Effect of feeding modality on interstage growth after stage I palliation: A report from the National Pediatric Cardiology Quality Improvement Collaborative

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Objectives: Achieving adequate growth after stage 1 palliation for children with single-ventricle heart defects often requires supplemental nutrition through enteral tubes. Significant practice variability exists between centers in the choice of feeding tube. The impact of feeding modality on the growth of patients with a single ventricle after stage 1 palliation was examined using the multiinstitutional National Pediatric Cardiology Quality Improvement Collaborative data registry.

Methods: Characteristics of patients were compared by feeding modality, defined as oral only, nasogastric tube only, oral and nasogastric tube, gastrostomy tube only, and oral and gastrostomy tube. The impact of feeding modality on change in weight for age z-score during the interstage period, from stage 1 palliation discharge to stage 2 palliation, was evaluated by multivariable linear regression, adjusting for important patient characteristics and postoperative morbidities.

Results: In this cohort of 465 patients, all groups demonstrated improved weight for age z-score during the interstage period with a mean increase of 0.3 ± 0.8. In multivariable analysis, feeding modality was not associated with differences in the change in weight for age z-score during the interstage period (P = .72). Risk factors for poor growth were a diagnosis of hypoplastic left heart syndrome (P = .003), vocal cord injury (P = .007), and lower target caloric goal at discharge (P = .001).

Conclusions: In this large multicenter cohort, interstage growth improved for all groups and did not differ by feeding modality. With appropriate caloric goals and interstage monitoring, adequate growth may be achieved regardless of feeding modality and therefore local comfort and complication risk should dictate feeding modality. (J Thorac Cardiovasc Surg 2014;148:1534-9)

Although operative survival continues to improve after stage 1 palliation (S1P) for children with single-ventricle heart lesions, the interstage period, from discharge after S1P until stage 2 palliation (S2P), continues to be a high-risk time. Many patients require supplementation with either nasogastric (NG) or gastrostomy tube (GT) at the time of discharge after S1P.7,11,12 The implementation of an interstage home-monitoring program including daily recording of weight and intake has been associated with improved survival as well as normal growth outcomes, and has been adopted by many programs.9,12-15 There is considerable variation in feeding modality chosen when supplementation is required, and there may be important differences between children able to feed orally versus those fed via NG or GT.9,14,16-18 The inability to achieve normal growth and to feed orally may be surrogates of more severe illness and vulnerability.2,12,19-21 Recent single-center studies have demonstrated conflicting results for morbidity and mortality in patients with a single ventricle fed by NG versus GT.2,10,19,22 No study to date has compared growth between feeding modalities in patients with a single ventricle using multinational data.

The National Pediatric Cardiology Quality Improvement Collaborative (NPC-QIC) is a multicenter quality improvement collaborative with a primary aim “To reduce mortality by mouth because of comorbidities. Previous studies have demonstrated that to ensure normal growth, 18% to 75% of patients require supplementation with either nasogastric (NG) or gastrostomy tube (GT) at the time of discharge after S1P.7,11,12 The implementation of an interstage home-monitoring program including daily recording of weight and intake has been associated with improved survival as well as normal growth outcomes, and has been adopted by many programs.9,12-15 There is considerable variation in feeding modality chosen when supplementation is required, and there may be important differences between children able to feed orally versus those fed via NG or GT.9,14,16-18 The inability to achieve normal growth and to feed orally may be surrogates of more severe illness and vulnerability.2,12,19-21 Recent single-center studies have demonstrated conflicting results for morbidity and mortality in patients with a single ventricle fed by NG versus GT.2,10,19,22 No study to date has compared growth between feeding modalities in patients with a single ventricle using multinational data.

The National Pediatric Cardiology Quality Improvement Collaborative (NPC-QIC) is a multicenter quality improvement collaborative with a primary aim “To reduce mortality
and improve the quality of life in infants with HLHS during
the interstage period."23 Based on previous studies
and improve the quality of life in infants with HLHS during
the interstage period.23 Based on previous studies
demonstrating an association between growth and improved
outcomes, the NPC-QIC has identified improvement in
interstage growth as a primary driver to achieve improved
overall outcomes.23 Using data from 47 institutions
contributing to the NPC-QIC, we sought to (1) describe
the differences in patient characteristics between feeding
modality groups, and (2) compare growth outcomes during
the interstage period by feeding modality.

