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Creation of a Standard Model for Tube Feeding at Neonatal Intensive Care Unit Discharge

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Abstract

Background: Feeding dysfunction is a common consequence of prematurity and illness in neonates, often requiring supplemental nasogastric (NG) or gastrostomy (GT) feeding tubes. A standardized approach to the discharge of infants receiving home enteral nutrition (HEN) is currently lacking. *Methods:* The Home Enteral Feeding Transitions (HEFT) program was developed to identify patients eligible for HEN and create a standard discharge process. A structured tool helped determine discharge timing and route, and a dedicated outpatient clinic was created for infants discharged on HEN. Demographic, inpatient, and outpatient data were prospectively collected and compared with a historical cohort. *Results:* A total of 232 infants discharged from our neonatal intensive care unit (NICU) over 9 months met inclusion criteria. Ninety-eight (42%) were discharged with HEN, 68 NG and 30 GT, compared with 134 (58%) receiving full oral feeds. This represented a 10% increase in HEN utilization ($P = 0.003$) compared with our historical control group. Median HEN length of stay was 31.5 days compared with our historical average of 41 days ($P = 0.23$). Frequency of emergency department visits and admissions because of HEN was unchanged postintervention. Parents were satisfied (8.6/10), and 98% said they would choose HEN again. The median time to NG discontinuation after discharge was 13.5 days, with an estimated cost savings of $2163 per NICU day. *Conclusion:* Our program is the first of which we know to use a standard care-process model to guide the decision-making and utilization of HEN at NICU discharge. HEFT shows that HEN at NICU discharge can be safe and effective, with high parental satisfaction. (*JPEN J Parenter Enteral Nutr.* 2020;44:491–499)

Keywords

neonates; nutrition; outcomes research/quality

Clinical Relevancy Statement

Prolonged oral feeding dysfunction is a common complication in neonates that requires the administration of enteral nutrition. Home enteral nutrition (HEN) is commonly described in older populations, but its use in the neonatal population has only been infrequently studied. Here we present a standardized approach to the inpatient and outpatient aspects of HEN at neonatal intensive care unit discharge and show that the practice can be achieved safely, with high parental satisfaction, and significant cost savings.

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Introduction

Full oral feeding is generally the last milestone achieved for neonates prior to hospital discharge from the neonatal intensive care unit (NICU), but many infants have prolonged oral feeding dysfunction that extends their hospital admission.[1] Few studies have explored the scope of this problem, but available data suggest that this group represents as much as 16%–33% of the NICU population.[2-4] Prolonged NICU admission not only adds cost but also carries the risk of iatrogenic harm to the patient and emotional stress for the family.[2]

Approaches to prolonged feeding dysfunction have historically involved either continuing admission until full oral feeding is achieved or until a gastrostomy tube (GT) is placed.[5] The use of home nasogastric tube (NG) feeding can allow for earlier discharge of these infants from the NICU, and the medical literature on home NG feeds supports its safety and utility in diverse groups, including older children, infants with congenital heart disease, and neonates.[2,4,6-16] Yet, this practice has not been widely adopted, and processes that effectively recognize neonates who are candidates for HEN, determine their appropriate feeding modality (NG vs GT), and inform optimal discharge timing are still lacking.

The Home Enteral Feeding Transitions (HEFT) project described here sought to improve patient care by standardizing the inpatient and outpatient care of infants whose continued hospitalization in the NICU was due to prolonged feeding dysfunction. We hypothesized that the program's structured approach to decisions around HEN and its outpatient support would increase HEN utilization, decrease length of stay (LOS), prevent serious adverse events, and lead to high parental satisfaction.

Methods

The Institutional Review Board (IRB) at the University of Utah and Primary Children's Hospital reviewed this project and found it to be exempt from IRB approval because of its focus on quality improvement. The HEFT project was initiated in September 2016 at the Primary Children's Hospital NICU, a large level IV referral-based tertiary care unit in Salt Lake City, Utah. Primary Children's Hospital is a part of Intermountain Healthcare, a not-for-profit regional healthcare system that operates 22 hospitals throughout Utah and Idaho.

A prospective database was created and included all patients discharged from September 2016 through May of 2017. All infants admitted to the NICU were evaluated for inclusion in the study. Exclusion criteria included death prior to discharge, transfer to another institution, discharge on transpyloric feeds, discharge on parenteral nutrition without supplemental tube feeds, discharge for palliative care, and LOS <2 days. Infants discharged on HEN were compared with those discharged on full oral feeds, and both groups were compared with a previously described cohort of infants discharged from January 2013 to December 2015.[4] Data from the preintervention cohort were gathered retrospectively from the Intermountain Healthcare electronic medical record (EMR), and identical exclusion criteria were used.

