# EFFECT OF FEEDING PROTOCOL IMPLEMENTATION ON NUTRITION IN THE PEDIATRIC INTENSIVE CARE UNIT

By

Katharine deForest Schuette

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CERTIFICATE OF APPROVAL

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This is to certify that the Master's thesis of
Katharine deForest Schuette
has been approved

Mentor/Advisor

Member

Member

Member

Member

# TABLE OF CONTENTS

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**Abstract**

Feeding protocols, which are guidelines for the initiation and advancement of nutrition support to be used prior to dietitian initial assessment, have been associated in some studies with earlier achievement of goal feeding rate, increased use of enteral over parenteral nutrition, reduced risk of mortality, and fewer incidences of infection. This retrospective chart review investigated nutrition-related outcomes before and after implementation of a feeding protocol in the Doernbecher Pediatric Intensive Care Unit (PICU) in 2013. Chart data on children aged 1 month through 18 years admitted to the PICU during a 4-month period in 2012 (pre-implementation group) and 2017 (post-implementation group) were screened for inclusion, and 50 total participants met inclusion criteria. Primary outcomes for this study were time of enteral nutrition initiation, percent of nutrition needs met from enteral and parenteral nutrition, duration of mechanical ventilation, and length of stay (PICU and hospital). Cox proportional hazard regression models were used to compare primary outcomes between groups. To determine percentage of calories and protein needs obtained, each patient's energy and protein support was plotted against time and then summarized as the area between the energy/protein profile over time and the energy/protein requirement set by the dietitian's initial assessment. There was a statistically significant difference in time to EN initiation ($p<0.05$), with feeds starting around twice as quickly in 2017 (Hazard ratio (95% CI) = 2.12(1.13, 3.98)). There were no significant differences in calorie or protein provision, duration of mechanical ventilation, or length of stay. Our research demonstrates that feeding protocols may improve nutrition practices in the critical care setting, especially with regard to routine early placement of feeding tubes and time to start enteral nutrition.

## Chapter I: Introduction

Adequate nutrition provision during critical illness is associated with attenuation of physiological stress and weight loss, reduction in cumulative energy and protein deficits, lower risk of infections, improved immune function, and decreased length of hospital stay.[1–4] Early enteral nutrition (EN), typically defined as initiation of feeds <24-48 hours from admission, is associated with decreased mortality and benefits to immune function.[5,6] Failure to provide nutrition, conversely, exacerbates weight loss and depletion of bodily nutrient stores while increasing risk for morbidity and mortality.[7,8] Nutrition is especially important for critically ill children due to comparatively low bodily stores of fat and protein and a high prevalence of malnutrition prior to pediatric intensive care unit (PICU) admission.[8,9] Children are at increased risk for impaired growth and development if adequate nutrition is not provided. Unfortunately, nutrition provision in PICUs is often delayed and inadequate to meet nutritional needs.[10]

PICU clinicians have begun to implement feeding protocols in order to improve and standardize nutrition practices. A feeding protocol is a guideline for the initiation and advancement of nutrition support to be used by doctors, nurses, dietitians, and other healthcare practitioners, along with clinical judgment. The content of feeding protocols varies widely between institutions,[11] but often includes the promotion of EN over parenteral nutrition (PN) when possible, and encourages early initiation of EN. Feeding protocols may also include guidelines for the following: formula selection, feeding start rate, rate advancement, and goal rate; feeding tube termination site (gastric vs. post-pyloric/trans-pyloric); management of gastrointestinal intolerance; and contraindications for EN.[11] A benefit of feeding protocols is that PICU staff are empowered to initiate EN when a dietitian is not available to determine the nutrition prescription, which some studies have shown reduces time to initiation and time to reach goal feeding rate.[10] The dietitian may then refine the EN order after a complete nutrition assessment. Feeding protocols may also help to make evidence-based nutrition practices routine, while educating the interdisciplinary team on current best practices for nutrition in critical care.

The effect of feeding protocols on nutrition-related outcomes in PICUs is a relatively new topic, though a few notable studies regarding this subject have been performed over the past decade.[2,10–14] Mehta et al. observed in a 2012 international, multicenter cohort study that PICUs using feeding protocols had a lower incidence of infectious complications including ventilator-assisted pneumonia, bloodstream infections, and urinary tract infections.[2] The current study will compare data collected prior to implementation of a feeding protocol to current data in order to examine whether use of a feeding protocol affected nutrition-related outcomes. Outcomes of interest in this study were time to enteral feed initiation, percentage of prescribed energy and protein intake obtained during ICU stay, length of ICU and hospital stay, time to wean from ventilation, and prevalence of malnutrition at admission as classified by z-scores.

## Chapter II: Specific Aims

*Aim 1* will determine whether implementation of the PICU feeding protocol was associated with a reduced time to initiate EN. We hypothesize that patients who were admitted after the feeding protocol was implemented will have started EN earlier than those who were admitted before it was implemented.

*Aim 2* will examine whether the feeding protocol affected percentage of estimated nutrient needs met during a stay up to 10 days in the PICU. We hypothesize that patients admitted after the feeding protocol was implemented will have met a higher percentage of their estimated energy and protein needs via nutrition support during their hospital stay.

Aim 3 will explore health outcomes that have been associated with quality of nutrition in pediatric critical care settings: Prevalence of infectious complications (including blood stream and urinary tract infections), duration of mechanical ventilation, and length of stay (PICU and hospital). We hypothesize that patients admitted after the feeding protocol was implemented will have had decreased infectious complications, a shorter time on mechanical ventilation, and a shorter length of stay.

## Chapter III: Background

### *Nutrition During Critical Illness*

Infants and children have comparatively lower body fat and protein stores than adults, and so are unable to forego nutrition for as long; they also have proportionally higher metabolic demands due to body composition and growth. For example, a six month old may require 80-100 calories per kilogram daily, compared to 25-30 calories per kilogram for an adult.[15] Infants and children under two years of age admitted to PICUs have been shown to be at greatest risk for worsening anthropometric measurements during PICU stay. [16,17] Catabolism associated with trauma or critical illness can increase demands on nutrient stores,[18] with muscle degradation accelerating in order to supply amino acids for the synthesis of acute phase response proteins and for gluconeogenesis. Lean body mass is also consumed for tissue repair and wound healing. Glucose and glycogen stores are rapidly exhausted as energy demands rise, and fatty acid oxidation accelerates, which may put infants and malnourished children at risk for essential fatty acid deficiency.[8,19] This cascade of events during critical illness necessitates timely and adequate nutrition provision to promote survival and recovery.

