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Feeding methods for infants with single ventricle physiology are associated with length of stay during stage 2 surgery hospitalization

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Abstract

Background: Tube feedings are often needed to achieve the growth and nutrition goals associated with decreased morbidity and mortality in patients with single ventricle anatomy. Variability in feeding method through the interstage period has been previously described, however, comparable information following stage 2 palliation is lacking.

Objectives: To identify types of feeding methods following stage 2 palliation and their influence on length of stay.

Design: Secondary analysis of the National Pediatric Cardiology Quality Improvement Collaborative registry was performed on 932 patients. Demographic data, medical characteristics, post-operative complications, type of feeding method, and length of stay for stage 2 palliation were analyzed.

Results: Type of feeding method remained relatively unchanged during hospitalization for stage 2 palliation. Gastrostomy tube fed only patients were oldest at time of surgery (182.7 ± 57.7 days, $P < 0.001$) and had lowest weight-for-age z scores at admission (−1.6 ± 1.4, $P < 0.001$). Oral + gastrostomy tube groups had the longest median bypass times (172.5 minutes, $P = 0.001$) and longest length of stay (median 12 days, $P < 0.001$). Multivariable modeling revealed that feeding

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Author Contributions:

All of the authors conceptualized and designed the study as a group. Ms. Hoch and Dr. Fatusin drafted the article, reviewed and revised the article, and approved the final manuscript as written. Dr. Yenokyan completed statistical analysis of the data, contributed to the body of the article, and approved the final manuscript as written. Dr. Thompson and Dr. Lefton-Greif critically reviewed and revised the article, secured funding for the statistical analysis, and approved the final manuscript as written.

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by tube only ($P < 0.001$), oral + tube feeding ($P \leq 0.001$), reintubation ($P < 0.001$), and prolonged intubation ($P < 0.001$) were associated with increased length of stay. Neither age ($P = 0.156$) nor weight-for-age z score at admission ($P = 0.066$) was predictive of length of stay.

Conclusions: Feeding methods established at admission for stage 2 palliation are not likely to change by discharge. Length of stay is more likely to be impacted by tube feeding and intubation history than age or weight-for-age z score at admission. Better understanding for selection of feeding methods and their impact on patient outcomes is needed to develop evidence-based guidelines to decrease variability in clinical practice patterns and provide appropriate counseling to caregivers.

Keywords

hypoplastic left heart syndrome; single ventricle; feeding; stage 2 palliation; deglutition

INTRODUCTION:

Children with single ventricle physiology such as hypoplastic left heart syndrome (HLHS) require staged surgical management, including the Norwood procedure (stage 1 palliation, [S1P]) shortly after birth followed by the Glenn procedure (stage 2 palliation, [S2P]) several months later. The medically tenuous interval between these two surgeries is referred to as the interstage period with single centers reporting interstage mortality rates as high as 10–15%.[1, 2] The National Pediatric Cardiology Quality Improvement Collaborative (NPC-QIC) was formed in 2006 to decrease mortality, improve growth and nutrition, and reduce hospital readmissions for infants during the interstage period.[3] Recent cumulative aggregate data derived from NPC-QIC data base are encouraging, showing a decrease in interstage mortality from 9.5% (2008 – 2013) to 5.3% (2013 – 2014).[4] Improvements in mortality were associated with the use of home monitoring and nutritional assessment programs.[4] Compromises in the adequacy of growth and nutrition have been attributed to gastrointestinal complications, feeding/swallowing disorders, and high nutritional demand in the setting of shunt dependent physiology.[5–7] In response, nutrition support has been established by a variety of feeding methods - ranging from total oral feedings, to a combination of oral and tube feedings, to total tube feedings.