Inpatient care and decision-making was guided by the HEFT protocol (Figure 1) designed for this project following an extensive literature review of the topic and in consultation with neonatologists, neonatal nurse practitioners, dietitians, neonatal developmental therapists, surgeons, and gastroenterologists. A patient's steady improvement in full oral percent of total intake led to continued hospitalization until full oral intake was achieved, whereas poor or stagnant improvement resulted in the neonate's discharge on NG feeds. The interpretation of "improving oral intake" was left up to the individual providers to best harness their clinical experience and avoid arbitrary cutoff values. Discharge on HEN was dependent on full parental agreement, and parents received standardized teaching on GT or NG care and placement.

A dedicated follow-up clinic, the HEFT clinic, was created and was staffed by a gastroenterologist, dietitian, and developmental feeding therapist. All infants discharged with HEN were offered appointments, with a target first visit 2–3 weeks after discharge. Additionally, a standardized home health nursing schedule was created for patients receiving HEN. All primary care providers were notified of discharge and feeding plans. Families unable to come to the HEFT clinic because of increased travel burden had follow-up arranged with a local pediatrician comfortable with the care of NGs and GTs. All parents and primary care physicians were also provided with an individualized dietary plan that detailed expected feeding advancement and weight gain. Time to NG discontinuation and achievement of full oral feeds or GT placement was tracked for all infants discharged on NG by phone contact and/or EMR review.

Parental satisfaction was determined through a short survey administered at 2–3 weeks following discharge by phone interview or in-person interview at clinic visit (Supplementary Material). In the case that parents could not be reached in that time frame, repeat attempts at survey completion were made until 2 months after discharge.

A cost analysis was performed to measure the services relating to a neonate's inpatient and HEN-associated outpatient care. Individual inpatient costs (not charges) for each HEFT patient were gathered by querying the Intermountain electronic data warehouse. The inpatient costs of a single day in the NICU are highly variable, and costs were gathered from the single day prior to discharge for each patient to provide a conservative estimate of daily costs. Physician costs were not included in this data, as those financial data are handled by a separate employer. Outpatient costs,