METHODS

Study Design and Measurements

This was a retrospective analysis of patients enrolled in the NPC-QIC
registry. The NPC-QIC is a collaborative of 47 pediatric cardiac programs
that includes a voluntary registry of patients discharged home after S1P,
which includes surgical palliation or the hybrid alternative. Individual
participating sites obtain institutional review board approval and parental
informed consent. There is a standard dataset with data definitions, online
web-based data entry, and data quality checks. The deidentified data are
housed in a secure server at the James M. Anderson Center for Health
Systems Excellence at Cincinnati Children’s Hospital Medical Center.
Individual programs complete detailed data forms consisting of
demographic data, birth information, surgical information, as well as
clinical variables collected at the time of discharge and at each subsequent
visit until discharge from S2P.

Patients completing S2P between June 2008 and July 2012 were
included. Interstage deaths were excluded. The cohort was divided into
5 groups based on the feeding modality at discharge from S1P: (1) those
fed exclusively by mouth (PO only); (2) exclusively by NG tube (NG
only); (3) by a combination of oral and NG tube (PO + NG); (4) exclusively
by GT (GT only); and (5) a combination of oral and GT (PO + GT).
Indications for preferred feeding modality and morbidity associated
with specific enteral tubes were not available in the database.

Demographic data collected were limited to gender and race/ethnicity,
which was categorized as white, black or African American, Hispanic,
or other. Preoperative factors collected included gestational age, cardiac
diagnosis, which for analysis was dichotomized to HLHS versus non-
HLHS, the presence of any known genetic syndrome or other chromosomal
anomaly, as well as the presence of any other organ system anomalies.
Preoperative risk factors recorded were mechanical ventilation and a
composite complication variable that included preoperative arrhythmias
requiring treatment, shock or acidosis, renal insufficiency, septicemia,
neonatal necrotizing enterocolitis, and seizures. Postoperative complications
were considered as the need for extracorporeal membrane oxygenation
(ECMO), prolonged mechanical ventilation (>14 days), vocal cord
paralysis, or a composite variable consisting of cardiac arrest, arrhythmia
requiring therapy, pneumonia or tracheitis, acute renal failure, wound
infection or mediastinitis, diaphragm paralysis, seizures, or necrotizing
enterocolitis. Feeding method at discharge from S1P and readmission for S2P
as well as target caloric intake at both times were recorded. Anthropomorphic data included weight at birth, at discharge from S1P,
and at readmission for S2P. These were converted to weight for age z-scores
(WAZ) to adjust for variation in ages.

Statistical Analysis

Descriptive data are presented as count and percentage, mean with
standard deviation, or median with range as appropriate. For the purposes
of analysis, feeding modality at the time of discharge was used as the
grouping variable. Comparison between groups for categorical data was
performed using the χ² test or the Fisher exact test where required by
insufficient numbers, and analysis of variance or the Kruskal-Wallis test
for continuous data based on distribution. Multivariable linear regression
was used to determine the risk factors for poor interstage growth.
All statistical analyses were performed using SAS version 9.2 (SAS
Institute Inc, Cary, NC).

RESULTS

A total of 465 patients who completed S2P had their
weight documented at the time of S2P and were included
in the study. At S1P discharge, 56% required supplementation
of intake with a feeding tube; the feeding group breakdown is shown in Figure 1. There was improvement in
oral intake during the interstage period with a decrease
to 37% requiring supplementation at the time of S2P,
with significant crossover between groups. Within the
cohort, 193 of 465 (41.5%) patients had a change in
their feeding modality during the interstage period; the
PO + NG group accounted for 90 (47%) of those 193
patients. A GT was placed during the interstage period
in 23 patients. The indications for a change in feeding
modality are not documented in the NPC-QIC database.