Hill et. al (2014) provided a comprehensive analysis of aggregate NPC-QIC data to examine interstage growth and to compare feeding methods until S2P admission. Although they did not identify any growth advantage on the basis of feeding modality, patients with HLHS, vocal fold paralysis, and lower caloric goals at S1P discharge were at disadvantage for growth. Comparison of feeding method between S1P discharge and S2P admission showed that the percentage of orally fed patients increased from 25% to 69%, and patients requiring tube feedings decreased from 75% to 35%. Though intensive nutrition support is often used in the management of single ventricle patients, it has become evident that feeding/swallowing disorders and growth and nutrition problems persist beyond the S1P hospitalization and interstage period.[9,10]Additionally, considerable variability in practice exists among institutions regarding introduction and progression of oral feeding.[11,12] To date, little is known about the type of feeding methods used during S2P hospitalization and their impact on length of stay (LOS). Such information is needed for development of best practice guidelines and to decrease center to center variability. This study provides additional information about expectations for the hospital stay, giving families information and reducing unnecessary clinical variation. To begin to address gaps in knowledge, we performed a secondary analysis of the NPC-QIC cohort data to (1) identify patient characteristics that may be associated with status of feeding method at S2P discharge, (2) compare changes in feeding method at S2P admission and discharge, and (3) determine whether feeding method at S2P discharge had an impact on LOS during the hospitalization for S2P.

METHODS:

Patient Selection

Data were extracted from the NPC-QIC registry, which includes aggregate data from 52 cardiac centers. Each center contributed de-identified data using standard data forms at specified intervals with data definitions and a computer-based data entry system. The registry includes information about patient demographics, birth history, medical/surgical factors during S1P hospitalization, interstage clinic visits, and S2P hospitalization through discharge. Data are stored in a secure server at the James M. Anderson Center for Health Systems Excellence at Cincinnati Children's Hospital Medical Center. Parental informed consent and institutional review board (IRB) approval were obtained at each participating center. The Johns Hopkins School of Medicine IRB approved this study.

Inclusion in the database required patient discharge following S1P. Patients discharged from S2P between August 2008 and September 2014 were included in this investigation. Data were available for 932 patients, and 346 were excluded due to missing data on type of feeding method at S2P discharge or with presumed errors in data entry (i.e., discharge date listed as occurring before admission date). See Figure 1. Feeding methods at S2P admission and S2P discharge were recorded. Pre-defined feeding methods within the database included: total oral (PO), oral + nasogastric tube/ nasojejunal tube (PO + NG/ NJ), oral + gastrostomy tube (PO + GT), total NG/ NJ, or total GT. Demographic data, medical characteristics, S2P surgery bypass time, S2P post-operative complications (prolonged intubation defined as >14 days, reintubation), additional procedures during S2P hospitalization (e.g., GT placement or Nissen fundoplication), and LOS during S2P hospitalization were collected (Table 1).

Statistical Analysis

Patient characteristics are presented as counts and percentages (for categorical variables), mean with standard deviation (SD) or median with range (for continuous variables). Patient characteristics were compared by S2P discharge feeding method status using Kruskal-Wallis test (accounting for ties) for all continuous variables and race/ethnicity. Chi-square or Fisher's exact tests were used to compare categorical variables. Dunn's pairwise comparison with Benjamini-Hochberg adjustment for multiple comparison was used after significant Kruskal-Wallis tests.

Multiple linear regression models with log transformed outcome were fit to estimate the relationship between the feeding method at S2P and LOS after S2P, adjusting for age, weight, bypass time, post-operative re-intubation and post-operative prolonged intubation. Patients missing any data points were excluded. The LOS was computed as the number of days from S2P admission to discharge. LOS greater than 340 days for 3 patients were excluded from the model because they were outliers. All statistical analyses were performed using STATA 14 statistical software (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP). All tests were two-sided and statistical significance was set at 0.05.

RESULTS:

Patient Characteristics and Feeding Method at S2P Discharge

Patient demographics and characteristics for 932 patients with full data sets are listed in Table 1. Of note, data were not available to analyze for the 346 patients who were excluded due to missing data sets or presumed errors in data entry. Genetic syndrome, S2P bypass time, age at S2P, and weight-for-age z score (WAZ) at S2P admission were significantly different across feeding groups. The GT only and PO + GT groups were older at S2P admission and had longer S2P bypass times than other feeding groups. The GT only group had the lowest WAZ values at S2P admission and discharge. Out of 152 patients feeding by GT only at S2P discharge, 27 (17.8%) had a known genetic syndrome.