Inadequate nutrition provision during critical illness, which may be a result of increased metabolism, inaccurately estimated nutrition requirements, or insufficient nutrition infusion, is associated with higher morbidity and mortality, as well as increased time to recovery.[3] Research has demonstrated that inadequate nutrition during critical illness affects health outcomes, but whether these deficits affect long-term growth potential and development is still under investigation. The effect of critical illness on the child's ultimate growth potential depends on many variables including duration of nutrition deficiency, protraction of illness, the child's age, and underlying medical condition. A study of 293 children (including preterm neonates, neonates, and older children) showed that at six months after discharge, almost all children regained initial hospital admission nutrition status (as measured by z-scores).[17] Children with burn injuries specifically, however, have been shown to experience declines in muscle mass from nine to 12 months after injury and ongoing impaired growth for up to two years.[20,21] Further investigation of growth and development outcomes in children with a history of PICU admissions will help to clarify the long-term effects of critical illnesses requiring PICU stays.

*Malnutrition in the PICU*

Children admitted to PICUs are more likely to be malnourished or at risk for malnutrition compared to the general population, most often due to chronic disease states.[9,17,22] There are limited studies of the prevalence of malnutrition in PICUs, but past estimates range from 15-30%.[2,17,23] A US study of 71 critically ill children receiving EN showed that at admission, 38% of the children were considered at risk for malnutrition while 10% met established malnutrition criteria.[18] On the first day of the study, 17% of the study subjects had depleted protein stores, and 31% had depleted fat stores. Researchers found that protein stores were associated with poor health outcomes; 37% of those at risk for or with existing protein deficiencies developed multiple organ system failure, compared to 23% of those without. Caloric repletion was associated with survival. Malnourished children are even more susceptible to the metabolic demands of critical illness than nourished children of similar ages, given that they have fewer endogenous nutrient stores available. Their immune response is impaired,[18] and they are more vulnerable to infections, complications, longer duration of mechanical ventilation, and lengthened hospital stays.[2,24,25] In one study of 60 critically ill children, acute protein-energy malnutrition was significantly associated with physiologic instability and mortality.[26]

There are diverse etiologies of malnutrition in the pediatric population. Diseases that affect nutrient absorption and metabolism such as cystic fibrosis,[27] inflammatory bowel disease,[28] and other conditions increase risk for malnutrition and can impair normal growth. Ongoing respiratory issues or feeding difficulties may cause chronic inadequate weight gain or weight loss. Those with a history of prematurity are more susceptible to inadequate weight gain[29] and may suffer from comorbidities affecting nutrition status. Furthermore, it must not be ignored that socioeconomic issues influence childhood nutrition - one in 10 households in the United States struggle with food insecurity,[30] which may further stress ongoing nutrition issues, especially in medically complex children.

The lack of universally accepted parameters for diagnosing pediatric malnutrition is a significant challenge to evaluating its prevalence. In a 2013 special report, the American Society for Parenteral and Enteral Nutrition (ASPEN) defined malnutrition as "an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein, or micronutrients that may negatively affect growth, development, and other relevant outcomes."[31] ASPEN's classification of pediatric malnutrition considers anthropometric measurements, duration of malnutrition (acute vs. chronic), etiology, and developmental/functional outcomes. For clinical diagnosis of malnutrition, they recommend use of standard deviations above and below the mean (z-scores) for weight and weight-for-length/ BMI on WHO growth charts for ages 0-2, and on CDC growth charts for ages 2-20. Weight loss and weight gain deceleration may also be taken into account, among other factors.[32] In literature, malnutrition is typically classified using z-scores below -2. Standardization of the definition of pediatric malnutrition across institutions and among researchers will help provide better estimates of its prevalence and lead to improved understanding of the critically ill pediatric population.

Diagnosing malnutrition accurately in the critical care setting is challenging: intravenous fluid use, medical equipment, and fluid status affect the validity of weight measurements. Typical growth charts may not be accurate for children with conditions such as cerebral palsy, spina bifida, quadriplegia, or other growth-affecting disorders, although special growth charts for children with Down syndrome and cerebral palsy have been developed. Validated condition-specific growth charts, nutrition-focused physical examinations, and measures such as mid-upper-arm circumference and triceps skinfold thickness measurements can help to evaluate nutrition status in these children.

*Current Nutrition Practice Guidelines*

Due to the limited data from which nutrition guidelines are drawn, current recommendations are based on the best available evidence; large, prospective trials are needed in order to strengthen and clarify recommendations for the critically ill pediatric population. In 2017, ASPEN and the Society of Critical Care Medicine (SCCM) jointly published updated clinical guidelines for nutrition care in critically ill children ages >1 months to <18 years.[25] After analyzing 2,032 citations for relevance and quality, 16 randomized control trials (RCTs) and 37 cohort studies were selected to build evidence for best clinical practice. Key recommendations include that all patients should be screened for malnutrition or nutrition risk, EN should be initiated within 24-48 hours and advanced stepwise, and at least two thirds of prescribed energy requirements should be achieved by the end of the first week in the PICU. They also recommend, based in part on the recent PEPaNIC trial,[33] that supplemental PN be delayed at least one week after PICU admission in nourished children with low nutritional risk, although PN should be considered sooner for children unable to receive EN in the first week and for those at nutritional risk. The document emphasizes that due to the heterogeneity of patients admitted to PICUs, these recommendations are to be used only as starting points for individualized nutrition care.