Comparison of characteristics between groups can be
seen in Table 1. Preoperatively, the NG only, GT only, and
PO + GT groups were more likely to have other organ
system anomalies and the GT only group was more
likely to require preoperative mechanical ventilation.
Postoperatively, compared with the PO only group, those

FIGURE 1. Number of patients by feeding modality at discharge and at
admission for S2P. PO, Oral; NG, nasogastric; GT, gastrostomy tube; S1P, stage 1 palliation; S2P, stage 2 palliation.
TABLE 1. Characteristics by feeding modality: comparison of feeding groups in univariate analysis

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n = 465)</th>
<th>PO only (n = 204)</th>
<th>NG only (n = 63)</th>
<th>PO + NG (n = 112)</th>
<th>GT only (n = 51)</th>
<th>PO + GT (n = 35)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender, n (%)</td>
<td>293 (63)</td>
<td>136 (67)</td>
<td>40 (63)</td>
<td>69 (61)</td>
<td>25 (49)</td>
<td>23 (66)</td>
<td>.22</td>
</tr>
<tr>
<td>Race/ethnicity, n (%)</td>
<td>120</td>
<td>60</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>.14</td>
</tr>
<tr>
<td>White</td>
<td>285 (61)</td>
<td>121 (60)</td>
<td>36 (57)</td>
<td>12 (19)</td>
<td>11 (22)</td>
<td>11 (22)</td>
<td>.16</td>
</tr>
<tr>
<td>Black</td>
<td>70 (15)</td>
<td>29 (14)</td>
<td>19 (30)</td>
<td>11 (16)</td>
<td>11 (22)</td>
<td>11 (22)</td>
<td>.16</td>
</tr>
<tr>
<td>Hispanic</td>
<td>97 (21)</td>
<td>48 (24)</td>
<td>12 (19)</td>
<td>11 (16)</td>
<td>11 (22)</td>
<td>11 (22)</td>
<td>.16</td>
</tr>
<tr>
<td>Other</td>
<td>13 (3)</td>
<td>6 (2)</td>
<td>2 (3)</td>
<td>2 (2)</td>
<td>2 (4)</td>
<td>1 (3)</td>
<td>.16</td>
</tr>
<tr>
<td>HLHS, n (%)</td>
<td>302 (65)</td>
<td>133 (65)</td>
<td>35 (56)</td>
<td>37 (66)</td>
<td>37 (73)</td>
<td>22 (63)</td>
<td>.42</td>
</tr>
<tr>
<td>Genetic syndrome, n (%)</td>
<td>32 (7)</td>
<td>13 (7)</td>
<td>3 (5)</td>
<td>7 (6)</td>
<td>8 (16)</td>
<td>1 (3)</td>
<td>.16</td>
</tr>
<tr>
<td>Other anomaly, n (%)</td>
<td>51 (11)</td>
<td>18 (9)</td>
<td>10 (16)</td>
<td>7 (6)</td>
<td>10 (21)</td>
<td>6 (17)</td>
<td>.03</td>
</tr>
<tr>
<td>Preoperative ventilation, n (%)</td>
<td>164 (35)</td>
<td>61 (30)</td>
<td>25 (40)</td>
<td>36 (32)</td>
<td>30 (59)</td>
<td>12 (34)</td>
<td>.003</td>
</tr>
<tr>
<td>S1P type, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.004</td>
</tr>
<tr>
<td>Norwood + BT shunt</td>
<td>150 (32)</td>
<td>74 (36)</td>
<td>14 (22)</td>
<td>30 (27)</td>
<td>22 (43)</td>
<td>10 (29)</td>
<td>.44</td>
</tr>
<tr>
<td>Norwood + RV-PA</td>
<td>260 (56)</td>
<td>97 (48)</td>
<td>44 (70)</td>
<td>75 (67)</td>
<td>23 (45)</td>
<td>21 (60)</td>
<td>.16</td>
</tr>
<tr>
<td>Hybrid procedure</td>
<td>33 (7)</td>
<td>22 (11)</td>
<td>4 (6)</td>
<td>1 (1)</td>
<td>5 (10)</td>
<td>1 (1)</td>
<td>.16</td>
</tr>
<tr>
<td>Other</td>
<td>21 (5)</td>
<td>10 (5)</td>
<td>1 (2)</td>
<td>6 (5)</td>
<td>1 (2)</td>
<td>3 (9)</td>
<td>.16</td>
</tr>
<tr>
<td>Postoperative ECMO, n (%)</td>
<td>28 (6)</td>
<td>5 (2)</td>
<td>4 (6)</td>
<td>7 (6)</td>
<td>7 (14)</td>
<td>5 (14)</td>
<td>.004</td>
</tr>
<tr>
<td>Post operative ventilation &gt;14 d, n (%)</td>
<td>59 (13)</td>
<td>14 (7)</td>
<td>12 (21)</td>
<td>9 (8)</td>
<td>15 (29)</td>
<td>8 (23)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Vocal cord paralysis, n (%)</td>
<td>47 (10)</td>
<td>13 (6)</td>
<td>9 (14)</td>
<td>5 (4)</td>
<td>14 (27)</td>
<td>6 (17)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Birth WAZ, mean ± SD</td>
<td>-0.5 ± 0.9</td>
<td>-0.5 ± 0.9</td>
<td>-0.5 ± 1.1</td>
<td>-0.5 ± 0.8</td>
<td>-0.4 ± 1.2</td>
<td>-0.3 ± 0.9</td>
<td>.51</td>
</tr>
<tr>
<td>S1P discharge WAZ, mean ± SD</td>
<td>-1.5 ± 0.9</td>
<td>-1.5 ± 0.8</td>
<td>-1.5 ± 1.2</td>
<td>-1.5 ± 0.8</td>
<td>-1.8 ± 1.2</td>
<td>-1.4 ± 1.1</td>
<td>.16</td>
</tr>
<tr>
<td>S2P WAZ, mean ± SD</td>
<td>-1.3 ± 1.1</td>
<td>-1.2 ± 1.1</td>
<td>-1.3 ± 1.2</td>
<td>-1.3 ± 1.1</td>
<td>-1.5 ± 1.6</td>
<td>-1.0 ± 1.2</td>
<td>.27</td>
</tr>
<tr>
<td>Age at S2P, median (range)</td>
<td>150 (76-652)</td>
<td>133 (76-652)</td>
<td>140 (86-373)</td>
<td>141 (78-295)</td>
<td>163 (91-344)</td>
<td>160 (96-267)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Intestra WAZ change, mean ± SD</td>
<td>0.3 ± 0.8</td>
<td>0.3 ± 0.8</td>
<td>0.3 ± 0.8</td>
<td>0.3 ± 0.8</td>
<td>0.3 ± 0.8</td>
<td>0.3 ± 0.8</td>
<td>.93</td>
</tr>
</tbody>
</table>