S2P post-operative complications occurred in 288 (31%) of the patients. Prolonged intubation and re-intubation rates were significantly different between feeding groups ($P < 0.001$), with higher rates in those requiring tube feedings (Table 2). Other post-operative complications, (e.g., phrenic nerve injury, pulmonary hypertension, and new findings of recurrent laryngeal nerve injury) did not differ significantly among feeding methods at S2P discharge.

Feeding Method at S2P Admission and Discharge

There were very few changes in feeding method during S2P hospitalization of the 886 patients with data on feeding. Data on feeding method were missing for 46 (5%) of 932 patients at S2P admission. One patient transitioned from full PO feedings to PO+NG/NJ feedings. Of the 219 patients feeding either fully or partially by GT at S2P discharge, 36 (16%) patients underwent GT placement during the hospital stay. Ten of those patients also had a Nissen fundoplication. Information about decision-making for GT placement and/or Nissen was not available.

Length of Stay

Median LOS for the entire cohort (n=932) was 8 days. LOS was longer for patients requiring tube feedings compared to those with full PO feedings (median 10–11 days versus 7 days, $P < 0.001$). See Figure 2. The PO + GT group had the longest LOS (median 12 days). After controlling for variables potentially associated with feeding method (i.e., age, weight, S2P bypass time, intubation history), patients feeding by GT had an average LOS 36% longer than patients who were fed orally at S2P discharge (95% confidence interval:

from 20% to 54% longer, P <0.001). See Table 3. The 36 patients with new GTs placed during S2P hospitalization represented a relatively small subset of the entire population and hence, their data were not amenable to separate meaningful analyses. Consequently, it is not known if the LOS for patients with newly placed GTs was impacted by recovery from GT placement. Post-operative complications, including prolonged intubation and re-intubation were significantly associated with increased LOS with estimated 1.95- and 3.08-fold increase, respectively (P < 0.001). Notably, age and WAZ at admission (P = 0.156 and P = 0.066, respectively) were not associated with LOS in multivariate linear regression.

DISCUSSION:

Establishing and maintaining optimal nutrition is critical to the survival of infants with single ventricle physiology. Systematic enteral feeding algorithms and home nutritional monitoring programs have been shown to improve weight gain, decrease morbidity, decrease the incidence of necrotizing enterocolitis, and decrease LOS after S1P.[5,13–15] Evidence-based protocols that encompass all phases of palliative surgery to guide decision-making for introduction and advancement of oral feeding are not available. Variability in practice exists among institutions regarding when to introduce oral intake, the type and timing of feeding method, when supplementation is needed,[11,12] and timing and utility of comprehensive swallowing assessments [e.g., videofluoroscopic swallow studies (VFSS) or fiberoptic endoscopic evaluation of swallowing (FEES)].[7,18] To our knowledge, this is the first multicenter study to examine feeding method at S2P discharge for this high-risk population, and define patient characteristics associated with feeding method during S2P hospitalization and discharge.

LOS is an important performance indicator for cost and hospital management, as well as a surrogate measure of patient and family quality of life.[19] An association between younger age, lower WAZ, and GT feedings with increased LOS for S2P was previously reported.[20,21] Similarly, we found that GT feedings following S2P were associated with increased LOS and lowest WAZ scores at admission. However, our findings showed that age and WAZ were not associated with LOS after controlling for feeding method, S2P bypass time, and intubation history. This apparent contradiction may be explained by methodologic differences between investigations using data from a single center versus data derived from a large, multi-center database as used in the current investigation.[20,21] Decision-making for nutrition and feeding management involves complex issues, with potential impact of other confounding factors (e.g., presence of genetic syndrome). The need for enteral feedings likely signals patients who are at a cardiac/ hemodynamic disadvantage with greater medical complexity, particularly given association with other complications such as prolonged intubation.