EN is the first choice for nutrition support whenever possible as it is more physiologic, and has been shown to be safe for critically ill children even with the use of some vasoactive medications.[34–37] It is important for preservation of gut mucosal integrity because the intestinal villi atrophy without enterally-provided nutrition, resulting in a barrier permeable to bacteria (increasing risk for bacterial translocation)[4] and endotoxin.[38] EN helps maintain the enteric immune system and gut microbial diversity, and has been shown in animal models to have possible extra-intestinal immune benefits.[4,39–41] Further, use of EN avoids complications associated with PN such as line infections and thrombosis, hyperglycemia, liver complications, and gallbladder dysfunction, and is less costly.[2,42] A meta-analysis of 18 RCTs of adult ICU patients found EN was associated with a reduction in infectious complications and ICU length of stay compared to PN, though there was no difference in mortality between the groups.[43]

Evidence that PN should be used only when necessary in critically ill children is building. In the PEPaNIC trial, a recent three-center randomized controlled trial including 1440 critically ill children for whom EN was contraindicated, researchers investigated late PN provision (held for 1 week) versus early PN (provided within 24 hours). [33] Although mortality was similar between the two groups, children receiving early PN had a significantly greater incidence of new infections, as well as a longer mean length of PICU stay, regardless of age or severity of illness. Late PN was also associated with shorter duration of mechanical ventilation and a higher likelihood of earlier live discharge from the PICU. Based on the available evidence in pediatrics, EN provision is preferable to PN when medically feasible.

Early provision of EN, typically classified in the literature as earlier than 24-48 hours of admission, has become a standard of practice due to accumulating evidence of benefit to patients requiring nutrition support. Earlier initiation increases the likelihood that feeds will advance to goal rate sooner, offsetting cumulative energy and protein deficits. [10] Early protein provision has been shown to improve plasma concentrations of prealbumin and transferrin, with higher prealbumin levels associated with improved survival.[18] Early EN, started within 12 hours of admission, is well tolerated in critically ill children; this refutes earlier conventions based on the assumption that impaired gastric motility during critical illness would prevent feeding, and that children may go longer than five to seven days without nutrition.[18] In a 2014 retrospective multicenter study of 12 PICUs, researchers found early EN, defined here as meeting 25% of estimated cumulative caloric needs within 48 hours, was associated with lower mortality.[5] A meta-analysis of six RCTs showed a significant reduction in mortality and pneumonia in critically ill adults when EN was initiated within 24 hours of admit,[1] and a meta-analysis of 15 RCTs comparing early versus delayed EN in 753 hospitalized adult postoperative, trauma, burn, and medical ICU patients found early EN was associated with a lower incidence of infections and reduced length of hospital stay.[44] Based on the available evidence, consensus-based recommendations advise to initiate feeds within 24 hours of admission when oral intake is unavailable.[40]

Accurate determination of energy expenditure is important to prevent over and underfeeding, and the 2017 ASPEN/SCCM guidelines recommend the use of indirect calorimetry (IC) to predict nutrient requirements, or alternatively the Schofield or FAO/WHO equations without stress factors when IC is not available. It has been shown that children may not become hypermetabolic during critical illness in a similar manner as adults.[45] IC is the gold standard because predictive equations were originally developed to describe the resting energy expenditures of healthy children[46] and have been shown to lead to over or underfeeding compared to IC.[41] These equations are not appropriate for all children, for instance, for some medically complex or significantly over or underweight children. Although IC is the most accurate measure of energy expenditure, it is not readily available in the majority of PICUs. It is associated with higher costs, and may not be indicated for mechanically ventilated patients with elevated oxygen requirements or with >10% tube leakage.[47] Dietitians typically determine estimated nutrition needs by comparing the results of several predictive equations, taking into account additional information such as feeding and weight history. They monitor the response to nutrition provision closely by evaluating weight trends and nutrition-related laboratory tests, and fine-tune nutrition prescription accordingly. Until IC is routinely available, use of predictive equations is a limitation in clinical studies of the effects of nutrition support therapy.

Provision of nutrition closer to estimated nutrition needs is associated with desirable outcomes. Achieving predicted energy and protein goals via nutrition support is associated with increased survival in critically ill children.[18] Adequate protein has been associated with decreased 60-d mortality.[48] Unfortunately, many patients fail to obtain nutrition needs. Across several reports, children received only 30-70% of estimated energy requirements during their PICU stay.[34,49–51] In a retrospective chart review of 240 PICU patients, Kyle et al. found patients met on average only 75% of estimated energy and 40% of estimated protein needs during the first 8 days of admission.[52] In the complex care environment of the PICU, nutrition may be overlooked as clinicians focus on the acute illness at hand. Additionally, barriers such as fluid restrictions, delayed initiation, interruptions due to intolerance, and fasting around procedures, may affect nutrition provision. Nutrition therapy clinical guidelines, such as those published by ASPEN/Society of Critical Care Medicine (SCCM)[40] and the European Society of Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN),[53] have been developed to address these issues, and should serve as the basis for clinician-developed feeding protocols.

*Barriers to Feeding*

A 2003 study of nutrition support therapy in the PICU found fluid restriction was the most prominent risk factor for not achieving estimated energy requirements, affecting 67% of PICU patients including 17 out of 18 infants undergoing cardiac surgery for a median of four days of PICU stay.[50] Fluids allotted for nutrition were the most likely to be restricted first as opposed to fluids for medications, which affected cumulative energy and protein provision. Other major barriers were interruptions of feeds for procedures or extubation, which affected a similar number of patients (62%) but for a shorter duration (median one day of PICU stay). After feeds were interrupted, it was more common for staff to re-initiate feeds at a slower rate and advance gradually than to reinstate feeds at the previously tolerated rate, which affected the percentage of estimated needs achieved. Evidence of gastrointestinal intolerance, such as vomiting, high gastric residuals, abdominal distension, and diarrhea, occurred on a median of one day of PICU stay, affecting the energy intake of 57% of patients. Another study showed that delays to initiation were associated with failure to meet nutrition goals.[10] Issues associated with PN such as lack of central lines, line occlusions, and line infections have also been shown to affect nutrition provision.[54]

Though some of the aforementioned barriers are unavoidable, good clinical practice, including feeding protocols, may limit their effects on nutrition provision. Timely identification of nutritional risk within 24 hours of admission, early feeding tube placement and feed initiation, attempting to reduce rate or adjust from bolus to continuous rate instead of holding feeds, limiting periods of nil-by-mouth, and avoiding holding feeds for gastric residuals or gastrointestinal symptoms unnecessarily, are all tactics for optimizing nutrition therapy.[47,55]