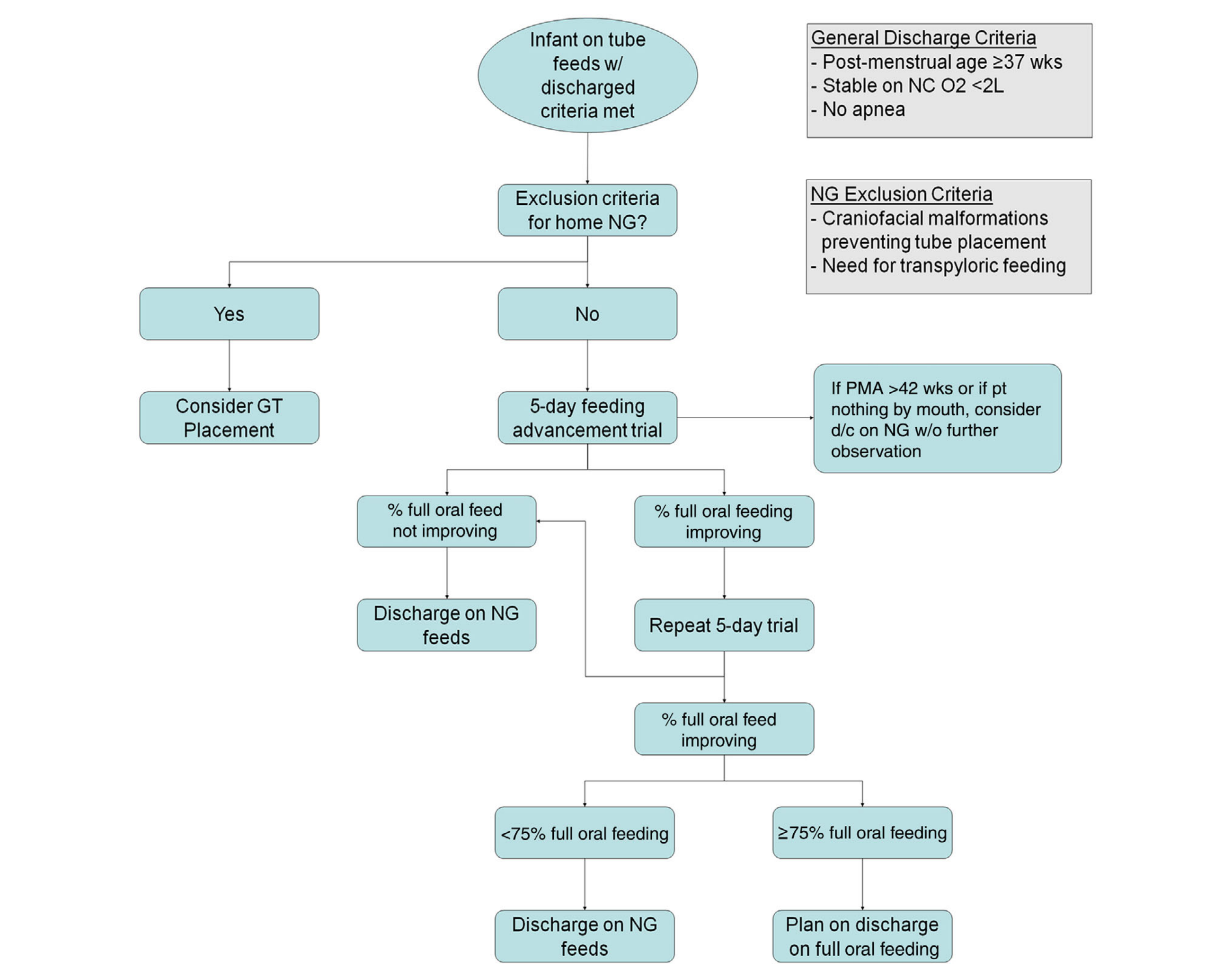

Figure 1. Inpatient Home Enteral Feeding Transitions algorithm. d/c, discharge; GT, gastrostomy tube; NG, nasogastric tube; PMA, postmenstrual age.

including home nursing, home NG/GT feeding equipment, other home health services and equipment, and HEFT clinic services in the 6 months following discharge, were measured as the "allowed amount" for each HEFT patient enrolled in SelectHealth, a not-for-profit insurance company run by Intermountain Healthcare. All dollar amounts were adjusted to 2017 dollars using the All Urban Consumers Consumer Price Index for all items.

Emergency department (ED) visits and admissions were tracked via the Intermountain EMR for 6 months following discharge for all patients receiving HEN. An adverse event was defined as an ED visit or hospital admission primarily because of a feeding tube–related complication. Individual chart review of postdischarge hospital encounters was performed by the primary investigator to determine adverse events. Parents were also queried whether any ED visits or hospital admissions had occurred outside the Intermountain system, and any additional encounters were also included. Patient encounters were analyzed in an intention-to-treat fashion with hospital encounters counted under a patient's discharge feeding modality, regardless if it changed following discharge.

Statistical Methods

Demographic and on-study variables were summarized as mean, SD, median and interquartile range (IQR) for continuous variables, or count (%) for categorical variables and stratified by preintervention or postintervention and feeding status. Summaries were repeated within the full oral feed, HEN, NG, and GT groups, stratified by preintervention or postintervention. Statistical tests across preintervention or postintervention and feeding type included *t*-test, Wilcoxon rank sum, and exact Wilcoxon rank sum tests for continuous predictors and χ^2 test or Fisher's exact tests for categorical variables, where indicated.

LOS had a right-skewed distribution, and we used a modified Park test, which identified the γ distribution as the optimal outcome model to use for regression analysis based on the mean-variance relationship for LOS.[17] We prespecified that the comparison of treatment group and preintervention or postintervention with the LOS outcome would be adjusted for sex, admission diagnosis category, and potentially gestational age and birth weight if these 2 variables were not correlated. Since birth weight and gestational age correlation was high at 0.84 (variance inflation factor = 3.5), we excluded birthweight from the model. We report ratios, 95% CI, and *P*-values for each model. All statistical analyses were conducted in R 3.4.4. Significance was assessed at the 0.05 level, and all tests were 2-tailed.