Consistent with previous reports in the literature, patients with full or partial GT feedings were the oldest at the time of S2P and had the lowest WAZ scores at admission.[8] We found that these groups also had the longest median S2P bypass times. Possibilities for later S2P surgery include prolonged S1P hospitalization, complications during the interstage period, practice variability between centers, and the need to establish adequate weight gain prior to surgery by means of a stable nutritional source. Presence of GTs at S2P discharge may be surrogate markers for children with the greatest medical complexity and increased nutritional challenges, and signal risk factors for suboptimal neurodevelopmental outcomes.[22,23] Information about decision making for GT placement was not available within the registry. The influence of genetic syndromes on decision making for feeding method based on predictions of improved oral feeding need further study. Of note, the overall percentage of patients with genetic syndromes within several feeding groups was very similar to prior findings at S1P discharge by Hill et al 2014. Consistent with the literature, our investigation showed that the presence of GTs did not lead to an advantage in growth or weight gain.[8,24]

In this investigation, feeding methods did not appreciably change during S2P hospitalization. Only 36 new GTs were placed during the hospitalization. We speculate that once feeding method is established for sufficient growth and nutrition to reach S2P surgery, the majority of medical teams and families are not likely to make dramatic feeding changes during this relatively short hospital stay. Supplemental tube feedings provided nutritional benefit for patients unable to feed by mouth only, with 44.8% of patients still requiring some tube feeding at time of S2P discharge. Knowledge that feeding methods are not likely to change during S2P hospitalization remains an important finding, adding to the knowledge base that will contribute to development of best practice guidelines for reduction of center variability. Also, this provides medical providers with evidence-based information for use when ordering tests and counseling families on expectations for this hospitalization.

Post-operative complications (e.g., prolonged intubation and re-intubation) contribute to the medical complexity in these patients, with higher complication rates observed in patients requiring tube feedings. These findings may be explained by prolonged duration of respiratory support, which has been shown to delay the both the initiation of oral feedings and attainment of goal oral and gavage feedings following S1P.[25] Of note, many centers try to promptly extubate following 4–5 days or 1 week, therefore; the multicenter data definition of prolonged intubation >14 days was a limitation in our study. Nonetheless 6% of the patients had prolonged intubations and the frequency of prolonged intubations was more than double in the GT only patients. Therefore, although uncommon, prolonged intubation may be a marker of greater complications during the stage 2 admission (see Table 2). Our findings that recurrent laryngeal nerve injury (RLN) were less common after S2P than previously reported after S1P are not surprising given the location of the RLN relative to the surgical repairs.[8] Of note, oropharyngeal dysphagia with concomitant aspiration occurs independent of vocal fold paralysis in this population.[7,26] Additional studies are needed to elucidate long term implications for RLN injury and recovery, and swallowing outcomes.

LIMITATIONS:

This retrospective review of aggregate observational data is subject to several limitations. The NPC-QIC dataset contains retrospective, observational data that are voluntarily submitted from programs participating in the improvement collaborative. Therefore, limitations in the data may relate to patient selection bias, partial datasets for some patients, definitions used in the database, and/or the heterogeneous composition of participating programs of different sizes and geographic locations. Also, information may be influenced by variability in practice among the centers. For example, some centers discharge patients only if they are total oral feeders or have GTs, and centers will discharge patients with NG/NJ feeds. Information about clinical decision-making for type of feeding method and timing of assessments (e.g., instrumental swallowing evaluations) were not available.

CONCLUSIONS:

In conclusion, presence of GT and intubation history are likely to influence LOS during S2P admission. Age and WAZ at admission are not independently predictive of LOS. Feeding method is not likely to change during S2P hospitalization. Presence of a genetic syndrome, S2P bypass time, age at S2P, WAZ at admission for S2P, and intubation history are primary variables associated with feeding method at S2P discharge. Identification of key patient characteristics and salient outcomes associated with different feeding methods is critical for the development of evidence-based algorithms that decrease practice variability, guide feeding progression, and potentially limit LOS.