For statistically different characteristics, superscript numbers (1,2,3,4) are shared by groups that are not statistically different and those without shared numbers are statistically different. PO, Oral; NG, nasogastric; GT, gastrostomy tube; HLHS, hypoplastic left heart syndrome; S1P, stage 1 palliation; BT, Blalock-Taussig; RV-PA, right ventricle-pulmonary artery; ECMO, extracorporeal membrane oxygenation; WAZ, weight for age z-score; SD, standard deviation; S2P, stage 2 palliation. *P value for a difference between any group obtained by χ² test or Fisher exact test for categorical data and analysis of variance or Kruskal-Wallis test for continuous variables.

For worse growth were a diagnosis of HLHS (P = .002), a diagnosis of vocal cord injury (P = .007), and having a lower documented target caloric intake at discharge from S1P (P = .001). All factors included in the initial model are presented in Table 2. The mean difference between change in WAZ during the interstage period for those with a diagnosis of HLHS versus those without was −0.3 (95% confidence interval, −0.6 to −0.1) and −0.5 (95% confidence interval, −0.8 to −0.1) for vocal cord injury versus those without vocal cord injury. For every 10 kcal/kg/d increase in target caloric intake at discharge, there was an increase of 0.15 in the WAZ at readmission for S2P.

DISCUSSION

In this large multiinstitutional database review of infants with single-ventricle heart disease, there was a positive change in WAZ during the interstage period across all groups. Intersstage growth was found to be the same between feeding groups with no growth advantage found in selecting one mode of supplemental tube feeding over another. This result is important given the focus on nutrition and growth in this population, and the impact of normal growth on improving outcomes. In addition, previous research has highlighted the considerable variability in practice between.
centers with regard to the choice of feeding modality when supplementation by feeding tube is required. The reasons for this variability are unclear, and may represent differences in patient characteristics as well as individual provider or center-specific practice patterns and preferences when submitting high-risk patients for elective noncardiac surgery. This analysis was not designed to test differences in morbidities specific to the choice of feeding modality, such as complications related to feeding tube placement. However, this description of the characteristics of a large cohort helps to define the needs of this vulnerable patient population and predict those patients most at risk for poor outcomes.