Results

During this study, 292 infants were discharged from the NICU. Sixty infants were excluded, 46 because of transfer to another institution, 8 because of discharge on transpyloric feeds, 4 because of LOS <2 days, 1 because of discharge on hospice, and 1 because of discharge on parenteral nutrition without supplemental tube feeding. The remaining 232 infants were included in our cohort, 134 discharged on full oral feeds and 98 infants discharged through the HEFT program. In the HEFT program, 68 (69%) infants were discharged on NG feeds and 30 (31%) on GT feeds. Demographic variables for preintervention and postintervention cohorts are presented in Table 1. Stratified by feeding type, those discharged on NG feeds after our intervention were born earlier (33.9 vs 35.8, $P = 0.008$), at a lower birth weight (2291 vs 2596, $P = 0.045$), and had a greater proportion of male infants (62% vs 48%, $P = 0.046$) compared with the NG preintervention cohort. Those discharged with GTs had no clinical differences compared with the preintervention cohort (Table 2). Primary discharge diagnosis was not different between pre-cohorts or post-cohorts (Supplementary Table S1).

We observed a significant change in HEN utilization, increasing from 32% to 42% ($P = 0.003$) (Supplementary Table S2). This increase is accounted for by the discharge of more patients receiving NG feeds, increasing from 17% to 29% ($P < 0.001$). Fewer patients had GTs placed prior to discharge, a decrease from 15% to 13%, but more patients discharged with NG feeding had a GT placed after discharge compared with prior to discharge, increasing from 2% to 4% ($P = 0.043$). The overall proportion of infants with a history of GT placement at 6 months postdischarge was essentially unchanged, from 17.6% preintervention to 17.2% postintervention.

Median hospital LOS was not significantly different between the pre and post-intervention periods in the overall

Table 1. Descriptive Summary of Demographic Variables Comparing Preintervention vs Postintervention Overall and by Feeding Type at Discharge.

Variable	Pre-All N = 1207	Post-All N = 232	*P*-Value	HEN Pre N = 388	HEN Post N = 98	*P*-Value	Full Oral Feeding Pre N = 819	Full Oral Feeding Post N = 134	*P*-Value
Sex, male, n (%)	664 (55%)	145 (62%)	**0.035**	190 (49%)	59 (60%)	**0.047**	474 (58%)	86 (64%)	0.17
Gestational age, wk, mean (SD)	36.2 (4.2)	36.2 (4.4)	>0.99	35 (4.8)	34.4 (5)	0.35	36.8 (3.7)	37.5 (3.4)	**0.031**
Median (IQR)	37.4 (34.7, 39)	37.7 (34.4, 39.1)	–	36.8 (32, 38.9)	36.1 (31.4, 38.4)	–	37.9 (35.4, 39.1)	38.7 (36.9, 39.3)	–
Birth weight, g, mean (SD)	2675 (953)	2717 (1011)	0.56	2414 (1077)	2343 (1087)	0.56	2799 (862)	2991 (857)	**0.018**
Median (IQR)	2811 (2110, 3360)	2887 (2000, 3500)	–	2530 (1611, 3161)	2332 (1492, 3051)	–	2930 (2320, 3408)	3203 (2552, 3631)	–
Postmenstrual age at discharge, wk, mean (SD)	42.1 (4.6)	42.9 (5.8)	–	45.3 (6)	45.3 (7.6)	–	40.6 (2.7)	41 (2.7)	–
Median (IQR)	41 (39.4, 43.4)	41.3 (40.1, 44)	0.081	43.9 (41.9, 47.6)	43.2 (41.1, 46.5)	0.16	40.4 (39, 41.9)	40.4 (39.6, 42)	0.073
LOS, mean (SD)	32.7 (39)	34.5 (43.9)	–	56.2 (49)	53.6 (55)	–	21.5 (26.5)	20.41 (25.8)	–
Median (IQR)	17 (8, 40)	17 (9, 37)	0.75	41 (17.8, 80)	31.5 (15.2, 73)	0.23	12 (6, 25.5)	11 (7, 21.8)	0.67

Bolded values indicate statistical significance.
HEN, home enteral nutrition; IQR, interquartile range; LOS, length of stay.

Table 2. Descriptive Summary of Demographic Variables in HEN Cohort Comparing Preintervention vs Postintervention by NG/GT tube type.