*Feeding Protocols*

Feeding protocols are designed to guide clinicians on the initiation, advancement, and management of feeding, while standardizing nutrition care for PICU patients. In several pediatric studies, they have been associated with earlier achievement of goal feeding rate, increased use of EN over PN, and fewer incidences of infection.[2,10,13,14] Researchers have also observed improved GI tolerance when enteral feeding protocols were implemented, with decreased frequency of gastrointestinal bleeding and diarrhea.[12,24] In a 2006 retrospective chart review comparing nutrition-related outcomes in a single PICU before and after feeding protocol implementation, time to goal nutrition decreased from 57.8 to 18.5 hours. Further, the percentage of patients who vomited decreased from 20% to 11%, and constipation was reduced from 51% to 33%. Key components of the protocol, according to the authors, were the initiation of feeds within six hours of ICU admit unless contraindicated, and the institution of an aggressive bowel regimen.[10] In a similar study, after implementation of a feeding protocol, there was a greater use of EN in medical patients, and a reduction of PN in both medical and surgical patients.[56] Finally, in a study published in 2009, prospective audits demonstrated patients had an earlier initiation of EN and delivery of a greater percentage of estimated energy needs after a feeding protocol was implemented.[13]

Although studies have shown improvements in nutrition-related outcomes in PICUs with feeding protocols, they are not yet in widespread use, and studies have shown they often do not adhere to current evidence-based guidelines. In an international cohort study by Martinez et al.,[11] of 31 participating PICUs, only nine reported use of detailed feeding protocols. Of these, the content of protocols varied widely between institutions, and they did not consistently adhere to current best practice recommendations as indicated by ASPEN/SCCM or ESPGHAN.[11] Only three protocols recommended nutrition screening for all patients. Of the seven protocols recommending methods for determining nutrition prescription, protocols suggested institutional tables, age/weight indicators, and use of a predictive equation, while only one center recommended IC. All nine protocols provided suggestions for feeding rate advancement, but recommendations varied considerably. Seven out of nine indicated gastric residual volume of varying amounts as a marker of feeding intolerance, even though it is a poor marker for gastric emptying and may lead to unnecessary EN interruptions. In this study, adequacy of nutrition provision was not associated with the use of feeding protocols, nor was it associated with promotility agents or post-pyloric feeding. Optimal EN delivery (set at >66.7 of estimated needs) occurred in less than a third of the cohort. The authors suggest that feeding protocols and practices that follow consensus-based guidelines may help better achieve nutrition goals in the PICU.

*Summary*

Providing appropriate nutrition to critically ill children is associated with better health outcomes including lower risk for infection, reduction in energy and protein deficits, and improved survival. Children are particularly vulnerable to the metabolic demands of trauma and critical illness, and have a more immediate need for nutrition than adults. Early initiation of enteral feeds and decreased feeding interruptions are key areas for improvement, and feeding protocols have been studied as a way to improve nutrition practices in the PICU and increase achievement of nutrition goals. Although use of feeding protocols in PICUs is a relatively new practice, implementation provides an opportunity to examine their efficacy and identify areas for improvement.

## Chapter IV: Materials and Methods

*Study Design/Description of Study*

This was a retrospective chart review comparing existing anthropometric and nutrition-care related data from patients admitted to the Doernbecher PICU before and after implementation of a feeding protocol. Study data were obtained by chart review of patients during PICU and hospital admission, and included data obtained in the process of routine clinical care and recorded in EPIC. The Oregon Health & Science University (OHSU) Institutional Review Board (IRB) approved this study.

*Setting and Study Populations*

Chart data on consecutively admitted children aged one month through 18 years admitted to the Doernbecher PICU during approximately a four month period in 2012 (pre-implementation group) as well as consecutively admitted children admitted during approximately a four month period in 2017 (post-implementation group) were screened for inclusion in this data-only chart review. 50 total participants met inclusion criteria for this study (from both pre-implementation and post-implementation groups).

*Inclusion and Exclusion Criteria*

Inclusion criteria for this study were: 1) ages one month through 18 years, and 2) admitted to the PICU and mechanically ventilated or on HFNC >5L within 48 hours of admission and for longer than 48 hours duration. Exclusion criteria for this study were: 1) children not mechanically ventilated within 48 hours of admission or for fewer than 48 hours duration, 2) on compassionate care (end-of-life), and/or 3) patients achieving full oral diet in fewer than three days of PICU admission.

*Data Collection and Management*

Data were collected by study personnel and were entered and stored using the Research Electronic Data Capture (REDCap) data system, which is available through the Oregon Clinical and Translational Research Institute (OCTRI). A de-identified Excel dataset was exported from REDCap for data analysis and stored on password protected, encrypted OHSU workstations, with access to all locations restricted to study personnel.

Individual data collected included: demographic data, including name, date of birth, medical record number, sex, and age; anthropometric data including height or length, weight, weight-for-length or BMI; and medical data including admission diagnosis and other relevant diagnoses and timing of events of interest. Nutrition data collected included estimated calorie and protein needs as determined by dietitian at initial assessment; timing and placement of feeding tubes; nutritional content of enteral and parenteral nutrition provision; formula type, volume and rate of feeding; mechanical ventilation data; and length of stay in PICU and in hospital. The end point for nutritional data collection was 10 days after admission or discharge from the PICU, whichever was sooner. The end point for clinical outcomes was 60 days from admission.

*Statistical Analysis*

Primary outcomes for this study were time of EN initiation, percent of estimated nutrient needs met from EN and/or PN, prevalence of infectious complications (including bloodstream, hospital-acquired pneumonia, and urinary tract infections), duration of mechanical ventilation, and length of stay (PICU and hospital). Descriptive statistics were used to describe patient characteristics including sex, age, anthropometrics, and primary medical diagnosis. Categorical variables were reported as counts and percentages, and continuous variables were summarized as means/standard deviations. The prevalence of malnutrition was reported; malnutrition was diagnosed using admission database anthropometrics and Doernbecher Children's Hospital Criteria for Diagnosing Pediatric Malnutrition Tool (see Appendix A). Length measurements were deemed inaccurate based on clear discrepancy with previous length measurements and z-score trends and clinical judgment. Statistical analysis was conducted using Stata version 15.1.

