Early Postoperative Severity of Illness Predicts Outcomes After the Stage I Norwood Procedure

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Background. **We hypothesize that a measure of the immediate postoperative severity of illness after the stage I Norwood operation reflects technical performance or the adequacy of anatomic repair and can serve as a predictor of hospital mortality, reinterventions, and clinical outcomes.**

Methods. **One hundred thirty-five patients undergoing stage I were retrospectively studied (2004 to 2007). The severity of illness on postoperative day 1 (POD1) was measured using the Pediatric Risk of Mortality III (PRISM) scoring system. Technical performance scores (optimal, adequate, inadequate) were calculated before hospital discharge. Hospital mortality, postoperative reinterventions, and complications were recorded. Postoperative reintervention was defined as need for cardiac catheterization laboratory or operating room based procedure that included balloon dilation or repair of arch obstruction, shunt revision, reoperations for bleeding, and extracorporeal membrane oxygenation support.**

Results. **Hospital mortality was 14.1% (n = 19). The rate of complications and reinterventions was, respectively, 28.1% (n = 38) and 26.7% (n = 36). The POD1 PRISM score was associated with technical performance ($p = 0.003$). Higher POD1 PRISM scores were associated with mortality ($p < 0.001$), complications ($p < 0.001$), and reinterventions ($p = 0.001$). The POD1 PRISM score had high discrimination for mortality, complications, reinterventions, and inadequate technical performance (areas under the receiver operating characteristic curve were 0.835, 0.776, 0.773, and 0.710, respectively; $p \leq 0.001$ for all).**

Conclusions. **The severity of illness as measured by PRISM score on POD1 after the stage I Norwood operation has strong association and discrimination with hospital mortality, postoperative reinterventions, inadequate technical performance, and major postoperative complications. It may be used as an early surrogate of technical performance to initiate a search for and correction of technical deficiencies.**

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Outcomes after the stage I Norwood procedure have been correlated with various factors including patient specific anatomic or physiologic variables (prematurity, lower weight, intact atrial septum, smaller ascending aorta, and so forth) as well as procedure-specific or technical factors (circulatory arrest time, shunt originating from the neoaorta, management of the ascending aorta, and so forth) [1–3]. We have previously examined the interaction between preoperative baseline physiology, case complexity, technical performance or adequacy of anatomic repair, and postoperative outcomes, focusing on hospital mortality [4]. We concluded that optimal technical performance attenuated the effects of poor preoperative physiologic status and high case complexity with reduced hospital morbidity and mortality, whereas inadequate technical performance resulted in poor outcomes regardless of preoperative status.

The Pediatric Risk of Mortality (PRISM) scoring system, a risk adjustment tool first published in 1988 [5], is a generic severity-scoring system developed to measure the probability of death on the basis of the hypothesis that physiologic instability reflects mortality risk. The newer and improved PRISM III [6] scoring system, developed in 1996, is more accurately calibrated and discriminates mortality well for individual patients.

Although it appears intuitive that a higher physiologic illness severity in the immediate postoperative period may be associated with higher mortality rate, this has not been previously tested for the stage I Norwood procedure. Early identification of patients likely to have postoperative complications attributable to poor technical performance may facilitate early intervention to correct the technical inadequacies, which may mitigate their

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impact. The potential use of a new tool available in the immediate postoperative period, with high predictive ability of outcomes, technical deficiencies, and need for reintervention could be used as a trigger for timely institution of diagnostic tests and necessary reinterventions, averting adverse outcomes. Certain perioperative monitoring strategies that include venous oximetry and near-infrared spectroscopy, and peak blood lactate levels in the postoperative period have been used to guide interventions and patient management [7–10], but a measurement of the postoperative physiologic illness severity by the constellation of different physiologic variables in a previously validated scoring system, such as the PRISM III, has not been tested. Although the measurement of technical performance in the stage I Norwood procedure, as shown in our previous studies [4, 11], offers invaluable information, it incorporates data collected retrospectively at the time of patient discharge, and thus has a limited utility in prospectively guiding patient management.

Therefore, we hypothesize that a measure of the immediate postoperative severity of illness after the stage I Norwood operation reflects technical performance and adequacy of anatomic repair and can serve as a predictor of hospital mortality, reinterventions, and clinical outcomes.

Patients and Methods

The Children's Hospital Boston Institutional Review Board approved this study. A waiver of informed consent was obtained. Patient data were rendered anonymous in our database in compliance with the hospital requirements.

Physiologic Illness Severity Measurement Tool

The PRISM III scoring system [6] was used as a measurement tool of the severity of illness. The PRISM III score has 17 physiologic variables, subdivided into 26 ranges that are age adjusted. These include the worst values of cardiovascular and neurologic vital signs, acid–base balance, blood gas values, chemistry, and hematologic tests, from the first 12 or 24 hours after admission to the intensive care unit (Table 1). Postoperative day 1 (POD1) PRISM III scores were calculated by using the standardized scoring system at 24 hours after the stage I Norwood procedure.

Technical Performance

The predischarge technical performance was judged based on criteria of the adequacy of anatomic repair, as previously described [4, 11, 12], and was categorized as optimal, adequate, or inadequate. In brief, the stage I Norwood procedure was divided into individual components defined as subprocedures, which were based on the specific anatomic regions subject to intervention. These subprocedures included atrial septectomy, aortic root reconstruction (coronary perfusion), proximal arch reconstruction, distal arch reconstruction, and source of pulmonary blood flow (either modified Blalock-Taussig shunt or right ventricle to pulmonary artery conduit). The variables for score assessment were based on clinical, echocardiographic, and cardiac catheterization data [4, 11].

Table 1. Pediatric Risk of Mortality (PRISM) III Physiologic Variables

Physiologic Variable
Cardiovascular and neurologic vital signs
Systolic blood pressure, heart rate, temperature, pupillary reflexes, mental status
Acid–base/blood gases
Acidosis, total CO_2, pH, paO_2, pCO_2
Chemistry
Glucose, potassium, creatinine, blood urea nitroge
Hematology
White blood cell count, prothrombin time or partial thromboplastin time, platelet count

Modified from Pollack et al [6].

Mortality

In-hospital mortality was defined as death before hospital discharge or within 30 days of the operation. Patients transferred back to their referring hospital were followed up through their discharge, and a death occurring at a referring hospital was counted in the mortality figures. Postoperative hospital and intensive care unit stays and ventilation time were measured in days after the stage I operation.

Major Complications

Major postoperative complications were defined as stroke or major neurologic deficit, cardiac arrest with cardiopulmonary resuscitation, and postoperative reinterventions, which included intraoperative or postoperative initiation of extracorporeal membrane oxygenation (ECMO) for resuscitation, reoperation for bleeding for hemodynamic instability, unplanned reoperation for residual defect or shunt revision, phrenic nerve paralysis requiring diaphragm plication, and mediastinitis with sternal debridement.

Postoperative Reinterventions

Postoperative reinterventions, many of which were also part of the major postoperative complications, were classified as catheterization laboratory–based or operating room–based. Catheterization laboratory–based postoperative reinterventions included balloon dilation of residual stenoses such as restrictive atrial septal defects, aortic arch obstructions, branch pulmonary artery, pulmonary vein or shunt stenoses, or catheter-based clot lysis. Operating room–based postoperative reinterventions included reoperations to correct residual aortic arch obstruction, modified Blalock-Taussig shunt, or right ventricle to pulmonary artery conduit deficiencies such as stenosis or clotted shunts, including downsizing of shunts, postoperative institution of ECMO for resuscitation, postoperative reexploration for bleeding for hemo-

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