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Appendix

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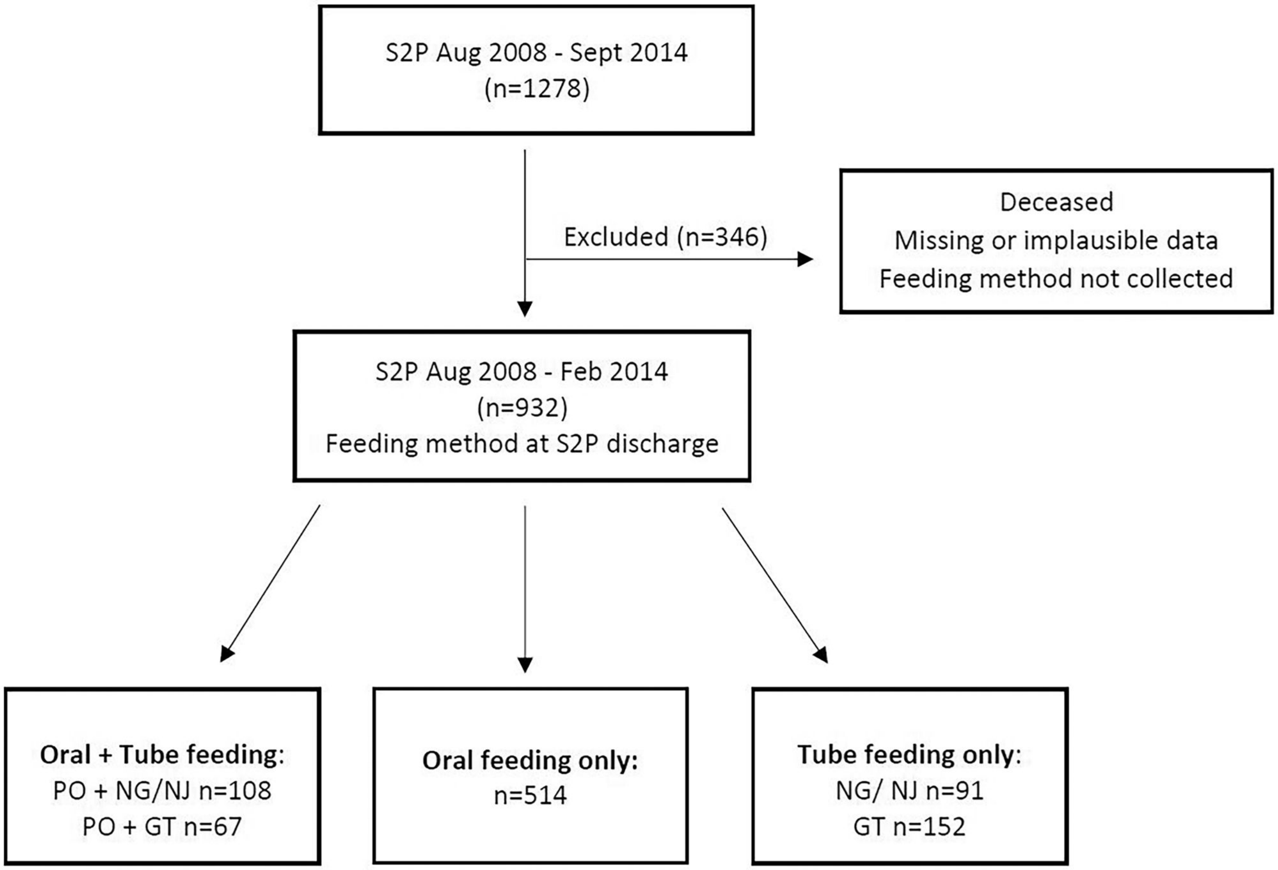

FIGURE 1. Flow diagram of patients undergoing S2P by feeding method at discharge

Flow chart of study population derived from NPC-QIC registry and feeding methods at discharge following S2P

