Association between Technical Performance Scores and neurodevelopmental outcomes after congenital cardiac surgery

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Objectives: Technical Performance Score (TPS) has been shown to have a strong association with early and late outcomes after congenital cardiac surgery, with greater morbidity and reintervention in children with major residual lesions (TPS class 3). We sought to explore the effect of TPS on the neurodevelopmental outcomes.

Methods: All infants undergoing cardiac surgery, excluding those with trisomy 21, were offered neurodevelopmental testing at 1 year of age using the Bayley Scales of Infant Development, 3rd edition. TPSs from the discharge echocardiograms were graded as class 1 (optimal), class 2 (minor residual), or class 3 (major residual). Multivariate regression analysis was performed using patient characteristics and preoperative variables.

Results: Neurodevelopmental testing was performed in 140 patients at a median age of 16 months. Of these, 28 (20%) had single ventricle palliation; 39 (28%) were in Risk Adjustment for Congenital Heart Surgery category 4 to 6. Significant differences between the groups were found in the cognitive ($P = .01$) and motor ($P = .05$) domains, with subjects in TPS class 3 having significantly lower cognitive and motor composite scores. The scores did not vary significantly according to single ventricle versus biventricular repair or Risk Adjustment for Congenital Heart Surgery categorization. In multivariate modeling, class 3 TPS remained significantly associated with a lower Bayley cognitive score ($P = .02$), with a trend toward a lower Bayley motor score ($P = .08$).

Conclusions: We found that TPS is an independent predictor of neurodevelopmental outcomes after infant heart surgery. Future research should explore whether a structured program of intraoperative recognition and intervention on residual lesions can improve the TPS and neurodevelopmental outcomes. (J Thorac Cardiovasc Surg 2014;148:232-7)

⌨ Supplemental material is available online.

Congenital heart disease is the most common birth defect, occurring in 9/1000 live births, one third of whom require intervention in infancy.[1,2] Although the survival rates have significantly increased, numerous studies have documented the neurodevelopmental (ND) deficits experienced by children with congenital heart defects across different ages.[1-8]

It is well known that the outcomes after surgery for complex congenital cardiac defects are dependent on multiple factors, including disease complexity, preoperative severity of illness and physiologic status, intraoperative conduct of the operation, and postoperative course, including length of hospital stay, care in the intensive care unit, and events requiring intervention before discharge.[9,10] Among these multiple factors, the technical adequacy of the repair might be the single most important factor determining outcomes. In previous work at our institution,[11,12] we have developed and validated a scoring system termed the "Technical Performance Score" (TPS) that scores the adequacy of the repair using specific echocardiographic and clinical criteria at discharge. We have shown that class 3 (inadequate TPS, major residual defect often requiring predischarge surgical or catheter-based reintervention on the treated anatomic area) was strongly associated, not only with early mortality and complications, but also with significantly increased resource use, as measured by ventilation time, hospital length of stay, and hospital charges after adjusting for patient-specific factors such as age, presence of chromosomal or other nonchromosomal abnormalities, prematurity, and disease complexity.[13-15] We were also able to show that this significant association between class 3 (inadequate) TPS persisted during mid-term follow-up for mortality and the need for late reintervention.[16,17]

We hypothesized that a strong association would exist between class 3 (inadequate) TPS and poorer ND outcomes (NDOs). The present study investigated the relationship

Abbreviations and Acronyms
BSID	= Bayley Scales of Infant Development, 3rd edition
ECMO	= extracorporeal membrane oxygenation
ICU	= intensive care unit
ND	= neurodevelopmental
NDO	= neurodevelopmental outcomes
RACHS-1	= Risk Adjustment for Congenital Heart Surgery
TPS	= Technical Performance Score

between the TPS and NDOs in a group of infants who had undergone a wide variety of congenital cardiac operations in the first year of life and returned for ND follow-up from 14 months to 3 years of age.

METHODS

A retrospective chart review of all infants <1 year old, who had undergone surgery from August 2008 to September 2011 and who had undergone ND testing at our center, was performed with institutional review board approval. Patients with trisomy 21 were excluded because of the known developmental delays associated with that population.

Technical Performance Score

Every patient had a TPS determined using discharge echocardiographic findings and clinical status at discharge from the index operation. The procedures were subdivided into components. Each component was scored as class 1 (optimal, no residual defect), class 2 (adequate, minor residual defect), or class 3 (inadequate or major residual defect). Any unplanned predischarge reintervention on the anatomic area repaired at the index surgery for a major residual defect resulted in a class 3 TPS. The final score for the procedure was determined by the summation of the subprocedure scores. The final score was deemed class 1 (optimal) if all subprocedure scores were optimal, class 2 (adequate) if ≥1 subprocedure scores were adequate, and class 3 (inadequate) if ≥1 subprocedure scores were inadequate.