Variable	NG Pre N = 201	NG Post N = 68	*P*-Value	GT Pre N = 187	GT Post N = 30	*P*-Value
Sex, male, n (%)	96 (48%)	42 (62%)	**0.046**	94 (50%)	17 (57%)	0.52
Gestational age, wk, mean (SD)	35.8 (4.3)	33.9 (5.2)	**0.008**	34.1 (5.2)	35.7 (4.3)	0.073
Median (IQR)	37.3 (34, 39)	35.6 (30.1, 38.1)	–	36.1 (30.3, 38.4)	36.4 (34.2, 39)	–
Birthweight, g, mean (SD)	2596 (1030)	2291 (1087)	**0.045**	2218 (1095)	2461 (1095)	0.27
Median (IQR)	2748 (1858, 3320)	2375 (1365, 3092)	–	2320 (1263, 2986)	2238 (1839, 3008)	–
PMA at discharge, wk, mean (SD)	43.1 (4.1)	43.2 (4.2)	–	47.6 (6.8)	50.2 (10.9)	–
Median (IQR)	42.6 (40.7, 44.9)	42 (40.6, 45.1)	0.88	46.1 (43.4, 49.6)	45 (43.4, 52.9)	0.78
LOS, mean (SD)	44 (36.3)	44.5 (41.9)	–	69.4 (57.5)	74.3 (73.8)	–
Median (IQR)	32 (15, 63)	28.5 (13.8, 64)	0.71	53 (23, 98.5)	43 (18.5, 100.8)	0.76

Bolded values indicate statistical significance.
GT, gastrostomy tube; HEN, home enteral nutrition; IQR, interquartile range; LOS, length of stay; NG, nasogastric tube; PMA, postmenstrual age.

Table 3. Comparison of ED Encounters and Hospital Admissions in 6 Months Following Discharge With HEN.

Variable	HEN Pre N = 388	HEN Post N = 98	*P*-Value
Patients seen in ED, n (%)[a]	125 (32)	32 (33)	0.93
Total ED visits	227	51	–
Patients with ED visits related to HEN, n (%)	42 (11)	11 (11)	0.91
Patients admitted to hospital, n (%)[b]	138 (36)	33 (34)	0.59
Total admissions	228	63	–
Unscheduled admissions	138	33	–
Patients with admissions related to HEN, n (%)	10 (3)	1 (1)	0.66
Patients with admissions for poor growth, n (%)	8 (2)	5 (5)	0.15

[a]Excluding visits associated with admissions.
[b]Excludes scheduled surgeries or procedures.
ED, emergency department; HEN, home enteral nutrition.

cohort (17 to 17), nor between the HEN (41 to 31.5) or PO (12 to 11) groups when evaluated separately (Table 1). LOS for the HEN group was analyzed further by logistic regression in which neither the unadjusted nor the adjusted model showed a significant change following initiation of the HEFT program (Supplementary Table S3).

There was no difference found in the rate of hospital utilization between the preintervention and postintervention HEN groups (Table 3). Within 6 months of discharge, 32 postintervention HEN patients (33%) (51 total visits) were seen in an ED (excluding ED visits that led to admissions), and 11 patients (11%) (15 total visits) were seen for reasons related to tube feeding. GT complications accounted for 11 (73%) of these visits and included tube dislodgement, irritation or leakage around the GT, and GT site cellulitis. One visit was due to a clogged nasal-jejunal tube placed postdischarge in a patient discharged on GT feeds. The remaining 3 (20%) visits related to NG tube dislodgement or fussiness after NG tube replacement at home. Thirty-four percent of patients had unscheduled hospital admissions. Of those, a single admission was related to tube feeding. This admission was secondary to apnea and bradycardia, which occurred after an NG feed at home which, based on malposition of the tube at hospital presentation, was assumed to be related to a reflux/aspiration event from the malpositioned tube. These 16 total adverse events associated with tube feeds occurred in the context of 9571 total outpatient tube days for an adverse event rate of 0.84 per 500 tube days.

Additionally, there were 5 admissions (8%) because of poor growth postdischarge, 4 in the NG group and 1 in the GT group. Three of these admissions were thought to be due to underlying disease with underestimation of their energy needs prior to discharge. Another was due to incorrect fortification of feeds at home, and the last was due to parental neglect. All patients were successfully discharged after demonstrating adequate weight gain in the hospital.

There were 97 HEFT clinic visits for our cohort in the 6 months following discharge, 59 NG and 38 GT. Forty-nine (40%) patients (30 NG and 9 GT) did not have a clinic visit. Those patients with NG feeds who were not seen in the HEFT clinic typically did not attend because their NG tube had already been removed, either by their pediatrician or at home by the parents when full oral feeding skills had developed. Those with GTs who chose not to be seen in the HEFT clinic had other adequate follow-up arranged, either in another specialty clinic or with a skilled pediatrician.

Table 4. Outpatient Experience of Patients With HEN in First 6 Months After Discharge.

