

## Technical performance score is associated with outcomes after the Norwood procedure

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**Objectives:** The technical performance score (TPS) has been reported in a single center study to predict the outcomes after congenital cardiac surgery. We sought to determine the association of the TPS with outcomes in patients undergoing the Norwood procedure in the Single Ventricle Reconstruction trial.

**Methods:** We calculated the TPS (class 1, optimal; class 2, adequate; class 3, inadequate) according to the predischarge echocardiograms analyzed in a core laboratory and unplanned reinterventions that occurred before discharge from the Norwood hospitalization. Multivariable regression examined the association of the TPS with interval to first extubation, Norwood length of stay, death or transplantation, unplanned postdischarge reinterventions, and neurodevelopment at 14 months old.

**Results:** Of 549 patients undergoing a Norwood procedure, 356 (65%) had an echocardiogram adequate to assess atrial septal restriction or arch obstruction or an unplanned reintervention, enabling calculation of the TPS. On multivariable regression, adjusting for preoperative variables, a better TPS was an independent predictor of a shorter interval to first extubation ( $P = .019$ ), better transplant-free survival before Norwood discharge ( $P < .001$ ; odds ratio, 9.1 for inadequate vs optimal), shorter hospital length of stay ( $P < .001$ ), fewer unplanned reinterventions between Norwood discharge and stage II ( $P = .004$ ), and a higher Bayley II psychomotor development index at 14 months ( $P = .031$ ). The TPS was not associated with transplant-free survival after Norwood discharge, unplanned reinterventions after stage II, or the Bayley II mental development index at 14 months.

**Conclusions:** TPS is an independent predictor of important outcomes after Norwood and could serve as a tool for quality improvement. (J Thorac Cardiovasc Surg 2014;148:2208-14)

See related commentary on pages 2214-5.

Supplemental material is available online.

The technical performance score (TPS) is a quality improvement tool that was developed to determine the technical adequacy of an intended surgical procedure. It has been validated for a subset of common congenital cardiac operations at a single center.<sup>1-8</sup> For neonates undergoing the Norwood procedure at a single institution,

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### Abbreviations and Acronyms

ASD	= atrial septal defect
IQR	= interquartile range
LOS	= length of stay
MDI	= mental developmental index
PA	= pulmonary artery
PDI	= psychomotor developmental index
SVR	= single ventricle reconstruction
TPS	= technical performance score

an optimal TPS mitigated the effects of the preoperative physiologic status and illness severity during the initial hospital stay.<sup>2,3,9</sup> However, the TPS requires validation in a multicenter study.

We sought to determine the validity of TPS across multiple centers using the database from the Pediatric Heart Network's Single Ventricle Reconstruction (SVR) trial.<sup>10-15</sup> Specifically, we explored whether the TPS could predict early and late outcomes, including resource usage. We hypothesized that the TPS could also identify patients at higher risk of reintervention in the interstage phase.

## METHODS

We performed a secondary analysis of the data from the SVR trial, for which the inclusion and exclusion criteria, study design, and data collection have been previously described.<sup>10-15</sup>

### Technical Performance Scoring System

All subjects were assigned a TPS according to the following data obtained before Norwood hospital discharge: postoperative, protocol-driven transthoracic echocardiographic findings interpreted by a core laboratory and unanticipated surgical or catheter-based reintervention in the areas of Norwood repair before discharge from the hospitalization associated with the Norwood procedure. The TPS module used in our analyses, as modified from the original reported by Bacha and colleagues,<sup>2</sup> is summarized in [Table E1](#).

In brief, the surgical procedures were divided into components that were assigned a score of class 1 (optimal), class 2 (adequate), or class 3 (inadequate) according to specific echocardiographic criteria and the occurrence of unplanned reinterventions at surgical repair sites before discharge from the Norwood hospitalization ([Table E1](#)). The overall classification of the operation as class 1, 2 or 3 was determined from the highest class assignment for any of the component subprocedures. All components of the Norwood TPS module in its current version were given equal weight.