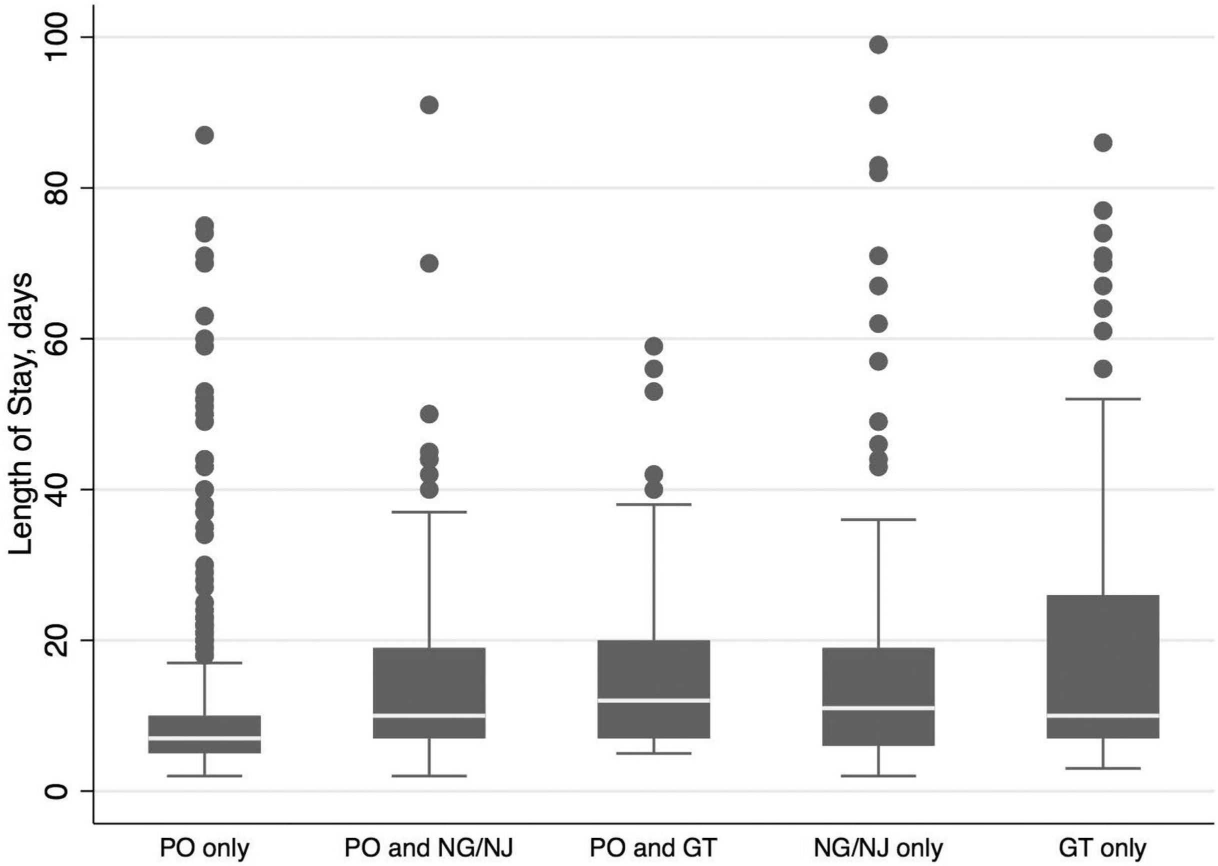

FIGURE 2.
Distribution of length of stay (days) by feeding method at time of S2P discharge

TABLE 1.

Patient demographics and characteristics by feeding status following S2P (n = 932)