Variable	NG N = 68	GT N = 30	*P*-Value
Responded to survey, n (%)	57 (84%)	25 (83%)	–
Total HEFT clinic visits	59	38	–
Parental satisfaction at 2 to 4 wk, mean (SD)[a]	8.4 (2)	8.9 (1.2)	0.64
Would choose HEN again	55 (97)	25 (100)	>0.99
Would have preferred GT	7 (10.3)	–	–
GT removed	–	1	–
Admissions for failure to thrive	4	1	0.39

[a]Scale 1–10, 10 = highest satisfaction.
GT, gastrostomy tube; HEFT, home enteral feeding transitions; HEN, home enteral nutrition.

Table 5. Cost Analysis for Infants Discharged on HEN.

Variable	All	GT	NG
Cost of single NICU day, median[a]	$2340	$2546	$2163
Total allowed amount for outpatient care, median[b]	$2318	$3484[c]	$1532
Time to NG discontinuation after NICU discharge, median, days	13.5	–	–
Estimated cost prevented per patient discharged on NG, median[d]	$27,669	–	–

[a]Represents cost of the single day prior to discharge.
[b]Represents home health and HEFT clinic visits for the 6 months following discharge. Limited to 24 NG and 11 GT patients with available outpatient financial data.
[c]Three patients with ventilator/Bilevel Positive Airway Pressure charges excluded.
[d](Single NG NICU Day × 13.5) − (NG total allowed amount).
HEFT, home enteral feeding transitions; HEN, home enteral nutrition; NG, nasogastric tube; NICU, neonatal intensive care unit.

The response rate for our postdischarge survey was 84% (82/98). Parents reported high satisfaction with the process of discharge on HEN through the HEFT program, scoring it 8.4/10 in the NG group and 8.9/10 in the GT group ($P = 0.64$) (Table 4). Only 2 families reported they would not have chosen HEN again, 1 because their infant began eating everything by mouth the day after discharge and the other because of difficulty operating the NG feeding pump at home.

Feeding outcomes for all infants were known at 6 months postdischarge and no infants were lost to follow-up. In the 6 months following discharge, 52/68 (76%) patients weaned off NG feeds completely, 10 (15%) had a GT placed, and 6 (9%) continued to use their NG tubes. Figure 2 shows a survival curve of when these infants were able to develop full oral feeds or had a GT placed. Within 14 days following discharge, 40% of infants weaned off their NG tubes, and 65% had done so by 8 weeks. The median time to NG discontinuation was 13.5 days (IQR: 4, 38.8).

The median total cost for the single day prior to discharge for our cohort was $2340 (NG: $2163, GT: $2546) (Table 5). For our outpatient cost analysis, 35/98 (24 NG, 11 GT) patients used outpatient services through SelectHeath. The median "allowed amount" for their cumulative outpatient home health services and HEFT clinic visits in the 6-month period following discharge was $2318 (NG: $1532, GT: $5120). Of note, 3 GT patients had values for their outpatient services in excess of $20,000, secondary to home ventilator or Bilevel Positive Airway Pressure devices. Removing these outliers changes the median value for patients with a GT to $3484.

Discussion

The HEFT project demonstrates the successful implementation of a standardized approach to HEN at NICU discharge that both guides inpatient decision-making and structures outpatient care. We found that this program increased HEN utilization and did so with high parental satisfaction and very low rates of adverse events. Our program highlights that most infants discharged on NG feeds can successfully achieve full oral feeds within 8 weeks of their discharge. Additionally, we created a cost estimate that approximates the value of this HEN program. These findings are strengthened by the integration between specialties and patient families that was pursued at all phases of the project and also by the high capture percentage of outpatient patient data we were able to achieve.

Previous studies have established the safety and feasibility of discharging neonates home on NG feeds in diverse populations that range from premature infants with few other complications to children with complex congenital heart disease.[2,7-16,18-21] Many of these studies have also shown that HEN can be approached programmatically at NICU discharge with aspects that variably included follow-up clinics, coordinated subspecialty care, home nursing, and parent satisfaction surveys.[2,7,8,10-12,16] Similar to our own results, these studies showed low complication rates from HEN and high parental satisfaction when it was measured. However, these programs generally focused on premature infants without additional medical or surgical complexity, and guidance on discharge timing was limited to criteria representing physiologic stability. In a previous report, we described a retrospective cohort from our unit (also the comparison group for our current study) and showed that an NG feeding program can be done safely in highly complex neonates as well.[4] Our project differs