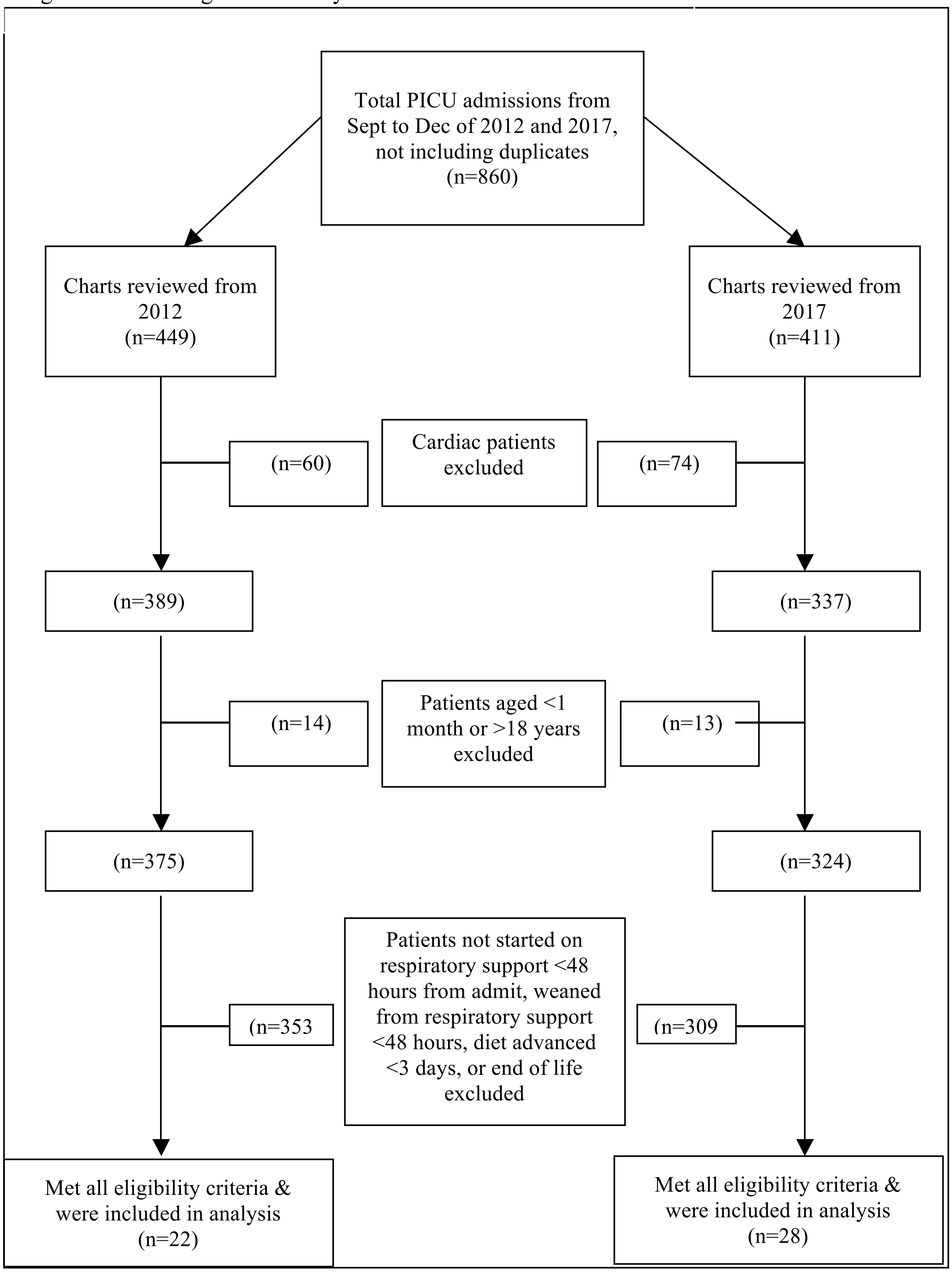
Hazard models (time-to-event analyses) were used to compare primary outcomes between the pre-implementation and post-implementation groups. "Time of initiation" was defined as the hour during which tube feeding of an enteral formula (not solely water flushes or an electrolyte solution such as Pedialyte) commenced for each child. It was recorded at any time from admission through 10th day of PICU stay. Only the first initiation was recorded for each patient. If feeds were interrupted, the restart did not count as a separate initiation. If a patient did not qualify for enteral feeds, or if PN only was provided, this was censored. Time to wean from mechanical ventilation and length of ICU and hospital stay were compared between the two groups. Outcome data were collected until 60 days from admission.

Daily nutrition support through day 10 of PICU stay or transfer/discharge out of PICU (whichever was sooner) was collected for each patient. Mode of delivery (EN, PN, or both) was recorded. Energy was defined as the total calories obtained from carbohydrate, protein, and fat/lipids. Protein was defined as total grams of protein from enteral formulas or amino acids. Dextrose as a component of fluid replacement was not included in energy calculations, but scheduled (not one-time use for procedures) Propofol was, as this is factored into the dietitian's recommendations for nutrition provision. Each patient's energy and protein support was plotted against time and then summarized as the area between the energy/protein profile over time and the energy/protein requirement set by the dietitian's initial assessment. Number of days over which this area was computed was retained and used in models as a controlling covariate.

# Chapter V: Results

## *Study Population Characteristics*

Figure 1. Flow diagram for study inclusion



Between September 1st and December 31st of 2012 and 2017, a total of 860 patients were admitted to the PICU and retrospectively screened for inclusion/exclusion criteria (Figure 1). All patients admitted to the PICU during a pre-specified time period of September through December were screened for study inclusion rather than collecting a pre-determined number of patients in order to protect against over-representation of seasonal illnesses such as respiratory syncytial virus and the flu in either of the groups.

Patients admitted with cardiac conditions were excluded because the PICU has a separate cardiac feeding protocol. Patients were excluded from the study if respiratory support was not started within 48 hours or sustained for 48 hours duration, diet was advanced within three days of PICU admit, or were on end of life care. Further, patients younger than one month or older than 18 years were excluded. Out of 860 patients screened, 22 patients in the 2012 cohort and 28 patients in the 2017 cohort met all inclusion criteria, for a total study population of 50 patients.