	Total Cohort n= 932	PO only n= 514	PO and NG/NJ n= 108	PO and GT n= 67	NG/NJ only n= 91	GT only n= 152	*P* value
Patient demographics							
Male, n (%)	583 (62.6%)	347 (67.5%)	60 (55.6%)	39 (58.2%)	49 (53.8%)	88 (57.9%)	0.014
HLHS, n (%)	625 (67.3%)	337 (65.8%)	79 (73.8%)	46 (68.7%)	61 (67.0%)	102 (67.1%)	0.619
Race, n (%)							0.693
White	702 (75.3%)	393 (76.5%)	86 (79.6%)	48 (71.6%)	67 (73.6%)	108 (71.1%)	
Black	130 (14.0%)	72 (14.0%)	8 (7.4%)	9 (13.4%)	16 (17.6%)	25 (16.5%)	
Asian	9 (1%)	1 (0.2%)	2 (1.9%)	0 (0.0%)	2 (2.2%)	4 (2.6%)	
American Indian	3 (0.3%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	0 (0.0%)	2 (1.3%)	
Other	74 (7.9%)	41 (8%)	11 (10.2%)	7 (10.5%)	4 (4.4%)	11 (7.2%)	
Missing Race	14 (1.5%)	7 (1.4%)	0 (0.0%)	3 (4.5%)	2 (2.2%)	2 (1.3%)	
Hispanic Ethnicity	171 (18.4%)	97 (18.9%)	20 (18.5%)	11 (16.4%)	16 (17.6%)	27 (17.8%)	0.963
Missing Ethnicity	60 (6.4%)	41 (8.0%)	4 (3.7%)	5 (7.5%)	2 (2.2%)	8 (5.3%)	
Patient Characteristics							
GA, mean (SD), n = 923	38.5 (1.5)	38.6 (1.4)	38.3 (1.7)	38.5 (1.6)	38.3 (1.4)	38.2 (1.6)	0.174
BW (kg), mean (SD), n= 923	3.2 (1.1)	3.3 (1.4)	3.1 (0.6)	3.2 (0.6)	3.2 (0.6)	3.2 (0.6)	0.335
Genetic syndrome, n (%)	87 (9.3%)	39 (7.6%)	5 (4.6%)	8 (11.9%)	8 (8.8%)	27 (17.8%)	0.002
S2P bypass time (min), median (min-max)	146 (0–485)	138 (0–403)	138 (0–283)	172.5 (52–438)	150.5 (0–485)	155 (0–359)	< 0.001[a]
Age at S2P (days), mean (SD) n = 928	158.9 (63.8)	156.5 (70.5)	145.3 (47.7)	163.4 (52.7)	145.2 (45.3)	182.7 (57.7)	< 0.001[b]
Weight S2P admission (kg), mean (SD) n = 926	6.8 (19.8)	7.4 (26.6)	5.8 (1.0)	6.2 (1.0)	6.0 (1.1)	6.3 (1.2)	< 0.001[c]
WAZ S2P admission mean (SD) n = 922	−1.3 (1.2)	−1.2 (1.1)	−1.5 (1.2)	−1.4 (1.3)	−1.1 (1.3)	−1.6 (1.4)	0.001[d]
WAZ S2P discharge, mean (SD) n = 897	−1.4 (1.2)	−1.3 (1.2)	−1.5 (1.3)	−1.4 (1.2)	−1.3 (1.4)	−1.6 (1.4)	0.089

S2P- stage 2 palliation; PO- oral; NG- nasogastric; NJ- nasojejunal; GT- gastrostomy tube; HLHS- hypoplastic left heart syndrome; BW- birth weight; GA- gestational age; SD- standard deviation; min- minutes; WAZ- weight-for-age z score. Statistically significant differences using Dunn's pairwise comparison tests with Benjamini-Hochberg's multiple comparison procedure as follows:

[a] Bypass time between PO only versus GT only ($P = 0.001$), PO only versus PO and GT ($P = 0.002$), GT only versus PO and NG/NJ ($P = 0.008$), PO and NG/NJ versus PO and GT ($P = 0.004$)

[b] Age at S2P between PO only versus GT only ($P < 0.001$), GT only versus NG/NJ only ($P < 0.001$), GT only versus PO and GT ($P = 0.012$), GT only versus NG/NJ only ($P < 0.001$), PO and GT versus PO and NG/NJ ($P = 0.010$), PO and GT versus NG/NJ only ($P = 0.010$), PO and NG/NJ versus PO only ($P = 0.020$)

[c] Weight at S2P between PO only versus PO and NG/NJ ($P < 0.001$), PO and NG/NJ versus PO and GT ($P = 0.019$), GT only versus PO and NG/NJ ($P < 0.001$)

[d] Weight at S2P between PO only versus GT only ($P = 0.002$), GT only versus NG/NJ only ($P = 0.012$), PO only versus PO and NG/NJ ($P = 0.017$)

TABLE 2.