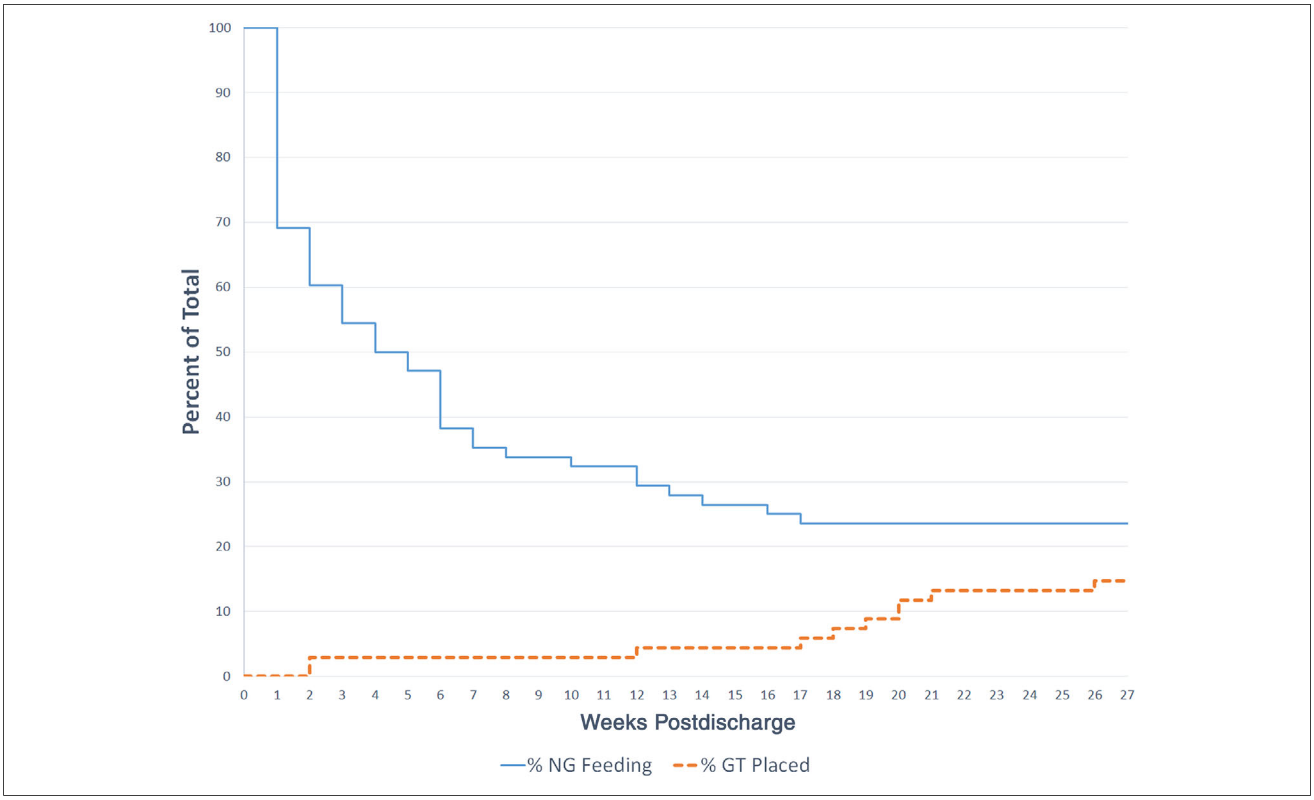

Figure 2. NG tube discontinuation or GT placement in 6 months following discharge in 68 patients discharged with NG feeds through the Home Enteral Feeding Transitions program. GT, gastrostomy tube; NG, nasogastric tube.

from these previous studies in that it creates a standard process for decision-making and follow-up around HEN in a heterogeneous population of neonates and has detailed outpatient outcome reporting.

The increased utilization of HEN, including a 12% increased rate of discharge on NG and a 2% decrease in inpatient GT placement, was a main finding of this study, and met our goal of discharging infants on HEN when clinically appropriate. A criticism of this approach is that it prioritizes early discharge to the detriment of patients, exposing them to excess risk with outpatient tube feeding, removing access to daily developmental therapy, and placing undue responsibilities on parents. This assumption that the inpatient environment is superior in safety and developmental resources to the outpatient environment is contradicted by our results, which show very low tube-related complications and high parent satisfaction with HEN. Additionally, that 31% of infants discharged on NG feeds achieved full oral feedings within 1 week of discharge may suggest that the home environment is superior to promote oral feeding. Alternatively, it may indicate that our unit could improve its system of oral skills development or that our discharge protocol is too conservative regarding discharge timing.

