cerebral perfusion strategies. Enter zero if cerebral perfusion was not used.	Yes
Cerebral Perfusion Cannulation	Indicate all sites of cannulation used for cerebral perfusion. Enter none if cerebral perfusion was not used. • Innominate artery • Right subclavian • Right axillary artery • Right carotid artery • Left carotid artery • Superior vena cava • None	Yes
Cerebral Perfusion Periods	Indicate the number of periods of cerebral perfusion. For example, if the cerebral perfusion time is a total of 20 minutes and the patient received four separate 5-minute periods of cerebral perfusion, the cerebral perfusion periods would be 4. Enter zero if cerebral perfusion was not used.	Yes
Arterial Blood Gas Management During Cerebral Perfusion	Indicate the arterial blood gas management strategy used during periods of cerebral perfusion. Enter zero if cerebral perfusion was not used. • Alpha STAT • pH STAT • Combination	No
Cerebral Perfusion Flow Rate	Indicate the cerebral perfusion flow rate in milliliters per kilogram (mL/kg). Enter zero if cerebral perfusion was not used.	Yes
Cerebral Perfusion Temperature	Indicate the perfusate temperature (Celsius) maintained during cerebral perfusion. Enter zero if cerebral perfusion was not used.	Yes
Maximum Arterial Inflow Temperature	Indicate the highest arterial inflow temperature (Celsius) during the rewarming phase of cardiopulmonary bypass.	No
Rewarming Time	Indicate the number of minutes from the initiation of rewarming until the target rewarming temperature is achieved	Yes
Highest Patient Temperature	Indicate the highest patient temperature (Celsius) achieved during cardiopulmonary bypass. Enter the temperature from the site identified in the field Patient Temperature Monitoring Site.	No
Pre-Induction Baseline Cerebral Regional Oxygen Saturation	Indicate the percent baseline left and right or center (single sensor) cerebral regional oxygen saturation (rSO2) values at the beginning of the operation, when the patient is awake and functional. Patient can be sedated or on supplemental oxygen at the time measurement is taken. In the absence of a user-specified baseline, the oximeter will automatically select a baseline value from the first few minutes of the procedure. Units are %.	Yes
Cumulative Cerebral Saturation Below Threshold	Indicate the cumulative integral of time and depth of desaturation events below the threshold of 50% for the left and right or center (single sensor) rSO2, calculated by the oximeter by multiplying the difference between the threshold and current rSO2 values times the duration that rSO2 is below the threshold. Values are accumulated throughout the operation. Units are minute-%. This is also called area under the curve.	Yes

(Continued)

Table 2. Continued

Variable Name	Definition	Selected for Inclusion
Skin Closure Cerebral Regional Oxygen Saturation	Indicate the left and right or center (single sensor) cerebral regional oxygen saturation of blood (rSO2) value at the time of skin closure at the end of the operation. Units are %.	Yes
Myocardial Protection		
Myocardial Ischemic Time	Indicate the sum of the periods of myocardial ischemia between intervals of cardioplegia administration. Each period of myocardial ischemia begins with the cessation of cardioplegia administration and ends either at the initiation of the subsequent interval of cardioplegia administration or coronary reperfusion at aortic cross-clamp removal. If only one interval of cardioplegia was used during the case, the myocardial ischemic time ends with coronary reperfusion at aortic cross-clamp removal.	No
Longest Myocardial Ischemic Interval	Indicate the maximum time interval in minutes (min) between the cessation of cardioplegia administration and either the initiation of the subsequent administration of cardioplegia or coronary reperfusion at the removal of the aortic cross-clamp.	Yes
Total volume of Crystalloid Cardioplegia Administered	Indicate the total volume (mL) of crystalloid cardioplegia administered during this procedure. This does not include the blood volume in blood cardioplegia. If microplegia was administered enter the total volume of additives administered in this procedure. Enter zero if cardioplegia was not used.	No
Cardioplegia Solution	Indicate the mechanism of arrest of the cardioplegia solution used during this procedure. Depolarizing cardioplegia would include solutions that use only a depolarizing agent (e.g., potassium) to arrest the heart. Hyperpolarizing cardioplegia would include solutions that use adenosine triphosphate–sensitive potassium channel opening agents (e.g., Nicorandil, pinacidil, cromakalim, minoxidil, aprilkalim, loprazolam, adenosine) to arrest the heart. Modified depolarizing cardioplegia would include solutions that combine a depolarizing agent (e.g., potassium) with additional membrane stabilizing additives (e.g., magnesium or lidocaine) to arrest the heart. • Hyperpolarizing • Depolarizing • Modified Depolarizing • None	Yes
Cardioplegia Delivery Ratio	Indicate the ratio of blood to cardioplegia solution (BS:CS) used during this procedure. This includes microplegia systems and cardioplegia systems utilizing a syringe pump to introduce the cardioplegic solution into the blood base solution. If only crystalloid cardioplegia was used in this procedure, the ratio is entered as 0:1. For microplegia and syringe pump systems enter the average ratio for all cardioplegia deliveries. For example, if a total of 300 mL of blood and 10 mL of cardioplegia solution were given during the entire procedure, the resultant average ratio would be 30:1.	Yes
Delivery Route of the Initial Administration of Cardioplegia	Indicate the delivery route of the initial administration of cardioplegia. Indicate all that apply. • Antegrade aortic root • Antegrade right coronary ostia • Antegrade left coronary ostia • Retrograde coronary sinus • None	Yes
Volume of Initial Administration of Cardioplegia	Indicate the volume of cardioplegia in milliliters (mL) delivered in the initial administration of cardioplegia. If a single or continuous administration of cardioplegia is used, enter the total volume of cardioplegia administered.	No
Temperature of Initial Administration of Cardioplegia	Indicate the temperature (Celsius) of the initial administration of cardioplegia.	No
Delivery Route of the Subsequent Administration(s) of Cardioplegia	Indicate the delivery route of the subsequent administration(s) of cardioplegia. Indicate all that apply. • Antegrade aortic root • Antegrade right coronary ostia • Antegrade left coronary ostia • Retrograde coronary sinus • None	Yes
Volume of Subsequent Administration(s) of Cardioplegia	Indicate the total volume of cardioplegia in milliliters (mL) delivered during all subsequent administrations of cardioplegia. Enter zero if a single administration or continuous cardioplegia was used.	No
Temperature of Subsequent Administration(s) of Cardioplegia	Indicate the temperature (Celsius) of subsequent cardioplegia administration(s).	No
Warm Blood Reperfusion	Indicate the volume in milliliters (mL) of warm blood reperfusion administered without cardioplegia solution during the aortic cross-clamp period. Enter zero if warm blood reperfusion was not used.	No
Arterial Temperature at Cross-Clamp Removal	Indicate the arterial inflow temperature (Celsius) at the time the aortic cross-clamp is removed.	No
Number of Defibrillations After Aortic Cross-Clamp Removal	Indicate the number of defibrillations after removal of the aortic cross-clamp. Enter zero if no defibrillations were performed.	No