Post-operative complications during S2P hospitalization by feeding method at S2P discharge (n=932)

	Total n= 932	**PO only n= 514**	**PO and NG/NJ n= 108**	**PO and GT n= 67**	**NG/NJ only n= 91**	**GT only n= 152**	***P* value**
VAD, n (%)	6 (0.6%)	2 (0.4%)	1 (0.9%)	1 (1.5%)	1 (1.1%)	1 (0.7%)	0.340
PHN, n (%)	27 (2.9%)	12 (2.3%)	4 (3.7%)	5 (7.5%)	1 (1.1%)	5 (3.3%)	0.155
Prolonged intubation, n (%)	60 (6.40%)	20 (3.9%)	8 (7.40%)	4 (6.0%)	6 (6.60%)	22 (14.5%)	<0.001
Re-intubation, n (%)	75 (8.1%)	24 (4.7%)	14 (13.0%)	5 (7.5%)	15 (16.5%)	17 (11.2%)	<0.001
PN injury, n (%)	25 (2.7%)	9 (1.8%)	5 (4.6%)	1 (1.5%)	5 (5.5%)	5 (3.3%)	0.119
RLN injury, n (%)	18 (1.9%)	7 (1.4%)	3 (2.8%)	4 (6.0%)	3 (3.3%)	1 (0.7%)	0.045
Neuro complications, n (%)	7 (0.8%)	2 (0.40%)	2 (1.9%)	0 (0.00%)	1 (1.1%)	2 (1.3%)	0.238
Seizures, n (%)	17 (1.8%)	8 (1.6%)	4 (3.7%)	2 (3.0%)	2 (2.2%)	1 (0.7%)	0.287

S2P- stage 2 palliation; PO- oral; NG- nasogastric; NJ- nasojejunal; GT- gastrostomy tube; VAD= ventricular assist device; PN= phrenic nerve; PHN= pulmonary hypertension; prolonged intubation >14 days; SD= standard deviation; RLN = recurrent laryngeal nerve

TABLE 3.

Results of multivariate linear regression model for log-length of stay (dependent variable) during S2P hospitalization as function of age, weight, feeding method at discharge, bypass time and history of intubations (n = 817)*

	Beta coefficient[1]	**95% confidence intervals**	***P* value**
WAZ S2P Admission	−0.035	[−0.0720, 0.00228]	0.066
Age at S2P (in months)	−0.016	[−0.0372, 0.00596]	0.156
Feeding Method at S2P Discharge			
NG/NJ only versus oral	0.295	[0.146, 0.445]	<0.001
G-Tube only versus oral	0.307	[0.181, 0.434]	<0.001
Oral and NG/NJ versus oral	0.236	[0.0922, 0.380]	0.001
Oral and G-tube versus oral	0.414	[0.236, 0.592]	<0.001
Oral only (reference)	-		
Bypass Time (in minutes)	0.000773	[0.0000414, 0.00150]	0.038
Re-intubation	0.669	[0.482, 0.856]	<0.001
Prolonged Intubation	1.337	[1.121, 1.552]	<0.001
Intercept	1.929	[1.763, 2.095]	<0.001
n	817		
adj. R^2	0.364		

S2P- stage 2 palliation; PO- oral; NG- nasogastric; NJ- nasojejunal; GT- gastrostomy tube; prolonged intubation >14 days

*Of the 932 patients, 115 were excluded due to missing data.

[1]Beta coefficients from the regression with log-transformed outcome should be interpreted as follows. First, note that with log-transformed outcome, we are estimating the geometric, rather than arithmetic mean in simple linear regression. Second, the exponentiated coefficient gives the ratio of geometric means for every unit increase in the independent variable. For example, the beta coefficient for comparing Glenn NG/NJ vs oral feeding is 0.295. After we exponentiate, we get exp (0.295) = 1.34. This is the estimated ratio of LOS geometric mean for Glenn NG/NJ vs oral feeding, which shows 34% longer LOS, after adjustment for age, weight, bypass time, reintubation and prolonged intubation status.