ND Testing

ND testing was conducted using the Bayley Scales of Infant Development, Third Edition (BSID), which was administered by a psychologist. The BSID is a standardized measure that evaluates the current development of infants and children ≤3.5 years old. Composite scores (mean ± standard deviation, normal range 100 ± 15) were reported for the cognitive, language, and motor domains. In addition, the parents completed the Bayley Social-Emotional and Adaptive Behavior Questionnaire, a standardized questionnaire assessing the social and emotional development and adaptive functioning of children. Composite scores (mean ± standard deviation, normal range 100 ± 15) were reported for the overall social and emotional and adaptive functioning.

Risk Adjustment for Congenital Heart Surgery Risk Categories

The Risk Adjustment for Congenital Heart Surgery (RACHS-1)[18,19] method was developed to adjust for baseline case mix differences in risk when comparing in-hospital mortality among groups of patients aged <18 years undergoing congenital heart surgery. A nationally representative 11-member panel of pediatric cardiologists and cardiac surgeons used clinical judgment to place surgical procedures into 6 groups with a similar risk of in-hospital mortality; these risk categories were then refined using empirical data from the Pediatric Cardiac Care Consortium and 3 statewide hospital discharge databases. Category 1 has the lowest risk of death and category 6, the highest. Patients with combinations of cardiac surgical procedures (eg, repair of coarctation of the aorta and ventricular septal defect closure) should be placed in the risk category corresponding to the single highest risk procedure. The RACHS-1 risk categories have been widely validated for the outcome of in-hospital mortality and have also been used with other outcomes, including complications and total hospital charges.

Statistical Analysis

The patient and procedural characteristics are summarized using the median and range for continuous variables and the frequency and percentage for categorical variables. The mean ND scores were compared across TPS categories using 1-way analysis of variance. Because ND testing is voluntary in our center, we performed a sensitivity analysis to compare patients who had undergone ND testing with those who had not, to confirm the presence or absence of a selection bias in our study cohort. Relationships between the pre- and postoperative factors and TPS category were explored using the Kruskal-Wallis test for continuous variables and Fisher's exact test for categorical variables. Univariate associations between the BSID cognitive and motor composite scores and the pre- and postoperative factors were assessed using the unpaired t test or Spearman rank correlation coefficient. Only preoperative patient factors were considered for inclusion in the multivariate linear regression models. Previous work has demonstrated collinearity between the TPS category and intraoperative factors, such as the cardiopulmonary bypass time and aortic crossclamp time. Similarly, TPS is strongly associated with postoperative variables such as the need for extracorporeal membrane oxygenation (ECMO), ventilator duration, and intensive care unit (ICU) length of stay. We, however, did include the circulatory arrest time in our multivariate modeling, because previous large ND studies have shown a relationship between circulatory arrest and NDO. Preoperative factors significant at the $P = .20$ level were considered for inclusion, and the models were fitted using forward selection. Only factors significant at the $P = .10$ level were retained in the final model. Our primary goal was to assess the association between the TPS and the NDOs. Other covariates were considered to be potential confounders in the present analysis. Because covariates that have only a borderline significant relationship with the outcome can still be confounders, we chose a less stringent significance level of $P = .1$ for inclusion. The TPS category was then added to the model to determine whether it remained significantly associated with the NDOs after risk adjustment. Partial coefficients of determination were calculated for each variable in the final model. All analyses were performed using STATA, version 12 (StataCorp LP, College Station, Tex) for statistical analysis.

RESULTS

ND testing was performed in 140 infants (excluding those with trisomy 21) at a median age of 16 months. Of the 140 patients, 28 (20%) had single ventricle anatomy, 11 (8%) were diagnosed with known genetic conditions, 29 (21%) had additional noncardiac congenital anomalies, and 122 (87%) underwent surgery using cardiopulmonary bypass. Seven patients (5%) were premature (1 at 30 weeks and 2 each at 33, 35, and 36 weeks of gestation). The patient and procedural characteristics are listed in Table 1. All patients who underwent ND testing could be assigned a RACHS-1 category.

The mean BSID composite scores for the entire cohort were as follows: cognitive, 100 ± 17 (range, 43-145);

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