Impact of postoperative nutrition on weight gain in infants with hypoplastic left heart syndrome

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Objective: The study objective was to evaluate risk factors for poor weight gain in infants with hypoplastic left heart syndrome after stage 1 palliation.

Methods: We reviewed all term infants with hypoplastic left heart syndrome who had stage 1 palliation and stage 2 palliation at Texas Children's Hospital between 2000 and 2011 (n = 120). Predictor variables included age at stage 1 palliation, intensive care unit factors, calories delivered, and echocardiographic findings. Outcome variables included weight for age *Z* scores at hospital discharge, stage 2 palliation, and change in weight for age *Z* scores between stage 1 palliation and hospital discharge.

Results: Complete nutritional data were available for 47 of 120 patients. Median total parenteral nutrition duration was 6 days (range, 1-43 days), and median intensive care unit calories delivered was 53.9 kcal/kg/d (range, 22.3-119.6 kcal/kg/d). Before hospital discharge, the median caloric intake was 106.7 kcal/kg/d (range, 70.0-152.0 kcal/kg/d). Median weight for age *Z* scores was −0.59 (range, −3.6 to 0.5) at stage 1 palliation, −1.62 (range, −4.5 to −0.1) at intensive care unit transfer, and −1.81 (range, −4.9 to −0.5) at hospital discharge. A total of 46 of 47 patients had a negative change in weight for age *Z* scores between stage 1 palliation and hospital discharge, with a median change of −1.14 (range, −2.3 to 0.6). Change in weight for age *Z* scores from stage 1 palliation to discharge was directly associated with calories delivered and indirectly associated with hospital length of stay and moderate tricuspid regurgitation ($P < .001$).

Conclusions: Postoperative nutrition fails to meet the needs of infants with hypoplastic left heart syndrome despite increased focus on nutritional support. Modifiable factors (eg, nutritional intake) and hemodynamic factors (eg, tricuspid regurgitation) may play roles in the poor weight gain of these infants. (J Thorac Cardiovasc Surg 2014;147:1319-25)

CHD

Infants with complex congenital heart disease are at increased risk of failure to thrive because of several factors, including chronic cyanosis, decreased mesenteric perfusion from low cardiac output, and increased energy expenditure from congestive heart failure.[1,2] Infants with hypoplastic left heart syndrome (HLHS) are at particular risk of poor weight gain between stage 1 surgical palliation (S1P) and stage 2 surgical palliation (S2P).[3,4] A low weight-for-age *Z* score at the time of S2P has been associated with poor clinical outcomes at S2P.[5] Mesenteric perfusion seems to be altered in infants after the Norwood operation.[6] Whether poor interstage somatic growth belies poor cardiovascular efficiency and somatic perfusion or is due to inadequate caloric intake is unclear.[3,7] A number of studies have shown that increasing caloric density of infant formula during the interstage outpatient period results in improved growth.[3,8] Thus, identifying any modifiable risk factors for poor weight gain may result in better short-term surgical outcomes and long-term neurodevelopmental outcomes.[9]

To date, there has been little focus on the in-hospital nutrition and calorie administration in infants with single-ventricle physiology. The hospital course surrounding the Norwood operation often is as long as 4 to 8 weeks.[8] Neonates with HLHS may be undernourished preoperatively for several reasons, including concern for mesenteric ischemia.[10] In the postoperative period, these neonates are often unstable, requiring inotropic support and mechanical ventilation. Total parenteral nutrition (TPN) often is used in place of enteral nutrition in the immediate postoperative period. We hypothesize that the early postoperative period is associated with significant under-nutrition, that TPN is not used fully to achieve adequate nutrition, and that this postoperative period provides an opportunity to improve nutritional delivery to these at-risk neonates.

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Abbreviations and Acronyms
HLHS = hypoplastic left heart syndrome
ICU = intensive care unit
S1P = stage 1 surgical palliation
S2P = stage 2 surgical palliation
TPN = total parenteral nutrition
WAZ = weight for age *Z* scores
⊿WAZ = change in weight for age *Z* scores

MATERIALS AND METHODS

Patient Data

We performed a retrospective study of all term neonates (gestation >36 weeks at birth) born with the diagnosis of HLHS from 2000 to 2011 at Texas Children's Hospital who underwent the Norwood operation as their S1P with a modified Blalock–Taussig shunt or Sano right ventricular to pulmonary artery conduit and who survived to S2P with a Glenn operation consisting of a superior cavopulmonary anastomosis. The institutional review board of our institution approved this study. We excluded infants of preterm gestation (<36 weeks) and those with chromosomal abnormalities, metabolic abnormalities, or gastrointestinal abnormalities. Infants who did not survive to S2P also were excluded.