The groups were not significantly different from one another regarding home feeding method (p=0.83, Fisher's exact test), ICU enteral feeding method (p=0.50, Fisher's exact test), admission diagnosis (p=0.19, Fisher's exact test), or ventilation type in the ICU (p=0.12, Fisher's exact test) (Table 1). Fisher's exact tests were used in order to examine values with small sample sizes in each category. Fifty percent of patients in 2012 and 36% of patients in 2017 were primarily fed orally at home, while the remainder were tube fed at baseline. The difference in the number of patients who received parenteral nutrition at any point during their admission trended toward significance (p=0.07, Chi-squared test), with 36% of admitted patients receiving parenteral nutrition in the 2012 cohort versus 14% of patients in the 2017 cohort.

Table 1. Nutritional and clinical characteristics

| | 2012 | 2017 | p-value[1] |
|---|---|---|---|
| **Feeding Method at Home** | n=22 | n=28 | p=0.83(f) |
| | n (%) | | |
| Oral | 11(50) | 10(36) | |
| Nasogastric | 2(9) | 2(7) | |
| Nasoduodenal/Nasojejunal | 1 (5) | 1(4) | |
| G-tube | 7 (32) | 12(43) | |
| J-tube/GJ-tube | 1(5) | 3(11) | |
| **ICU Enteral Feeding Method** | n=21 | n=26 | p=0.50(f) |
| Nasogastric | 3(14) | 2(8) | |
| Nasoduodenal/Nasojejunal | 11(52) | 12(48) | |
| G-tube | 7(33) | 8(32) | |
| J-tube/GJ-tube | 0 | 3(12) | |
| **Received TPN/PPN at Any Point** | n=8(36) | 4(14) | p=0.07 (c) |
| **Admission Diagnosis** | n=22 | n=28 | p=0.19(f) |
| Chronic Illness/Congenital & Comorbidities | 6(27) | 6(21) | |
| Gastrointestinal | 1(5) | 1(4) | |
| Hematologic/Oncologic | 3(14) | 0(0) | |
| Neurologic/Seizures | 0(0) | 1(4) | |
| Respiratory/Pneumonia | 9(41) | 10(36) | |
| Sepsis/Septic Shock/Infectious | 1(5) | 7(25) | |
| Trauma | 2(9) | 3(11) | |
| **Ventilation in ICU** | n=22 | n=28 | p=0.12(f) |
| High Flow Nasal Cannula >5L | 3(14) | 0 | |
| Intubation | 12(55) | 19(68) | |
| Nasal intermittent positive pressure ventilation | 1(5) | 4(14) | |
| Tracheostomy & Vent | 6(27) | 5(18) | |

[1] *(f) = Fisher's exact test (c)=Chi-squared test*

In both groups, respiratory issues were the most common PICU admission diagnosis, comprising 41% of admission diagnoses in 2012 and 36% in 2017. Illnesses related to a chronic or congenital condition were the second most common admission diagnosis. In 2012, only one patient (5%) was admitted with an admission diagnosis of shock/sepsis/infection, whereas 7 patients (25%) were admitted in this category in 2017. Over half of all patients in each group were intubated as primary respiratory support method during their ICU stay.

Age and sex of the subjects were not statistically different (Table 2). The average age of patients in both groups was around late preschool to early school age (6.2 years in 2012 and 5.3 years in 2017). The median age at admission in 2012 was 1.9 years (IQR 0.4, 12.5), but in 2017 was 3.6 years (IQR 0.7, 8.3); slightly older. The percentage of males was higher than the percentage of females in both groups. Anthropometrics were similar between groups for weight, length, and weight for length or BMI, and associated z-scores based on measures of central tendency. Mean z-scores for all parameters were <1 standard deviation above or below the mean of the reference population (or the $50^{th}$%ile trend line for age). Z-scores were included for all patients using either WHO growth charts for children ages 0-2, and CDC growth charts for children ages 2-18, and corrected for gestational age when necessary. Z-scores were calculated for all patients regardless of whether these growth charts (which were developed for typical children) were applicable to the individual child's condition. Length/height measurements of five patients in the 2017 group were excluded due to being missing or appearing inaccurate; this also resulted in incalculable weight-for-length/BMI measurements.

Table 2. Demographic and anthropometric characteristics

| | | 2012 (n=22) | 2017 (n=28) | p-value[1] |
|---|---|---|---|---|
| **Age (y)** | | | | |
| | Mean (SD) | 6.2(6.7) | 5.3(4.8) | p=0.60(t) |
| | Median (IQR) | 1.9(0.4,12.5) | 3.6(0.7,8.3) | |
| **Sex** | | | | |
| | Female (n%) | 9(41) | 13(46) | p=0.70(c) |
| | Male (n%) | 13(59) | 15(54) | |
| **Weight (kg)** | | | | |
| | Mean (SD) | 20(18) | 23.6(17) | p=0.43(w) |
| | Median (IQR) | 14.6(6.4,33) | 16(9.9,36.2) | |
| **Weight (z-score)** | | | | |
| | Mean (SD) | -0.5(1.4) | 0.8(1.6) | p=0.36(w) |
| | Median (IQR) | -0.9(-1.5,0.62) | -0.1(-0.8,0.9) | |
| **Length (cm)** | | | | |
| | Mean (SD) | 97.7(38) | 97.2(32)[2] | p=0.49(w) |
| | Median (IQR) | 92.7(63.5,134.6) | 91(74,120.7)[2] | |
| **Length (z-score)** | | | | |
| | Mean (SD) | -0.7(1.8) | -0.6(1.9)[2] | p=0.52(w) |
| | Median (IQR) | -0.4(-1.9,0.7) | -0.7(-1.3,0.3)[2] | |
| **Weight for Length (z-score)** | | | | |
| | Mean (SD) | 0.7(1.8) | 0.7(1.6)[2] | p=0.38(w) |
| | Median (IQR) | -0.2(-1.1,1.1) | 0.7(-0.2,1.7)[2] | |

*[1] (t) = Student's t-test, (c)=Chi-squared test, (w)=Wilcoxon rank sum test*
*[2]n=23*