Before the use of home-monitoring programs for infants with single-ventricle heart disease, growth failure during the interstage period was a frequent finding of interstage outcome studies. A typical growth pattern for these patients has emerged from numerous studies, characterized by a large decrease in WAZ from birth to S1P discharge, followed by a less precipitous but continued decline in WAZ during the interstage period. Previous data have shown the consequence of poor weight gain as poor growth and feeding problems are associated with earlier S1P, longer hospitalization after S1P, and higher mortality. However, recent single-center experience from programs using home-monitoring programs with intense nutritional monitoring and intervention demonstrate that catch-up growth can occur during the interstage period and is associated with improved outcomes in comparison with historical controls. A previous NPC-QIC study demonstrated significant institutional variation in the management and outcomes of interstage growth. The best growth was achieved at institutions using home monitoring, red flags for poor growth, frequent phone contact, and feeding evaluations after S1P. Our current analysis demonstrates a decline in WAZ from birth to S1P discharge, however, the improvement in interstage growth previously demonstrated only in single-center studies is sustained across programs in this cohort, with an overall increase in WAZ during the interstage period. The early decline in WAZ can be anticipated as the perioperative period can be characterized by critical illness, fluid limitations, intolerance of enteral feeds, and higher metabolic demands. All of these problems are less likely to be experienced during the interstage period, allowing for this catch-up growth.

Although supplementation of oral intake with tube feeding may be required to achieve normal growth in a safe and effective manner, the ideal choice of feeding modality remains unclear. Hebson and colleagues retrospectively reviewed their experience with patients undergoing single-ventricle palliation between 2003 and 2010. They noted higher mortality in the cohort that underwent GT placement with or without Nissen fundoplication. Ultimately, they hypothesized that the need for GT may be a marker of an unknown risk factor for mortality. A secondary analysis of the Single Ventricle Reconstruction trial cohort found, using univariate analysis, that the inability to feed orally at the time of discharge was a risk factor for mortality. In contrast to the Hebson study, patients discharged with NG tubes were found to have higher mortality than those with GT. Previous work by

![FIGURE 2](image2.png)  
**FIGURE 2.** Change in WAZ over time. Weights shown were obtained at birth, S1P discharge, and S2P admission. PO, Oral; NG, nasogastric; G, gastrostomy; WAZ, weight for age z-score.

![FIGURE 3](image3.png)  
**FIGURE 3.** Duration of pre-S1P period, intubation, hospitalization, and interstage period by feeding modality at discharge from stage 1 palliation. #Significantly longer interval (P < .05) than other groups by analysis of variance. PO, Oral; GT, gastrostomy tube; NG, nasogastric; S1P, stage 1 palliation.

### TABLE 2. Risk factors for worse growth

<table>
<thead>
<tr>
<th>Factor</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding modality</td>
<td>.72</td>
</tr>
<tr>
<td>Hypoplastic left heart syndrome</td>
<td>.003</td>
</tr>
<tr>
<td>Vocal cord paralysis</td>
<td>.007</td>
</tr>
<tr>
<td>Lower caloric goal at discharge</td>
<td>.001</td>
</tr>
<tr>
<td>Gender</td>
<td>NS</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td>NS</td>
</tr>
<tr>
<td>Presence of a genetic syndrome</td>
<td>NS</td>
</tr>
<tr>
<td>Other organ system anomaly</td>
<td>NS</td>
</tr>
<tr>
<td>S1P type</td>
<td>NS</td>
</tr>
<tr>
<td>Postoperative ECMO</td>
<td>NS</td>
</tr>
<tr>
<td>Post operative ventilation &gt;14 d</td>
<td>NS</td>
</tr>
<tr>
<td>Birth WAZ</td>
<td>NS</td>
</tr>
<tr>
<td>Gestation &lt;37 wk</td>
<td>NS</td>
</tr>
</tbody>
</table>

Results of multivariable analysis using linear regression for risk factors associated with worse growth as measured by weight for age z-score. NS, Not significant; S1P, stage 1 palliation; ECMO, extracorporeal membrane oxygenation; WAZ, weight for age z-score.
CONCLUSIONS

Feeding modality did not affect interstage growth in patients after S1P, with all feeding modalities showing an increase in growth velocity during this period. Factors that negatively influence growth during the interstage period are a diagnosis of HLHS, vocal cord injury, and a lower target daily caloric intake at discharge from S1P. There are significant differences in the population requiring GTs placed that increase length of hospitalization after S1P. Continued focus on growth during neonatal hospitalization may identify additional risk factors for growth failure and ultimately improve outcomes.

References