(Continued)

Table 2. Continued

Variable Name	Definition	Selected for Inclusion
Cardioplegia Number of Doses	Indicate the number of doses of cardioplegia administered.	Yes
Hemodilution and Allogeneic Blood Transfusions		
First Hematocrit in Operating Room	Indicate the first hematocrit (HCT) measured in the operating room and prior to any acute normovolemic hemodilution (ANH) procedure. If there is no HCT measured prior to ANH, the HCT value measured closest to the time of surgery should be entered	No
Acute Normovolemic Hemodilution	Indicate the volume of whole blood removed from the patient prior to initiation of CPB. Enter zero if ANH was not performed.	No
Target HCT	If ANH is performed, indicate the desired (Target) HCT range after completion of ANH procedure. Enter zero if ANH is not performed. • 25–30% • 20–25% • <20%	No
Post ANH HCT	Indicate HCT measurement after completion of the ANH procedure.	No
Autologous Prime Volume (Retrograde Autologous Prime/Venous Autologous Prime)	Indicate the volume of crystalloid prime removed from the CPB circuit prior to initiation of CPB.	No
Venous Line Preparation	Indicate if CPB was initiated with an unprimed venous line.	No
First HCT on CPB	Indicate the first HCT measured after initiation of CPB.	No
Lowest HCT on CPB	Indicate lowest HCT measured during CPB.	Yes
Last HCT on CPB	Indicate last HCT measured on CPB prior to termination of CPB.	No
Reinfusion of Autologous Blood	Indicate if the patient's whole blood removed during the ANH procedure was reinfused. • During CPB • After CPB • Postoperatively in the intensive care unit • Not reinfused	No
CPB Circuit Coatings	Indicate if a "biocompatible" circuit was used; characterize the type/brand. • Carmeda and Trillium (Medtronic, Brooklyn Park, MN) • Phosphorylcholine and SMART (Sorin Group, Arvada, CO) • Surface Modifying Additive Treated (SMART) • X-Coating (Terumo Cardiovascular Systems, Ann Arbor, MI) • GBS - Gish Biocompatible Surface Coating (Gish Miomedical, Rancho Santa Margarita, CA) • X-Coating • Combination • Other • No coating used	No
CPB Filter	Indicate the type of arterial filter incorporated in the CPB circuit. • Filter not used • Separate arterial filter • Integrated arterial filter and oxygenator	No
Static Prime Volume	Indicate the minimum volume of fluid necessary to prime the CPB circuit from tip to tip at a no-flow state and minimal reservoir level. This value is independent of the net priming volume after retrograde arterial prime, draining the venous line or other maneuvers to minimize hemodilution. Cardioplegia prime volume should be **excluded** from the static prime volume.	No
Asanguineous Volume	Indicate the total amount of asanguineous fluid used to initiate CPB. This should include crystalloid, colloid, and medications, but not blood or such volumes as removed by autologous priming or other strategies used to minimize hemodilution.	No
Blood Prime	If the CPB circuit was primed with blood, indicate the type of blood product and number of units used. Enter zero if blood prime was not used. • Whole blood • Packed red cells	No
Modified Ultrafiltration	Indicate the volume of fluid removed during modified ultrafiltration. Enter zero if modified ultrafiltration was not performed.	No
Ultrafiltration	Indicate the volume of fluid removed during ultrafiltration while on CPB. Enter zero if ultrafiltration was not performed during CPB.	No
Asanguineous Fluid Added During CPB	Indicate the total volume of asanguineous fluid including crystalloid, colloid, and medications added during CPB. This should not include crystalloid cardioplegia solutions.	No
Intraop Blood Products	Indicate whether blood products were transfused any time intraoperatively during the initial surgery. Intraoperatively is defined as any blood started inside of the operating room. • Whole blood units and milliliters • Packed red blood cells units and milliliters • Fresh frozen plasma units and milliliters • Platelets units and milliliters • Cryoprecipitate units and milliliters	Yes
Intraop Blood Products Refused	Indicate whether the patient or family refused blood products.	Yes

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