Though we were able to achieve greater HEN utilization, this did not translate to a statistically significant reduction in LOS. The explanation for this is likely multifactorial. Our study was not powered to detect small changes in LOS, especially given the wide variation in LOS between patients that is present in tertiary NICUs. The nature of improvement implementation lends to efficiency developing over time, and our data did show a trend toward lower LOS at the end of the study compared with the start (Supplementary Figure S1). Our unit's historical practice of HEN also likely limited the margin that was available to reduce LOS as opposed to instituting this program in a unit that never or only rarely discharged infants on home NG feeds.

Our outpatient safety outcomes were reassuring in the low need for admission for tube-related complications, and our patient's ED utilization, especially by those with GTs, was comparable with that of Khalil et al in their study of NICU discharges and with other studies of outpatient GT complications.[8,22-26] Our study did show a small reduction in GT placement prior to discharge, but when accounting for outpatient conversion to GT, both preintervention and postintervention cohorts had ≈17% of infants with GTs at 6 months postdischarge. This suggests that our protocol could delay GT placement in infants with oral feeding dysfunction under 12 months of life, a potentially advantageous change for premature or recently ill neonates. We do report 5 admissions for poor growth observed in our cohort. All these admissions were preventable and likely would have been avoided by prompter scheduling of clinic appointments, a challenge that improved over the project's course. The single admission secondary to parental neglect is also important to point out and highlights the continued vigilance a program such as ours needs to have in evaluating parental readiness for HEN.

The implementation of HEFT did not result in cost savings through significantly lower LOS, but it does show that a significant potential cost savings can be seen from the practice of home NG feeding. The median cumulative 6-month outpatient "allowed amount" ($1532) for our HEFT patients is exceeded by a single day's cost in the NICU ($2163). These figures are conservative estimates, as well, given that the inpatient cost data did not include physician costs. Our median time to NG discontinuation of 13.5 days suggests that a median cost savings for an NG home-feeding program would be over $27,000 per patient discharged. This measurement of prevented costs based on an accurate time to NG discontinuation and achievement of full oral feeds has not been previously described to our knowledge. In the current environment of fee-for-service models of reimbursement in the United States, this can be viewed as saving money for patient families, insurance companies, and Medicaid budgets but may reduce revenue for hospitals.[27] Reduced NICU occupancy through LOS reduction can have other beneficial effects for hospitals such as reduced strain on physical space limits, reduced need for capital expenditures that increase unit capacity, and decreasing staffing needs.[28] Additionally, in health systems that incorporate capitated pay models, any reduction in LOS will result in immediate cost savings for hospitals.

Our project has a number of limitations that may impact the generalizability of its conclusions. The number of patients enrolled in HEFT was small, and this has implications for the detection of small differences in outcomes, such as changes in LOS, but also may limit the detection of rare events such as serious complications related to tube feeding. The time frame of the study was also restricted, and in observing less than a full year of NICU discharges, we may have missed important seasonal or multiyear variations in patient makeup. Our study was limited to a single center that already had a strong history of utilizing HEN. The challenges of implementing a similar program at other institutions may not be fully reproducible because of provider variability, outpatient resources, and subspecialist availability. Additionally, as a referral NICU with only outborn patients, our data reflect a complex medical and surgical population that is not representative of all NICUs. Our algorithm was designed with this complex population in mind, and aspects may need to be optimized to better apply to units with lower acuity. For example, previous studies of premature infants without complexity showed discharge as early as 33–35 weeks postmenstrual age.[7,10,12] Future prospective multicenter studies are needed to investigate HEN in diverse neonatal populations and hospital settings.

The HEFT project and protocol we present demonstrates the feasibility and potential advantages in implementing a comprehensive HEN program in the NICU. Our data indicate that the practice has high cost savings, is associated with high parental satisfaction, does not prevent oral feeding progression, and is associated with few adverse events. Additionally, the creation of a reproducible or adaptable standard model of care has potential applications for further quality improvement or research initiatives. The validation of this model with greater numbers of infants and in different NICU environments will be key to that endeavor. Delivering infants safely to their family's care sooner is a goal worth pursuing, and we hope to sustain this project to further that effort in our own institution as well as others.

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Statement of Authorship

B. R. White, C. Y. Ling, and A. Ermarth equally contributed to the conception and design of the research; O. Arguinchona contributed to the design of the research; B. R. White contributed to the acquisition and analysis of the data; D. Thomas contributed to the acquisition of the data; A. P. Presson contributed to the analysis of the data; B. R. White, C. Y. Ling, and A. Ermarth contributed to the interpretation of the data; and B. R. White drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

Supplementary Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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