Patient demographic data were obtained, including gestational age at birth, gender, and age at S1P and discharge from hospital after S1P. Weight at various points for each patient was recorded, including weight at admission, S1P, discharge from intensive care unit (ICU), hospital discharge, and S2P. Weight for age *Z* scores (WAZ) were calculated using World Health Organization Anthro software, version 3.2.2. Medical data were noted, including total length of hospital stay after S1P, duration of ICU stay, and duration of intubation after S1P. Echocardiogram reports for each patient were reviewed for the presence of moderate or greater tricuspid valve regurgitation and moderate or greater right ventricular systolic dysfunction before S1P, at ICU discharge, and before hospital discharge.

Nutritional Data

Nutritional data, including postoperative TPN duration and caloric density after S1P, and postoperative day of enteral feed initiation, and volume and caloric density of enteral feeds were obtained. At our institution, neonates who undergo S1P are initially placed on intravenous fluids for the first postoperative day and then started on TPN after the initial 24-hour postoperative period. Enteral feeds are generally not started until the patients are off all inotropes, and a significant number do not start enteral feeds before extubation. The total caloric intake was calculated for each patient for each postoperative day up to the day of discharge from S1P hospitalization. Total caloric intake included calories from both TPN and enteral formula. The inpatient pharmacy records were reviewed to calculate the total intravenous daily caloric delivery via TPN for each patient. For enteral nutrition, the daily nursing flow sheets of each patient were reviewed to obtain daily enteral formula volume given, as well as the daily caloric density during the postoperative inpatient period after S1P. Intravenous fluids with dextrose (not ordered with TPN) were not included in calculating the average calories per kilogram per patient.

Data Analysis

The primary outcome variable was change in WAZ (⊿WAZ) from S1P to hospital discharge. All statistical analysis was performed using IBM SPSS Statistics Version 18.0 (Somers, NY). Continuous variables are expressed as mean ± standard deviation or median (range) where appropriate. Student *t* test was performed to compare continuous variables, and Fisher exact test was used to compare categoric variables where appropriate. We evaluated both the actual WAZ (at S1P, at ICU discharge, at hospital discharge, and at S2P) and the ⊿WAZ between S1P and hospital discharge. Univariate analysis of potential risk factors associated with the continuous outcome of ⊿WAZ was performed, and those variables found on univariate analysis to have an association with the primary outcome were selected for the multivariate analysis. The multivariate analysis was performed with backward regression.

RESULTS

From 2000 to 2011, 170 neonates born with HLHS were treated at our institution. Excluded patients included 12 preterm infants defined as gestational age less than 36 weeks, 5 infants with chromosomal abnormalities, and 33 patients who underwent cardiac transplant or died before S2P. Medical records were reviewed for the cohort of 120 patients. Of these 120 patients, 47 had complete nutritional records and ICU records available for review. The complete clinical characteristics of this patient population described next are summarized in Table 1.

Somatic Growth Measurement

Of the 47 patients for whom there were complete nutritional data, there was a decrease in WAZ between S1P and hospital discharge in all but 1 of the patients (98%). The median ⊿WAZ from S1P to hospital discharge was −1.14 (range, −2.3 to 0.6) (Figure 1). The median absolute weight at S1P was 3.10 kg (range, 2.17-4.75 kg), with a WAZ of −0.59 (range, −3.56 to 0.5). At cardiac ICU transfer to the medical floor, the median weight was 3.10 kg (range, 2.18-4.89 kg) with a corresponding decrease in WAZ to −1.62 (range, −4.5 to −0.1). At hospital discharge, the median weight was 3.39 kg (range, 2.37-5.02 kg), with a further decrease in WAZ to −1.81 (range, −4.9 to −0.5). The median daily weight gain was 12 g/d (range, −18 to 36 g/d) from S1P to hospital discharge. At S2P, the median weight in the cohort of 47 patients was 5.75 kg (range, 4.0-9.0 kg), with a median WAZ of −1.51 (−4.0 to 1.4).

Comparison of the excluded 73 patients with the included 47 patients in this study cohort found no differences in absolute weight or WAZ at both S1P ($P = .718$ for absolute weight and $P = .540$ for WAZ) and S2P ($P = .791$ for absolute weight and $P = .083$). The median weight of the excluded patients at S1P was 3.10 kg (range, 2.30-4.10 kg) with a median WAZ of −0.51 (range, −2.38 to 1.09). The median weight of the excluded patients at S2P was 5.80 kg (range, 3.40-8.72 kg) with a median WAZ of −2.07 (−4.30 to −0.04).

Intensive Care Unit Management

The median age of the 47 patients at S1P was 6 days (range, 2-34 days). All the patients were managed in the cardiac ICU after initial surgical palliation. All the patients returned from the operating room intubated and ventilated with median length of intubation of 4 days