Survival and right ventricular performance for matched children after stage-1 Norwood: Modified Blalock-Taussig shunt versus right-ventricle-to-pulmonary-artery conduit

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ABSTRACT

Objective: Early survival advantages after Norwood with right-ventricle-(RV)-to-pulmonary-artery conduit (NW-RVPA) over Norwood-operation with a Blalock-Taussig shunt (NW-BT) are offset by concerns regarding delayed RV dysfunction. We compared trends in survival, RV dysfunction, and tricuspid valve regurgitation (TR) between NW-RVPA and NW-BT for propensity-matched neonates with critical left ventricular outflow tract obstruction (LVOTO).

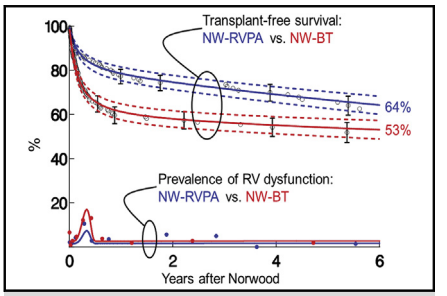
Methods: In an inception cohort (2005-2014; 21 institutions), 454 neonates with critical LVOTO underwent Norwood stage 1. Propensity-score matching paired 169 NW-RVPA patients with 169 NW-BT patients. End-states were compared between NW-RVPA and NW-BT using competing-risks, multiphase, parametric, hazard analysis. Post-Norwood echocardiogram reports (n = 2993) were used to grade RV dysfunction and TR. Time-related prevalence of ≥moderate RV dysfunction and TR were characterized using nonlinear mixed-model regression, and compared between groups via multiphase, parametric models.

Results: Overall 6-year survival was better after NW-RVPA (70%) versus NW-BT (55%; $P < .001$). Additionally, transplant-free survival during this time was better after NW-RVPA (64%) versus NW-BT (53%; $P = .004$).

Overall prevalence of ≥moderate RV dysfunction reached 11% within 3 months post-Norwood. During this time, RV dysfunction after NW-BT was 16% versus 6% after NW-RVPA ($P = .02$), and coincided temporally with an increased early hazard for death. For survivors, late RV dysfunction was <5% and was not different between groups ($P = .36$).

Overall prevalence of ≥moderate TR reached 13% at 2 years post-Norwood and was increased after NW-BT (16%) versus NW-RVPA (11%; $P = .003$). Late TR was similar between groups.

Conclusions: Among propensity-score–matched neonates with critical LVOTO, NW-RVPA offers superior 6-year survival with no greater prevalence of RV dysfunction or TR than conventional NW-BT operations. (J Thorac Cardiovasc Surg 2015;150:1440-52)



Transplant-free survival and trends in right ventricle dysfunction after NW-RVPA and NW-BT.

Central Message

In neonates with critical left ventricular outflow tract obstruction, NW-RVPA has better 6-year survival, and comparable late RV dysfunction and TR, compared with NW-BT.

Perspective

Norwood-RVPA has been shown to have better early survival than NW-BT. However, concerns about late RV dysfunction have diminished enthusiasm for NW-RVPA. The Congenital Heart Surgeons' Society experience demonstrated better survival at 6 years for NW-RVPA, and comparable late RV dysfunction between groups. For neonates with critical LVOTO, NW-RVPA may be preferable to NW-BT.

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Abbreviations and Acronyms

LVOTO = left ventricular outflow tract obstruction
NW-BT = Norwood operation with a modified Blalock-Taussig shunt
NW-RVPA = Norwood operation with a right-ventricle-to-pulmonary-artery conduit
RV = right ventricular
SVR = Pediatric Heart Network Single Ventricle Reconstruction Trial
TR = tricuspid valve regurgitation

Supplemental material is available online.

For patients with hypoplastic left heart syndrome and related variants, Norwood operations with a right-ventricle-to-pulmonary-artery conduit (NW-RVPA) have been associated with a more stable early postoperative recovery and improved early survival, compared with Norwood operations with a modified Blalock-Taussig shunt (NW-BT).[1] However, early survival advantages associated with NW-RVPA are offset by concerns regarding delayed right ventricle (RV) dysfunction.[2,3] The increased prevalence of late RV dysfunction after NW-RVPA has been suggested to account for, at least partially, the late equalization of transplant-free survival between groups.