Two additional classes were created to allow the inclusion of all subjects in the SVR trial. Class 4 included subjects who had had no core laboratory echocardiograms and no unanticipated reinterventions in the area of Norwood repair before discharge or death. Class 5 included subjects with echocardiograms inadequate for TPS assignment and no unanticipated Norwood surgical reinterventions before discharge or death.

### Outcomes

Our primary outcome was the interval to the initial endotracheal extubation, because it is a well known surrogate for resource usage. We did not choose mortality as our primary endpoint because a vast majority of class 4 (no echocardiogram) patients died and thus could not be

assigned a TPS. The secondary outcomes included early mortality or transplantation, defined as occurring before Norwood discharge or within 30 days of the Norwood procedure if discharged before 30 days, whichever was longer; Norwood hospitalization length of stay (LOS); late mortality or transplantation; unplanned reinterventions after Norwood discharge; and the psychomotor development index (PDI) and mental development index (MDI) scores of the "Bayley Scales of Infant Development, 2nd edition."

### Classification of Unplanned Reinterventions After Norwood Discharge

The following postdischarge reinterventions were considered to be attributable to the Norwood procedure technique: (1) any reintervention on the aortic arch, atrial septum, or ascending aorta or proximal pulmonary artery (PA) connection; (2) extensive PA rehabilitation, excluding simple PA augmentation at the stage II or Fontan procedure; and (3) any reintervention on the modified Blalock-Taussig shunt or right ventricle-to-PA shunt between Norwood discharge and the stage II procedure.

The following postdischarge reinterventions were considered not to be attributable to the Norwood procedure technique: (1) coiling of the aortopulmonary or venovenous collaterals; (2) an uncomplicated stage II procedure or Fontan procedure; and (3) any intervention on the superior vena cava after the stage II procedure or Fontan connections after the Fontan procedure.

### Statistical Analysis

The distributions of patient and procedural characteristics by TPS class were compared using the chi-square or Fisher exact test for categorical variables and the Kruskal-Wallis test or 1-way analysis of variance for continuous variables.

Cox regression modeling identified the factors associated with the interval to the initial extubation. The factors associated on univariate analysis at the 0.20 level were candidate predictors for stepwise multivariable modeling. Our multivariable analyses included only the patient factors and preoperative medical variables, because the intraoperative and postoperative outcomes were in the causal pathway of the measures used to calculate the TPS. The TPS was then added to the multivariable model to assess whether it was an independent predictor. Kaplan-Meier estimation with the log-rank test described the association of the interval to initial extubation and the TPS. The same approach was applied to the secondary outcome variables, using linear regression for continuous variables and logistic regression for dichotomous outcomes. We assessed the reliability of the TPS as an independent predictor of each outcome by creating 1000 samples with bootstrapping to determine the percentage of samples in which the TPS was significant at the 0.05 level, conditional on the demographic and preoperative variables already in the multivariable model. A reliability of  $\geq 50\%$  was set as the criterion for retaining the TPS term as an independent predictor.

We assessed whether the 3 components of the TPS (distal arch gradient, atrial septal defect [ASD] gradient, and unplanned reinterventions before Norwood discharge) were associated with Norwood hospitalization LOS, early mortality or transplantation, and reintervention before the stage II procedure. For the echocardiographic components, the medium and high categories for the distal arch gradient and the mean ASD gradient were combined before modeling owing to sparse data.

Sensitivity analyses were also conducted, using the data from subjects with missing and incomplete echocardiograms (class 4 and 5, respectively). The TPS was assumed to be optimal for all, and then inadequate for all, to set the bounds on the relationships between the interval to initial extubation and technical performance.

All analyses were performed using Statistical Analysis Systems, version 9.3 (SAS Institute, Cary, NC).

## RESULTS

The SVR trial randomized 555 subjects, of whom 5 did not undergo a Norwood procedure and 1 withdrew in the

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