## *Time to Initiate Enteral Nutrition*

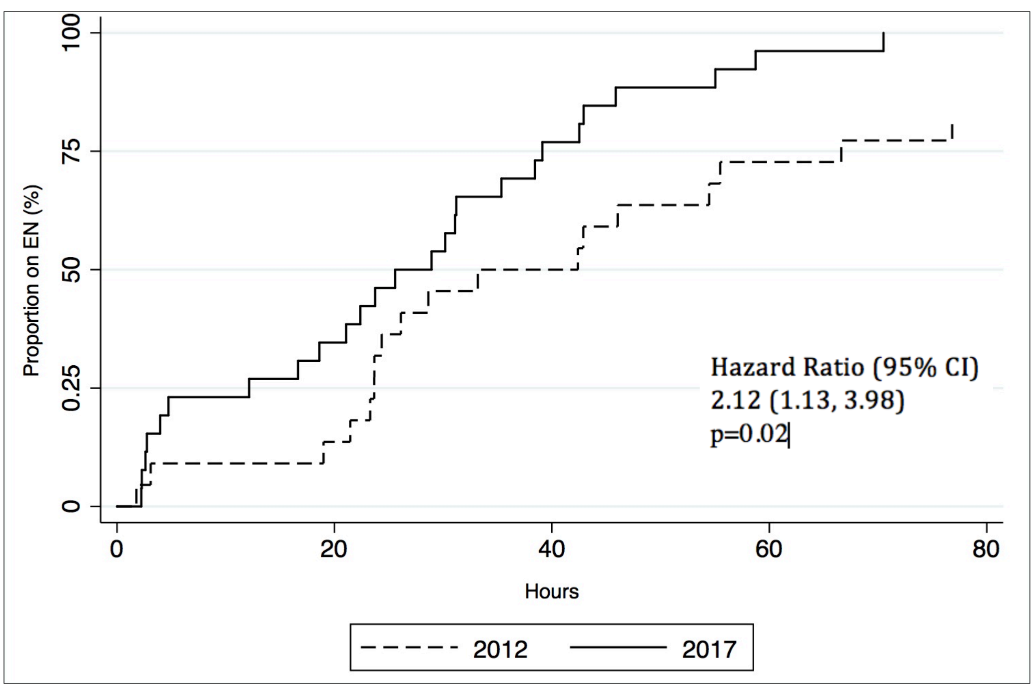
A Cox proportional hazard regression model (time to event analysis) was used to estimate and test whether hours from admission until start of EN differed between pre- and post-feeding protocol groups (Table 3). There was a statistically significant difference in time to EN initiation (p=0.02, Chi-squared test) between the 2012 and 2017 groups, with feeds being initiated around twice as quickly in 2017 (Hazard ratio (95% CI) = 2.12(1.13, 3.98)). In 2017, 25% of patients had started EN by around hour 12 (95% CI 2.3, 22.4), while in 2017 25% of patients starting EN by about 24 hours (95% CI 1.8-28.6) (Table 3). Similarly, in 2017, 50% of patients had started EN by around hour 26 (95% CI 16.7, 35.4), versus around hour 33 in 2012 (95% CI 23.7, 55.5).

Table 3. Hours from admission to start of enteral nutrition.

| | **25%(95%CI)** | **50%(95%CI)** | **75% (95%CI)** | **p-value**[1] |
|---|---|---|---|---|
| 2012(n=22) | 23.7(1.8,28.6) | 33.2(23.7,55.5) | 66.6(42.4, 136.65) | p=0.02(c) |
| 2017(n=26) | 12.2(2.3,22.4) | 25.6(16.7, 35.4) | 39.1(30.1,55.0) | |

[1] *(c)= Chi-squared test*

Figure 2. Hours from admission until start of enteral nutrition



*Calorie and Protein Provision*

Cumulative deficiencies in calories and protein over time as well as median percentages of protein and calories delivered over stay were compared between groups. The deficits were calculated using the difference in the area under the curve for calories or protein actually provided compared to the amount prescribed for each day of ICU stay until diet advance, discharge, or day 10 of ICU stay, whichever occurred first. For each patient, the daily percentage of prescribed calories and protein was computed and the median of these daily (calorie or protein) values was then computed within each patient. Group differences were estimated and tested by considering the mean of these patient-specific median values using t-tests, since initial inspection of the distribution of the median values showed no overt violations (outliers or pronounced skewness). Results were compared using Student's t-tests.

Calorie provision, which included calories from both enteral and parenteral nutrition, was not significantly different between the groups (Tables 4 and 5). The mean cumulative caloric deficiency in the 2012 group was -2960 calories (SD=2077), and in the 2017 group it was -3011 calories (SD=1769), for a difference of 51 calories (95% CI -1043, 1146) (Table 4). Cumulative deficiency of protein was also similar between the groups, with a mean deficit of 85g in 2012 and 86g in 2017, for a difference of <1g (95% CI -50, 52) (Table 5). The average of the median calories each patient obtained during their ICU stay was 62% (SD=35) of prescribed needs in 2012, and 66% (SD=25) in 2017 (Table 4). For protein, patients obtained 66% (SD=32) of their prescribed needs in 2012, and 78% (SD=39) in 2017, which was improved, but this finding was not statistically significant (Table 5).

Table 4. T-test results comparing calorie provision between groups

| Cumulative deficiency below prescribed calories over ICU stay (kcal) | | | p-value[1] |
|---|---|---|---|
| | **Mean kcal (SD)** | **95%CI** | p=0.92(t) |
| 2012 (n=22) | -2960(2077) | -3881, -2039 | |
| 2017 (n=28) | -3011(1769) | -3698, -2325 | |
| Difference | 51(--) | -1043, 1146 | |
| **Median percentage of prescribes calories delivered during ICU stay** | | | |
| | **Mean%(SD)** | **95%CI** | p=0.66(t) |
| 2012 (n=22) | 62(35) | 46, 78 | |
| 2017 (n=28) | 66(25) | 56, 76 | |
| Difference | 4(--) | -21, 13 | |

[1] *(t) = Student's t-test*

Table 5. T-test results comparing protein provision between groups

| Cumulative deficiency below prescribed protein over ICU stay (g) | | | p-value[1] |
|---|---|---|---|
| | **Mean g (SD)** | **95% CI** | |
| 2012 | -85(77) | -119, -51 | p=0.97(t) |
| 2017 | -86(98) | -124, -48 | |
| Difference | 0.88(--) | -50, 52 | |
| **Median percentage of prescribed protein delivered during ICU stay** | | | |
| | **Mean%(SD)** | **95% CI** | p=0.25(t) |
| 2012 | 66(32) | 51, 80 | |
| 2017 | 78(39) | 62, 93 | |
| Difference | -12(--) | -33, 9 | |