Recent reports have demonstrated statistically significant, although relatively slight, decrements in RV function after NW-RVPA.[2,3] Despite the reported association between NW-RVPA and decreased RV function,[2] the clinical impact and associated cause of these small decreases in RV function remain unknown. Furthermore, the relationship between Norwood operations and tricuspid valve regurgitation (TR), and the overall impact on survival, has not been extensively explored.

In 2005, the Congenital Heart Surgeons' Society initiated the critical left ventricular outflow tract obstruction (LVOTO) inception cohort. Most of the neonates enrolled (66%) have undergone a stage-1 Norwood operation. Additionally, for all patients who underwent a Norwood operation, the society data center has collected 4783 echocardiogram reports throughout follow up. Thus, the data center is uniquely positioned to explore differences in survival, postoperative RV dysfunction, and TR among Norwood strategies.

In a propensity-matched, multi-institutional cohort of neonates with critical LVOTO who had undergone either NW-RVPA or NW-BT, we sought to determine: (1) late survival differences; (2) differences in the prevalence of RV dysfunction; and (3) differences in the prevalence of TR.

METHODS

Between 2005 and 2014, an inception cohort of 692 consecutive neonates diagnosed with critical LVOTO were prospectively enrolled by 21 institutions (Table E1). All neonates were admitted within 30 days of birth. Critical LVOTO was defined as stenosis occurring at any level, from the subvalvar region to the innominate artery, with or without left ventricular hypoplasia, such that systemic circulation was ductal dependent.[4] A staged, single-ventricle strategy with an initial Norwood operation was undertaken in 454 (66%) neonates who had hypoplastic left heart syndrome and its variants, such as "borderline left ventricle," for whom single-ventricle palliation was favored. The NW-RVPA was undertaken in 222 (49%), and the NW-BT in 232 (51%). Selection of treatment strategy (including source of pulmonary blood flow) was made at the discretion of the treating physicians.

Similar neonates from each group (NW-RVPA and NW-BT) were statistically matched using propensity scores generated from baseline morphologic, demographic, and clinical characteristics (n = 338). For this study, analyses focused on 169 neonates who underwent NW-RVPA and were propensity-score matched with 169 neonates who underwent NW-BT. Details of all interventions and clinical investigations were acquired by the data center, including reports of all available echocardiograms throughout follow-up. The analysis strategy involved: (1) parametric risk-adjusted comparisons of survival, transplantation, and other competing end-states; and (2) risk-adjusted comparisons of the time-related prevalence of important (≥moderate) RV dysfunction and TR, using nonlinear, multiphase mixed-model techniques (Appendix 1).[5-7]

Data Acquisition and Follow-up

Participation in the study and submission of patient information was voluntary and confidential. Parental consent for enrollment and ethics board approval were obtained by individual institutions and the data center. Admission, diagnostic, and surgical patient data were abstracted from institutional medical records, echocardiogram reports, and surgical reports, as previously described.[8] Patients' families were contacted annually by data center staff to obtain details of subsequent clinical history, investigations, and interventions. Reports of all such investigations and interventions were then obtained from each institution to complete longitudinal follow-up. Median follow-up among survivors for the 338 propensity-matched children was 4.8 years (7 days to 8.6 years), and in 2014, the process had been completed for 79% of patients.

Statistical Analysis

Demographic, morphologic, and clinical information preceding stage-1 Norwood operations were included as baseline variables. Variables were processed as described in detail previously.[8] Measurements of cardiac dimensions were standardized as z-scores, based on published normative data, if available, or otherwise indexed to height or body surface area.[9] Missing values for baseline covariables were estimated using multiple imputation.[10] Missing values for outcome variables, however, were not imputed. For regression analyses and propensity matching, final variable selection was guided by bootstrap resampling for reliability (n = 500 resamples threshold for inclusion $P < .1$).[11]

Continuous variables were compared with the Wilcoxon rank-sum test, using Wilcoxon rank scores, and these are summarized as median with range, mean ± SD, or as equivalent 15th, 50th (median), and 85th