[1] *(t) = Student's t-test*

*Secondary Analyses of Anthropometrics, Time to Wean from EN, and Duration of Intubation*

Anthropometrics were compared between typically growing children and children with non-nutrition related conditions affecting growth. When patients with both weight and length measurements available (n=45) were sorted into groups based on whether standard growth charts were appropriate (meaning, whether anatomical or growth differences secondary to medical conditions such as severe cerebral palsy did or did not invalidate the use of a growth chart developed using a reference population of typically growing, well children), differences between z-scores for weight (p=0.15 (Wilcoxon rank-sum test)) and length (p=0.08 Wilcoxon rank-sum test)) trended toward significance (Table 6). Wilcoxon rank-sum tests were used to test the null hypothesis because data were not normally distributed. Patients for whom standard growth charts were not applicable (n=16) had a mean weight z-score of -1.2 (SD=0.9) and a mean length z-score of -2.7 (SD=1.6) compared to typical children's (n=34) z-scores, which were a mean of z=0.3 (SD=1.4) for weight and mean of z=0.2 (SD=1.5) for length.

Table 6. Anthropometrics by applicability of standard growth charts

| | Yes (n=34) | No (n=16) | p-value[1] |
|---|---|---|---|
| **Weight (kg)** | | | |
| Mean (SD) | 20.2 (17.1) | 26.9 (17.6) | p=0.61(w) |
| Median (IQR) | 13.7 (7.3,30) | 27.9 (9.6, 42.2) | |
| **Weight (z-score)** | | | |
| Mean (SD) | 0.3 (1.4) | -1.2 (0.9) | p=0.15(w) |
| Median (IQR) | 0.6 (-0.4,1.1) | -1.1 (-1.6, -0.6) | |
| **Length (cm)** | | | |
| Mean (SD) | 94.9 (34)[2] | 103.6 (38.1)[3] | p=0.56(w) |

Table 6. Anthropometrics by applicability of standard growth charts (continued)

| | | | |
|---|---|---|---|
| Median (IQR) | 88.8 (64.9, 115.5)[2] | 94 (72, 139)[3] | |
| **Length (z-score)** | | | |
| Mean (SD) | 0.2 (1.5)[2] | -2.7 (1.6)[3] | p=0.08(w) |
| Median (IQR) | 0 (-0.7, 1.3)[2] | -3.3 (-3.9, -1.36)[3] | |
| **Weight for Length (z-score)** | | | |
| Mean (SD) | 0.3 (1.7)[2] | 0.6 (1.7)[3] | p=0.55(w) |
| Median (IQR) | 0.7 (-0.9, 1.6)[2] | 0.7 (-0.7, 1.3)[3] | |

[1] *(w) = Wilcoxon rank-sum test*
[2]*n=32*
[3]*n=13*

Around 18% of children in the 2012 cohort and around 7% in the 2017 cohort were diagnosed with malnutrition using the Doernbecher Criteria for Pediatric Malnutrition (Appendix A) (Table 7). In the total study population, 6% of children (n=3) were considered at risk for/with mild malnutrition, and 6% (n=3) were diagnosed with moderate to severe malnutrition, for a total of 12% of children with some type of malnutrition diagnosis. There was not a significantly different number of children with malnutrition diagnoses in the 2012 compared to the 2017 cohorts based on the Fisher's exact test, which was used to evaluate these categorical variables with small sample sizes.

Table 7. Malnutrition Diagnosis

| | **Total (n=50)** | **2012 (n=22)** | **2017 (n=28)** | **p-value**[1] |
|---|---|---|---|---|
| **None (n%)** | 44(88.0) | 18(81.8) | 26(92.9) | 0.69(f) |
| **At Risk/Mild (n%)** | 3(6.0) | 2(9.1) | 1(3.6) | |
| **Moderate (n%)** | 2(4.0) | 1(4.6) | 1(3.6) | |
| **Severe (n%)** | 1(2.0) | 1(4.6) | 0(0) | |

[1]*p=0.69 (Fisher's exact test)*

Log rank tests and Cox proportional hazard models were used to evaluate days to wean from EN and days to extubation between the 2012 and 2017 groups (Table 8). Time to wean from EN trended toward significance between the groups (p=0.09, log rank test), with a hazard ratio of 2.6 (95% CI 0.8,8.0) (Table 8), with weaning occurring more quickly in 2017 (Figure 3). The total number of patients who weaned from EN (n=22) was fewer than the total number whose enteral nutrition had been initiated (n=48) because some patients were tube fed at home (meaning, this was their baseline feeding method and therefore would not be weaned), or because they did not wean from enteral nutrition prior to discharge from the PICU or within the 10 days of the study time period and were therefore censored.

Time to extubation (or, total duration of intubation) was not significantly different between the groups (p=0.69, log rank test) (Table 7). Patients spent a median of 3.8 days (95% CI 3.2, 10.6) intubated in 2012 and 5.9 days intubated (95% CI 3.8, 7.4) in 2017. There were fewer intubated patients in the 2012 group (n=12) than in 2017 (n=19).

Table 8. Survival analyses for nutrition-related clinical outcomes

| | | 25%(95%CI) | 50%(95%CI) | p-value[1] |
|---|---|---|---|---|
| **Time to wean from EN (in days)** | | | | |
| | 2012 (n=11) | 4.0(2.3,14.9) | 14.9(3.4,21) | p=0.09(l) |
| | 2017 (n=11) | 3.4(2.6,6.8) | 6.8(2.9,-) | |
| **Time to extubation (in days)** | | | | |
| | 2012 (n=12) | 3.3(3.1, 3.8) | 3.8(3.2, 10.6) | p=0.69 (l) |
| | 2017 (n=19) | 3.8(2.7, 5.9) | 5.9(3.8, 7.4) | |

[1]*(l)= Log-rank test*

Figure 3. Days to wean from EN, as measured from time of EN initiation (Kaplan-Meier survival curve)

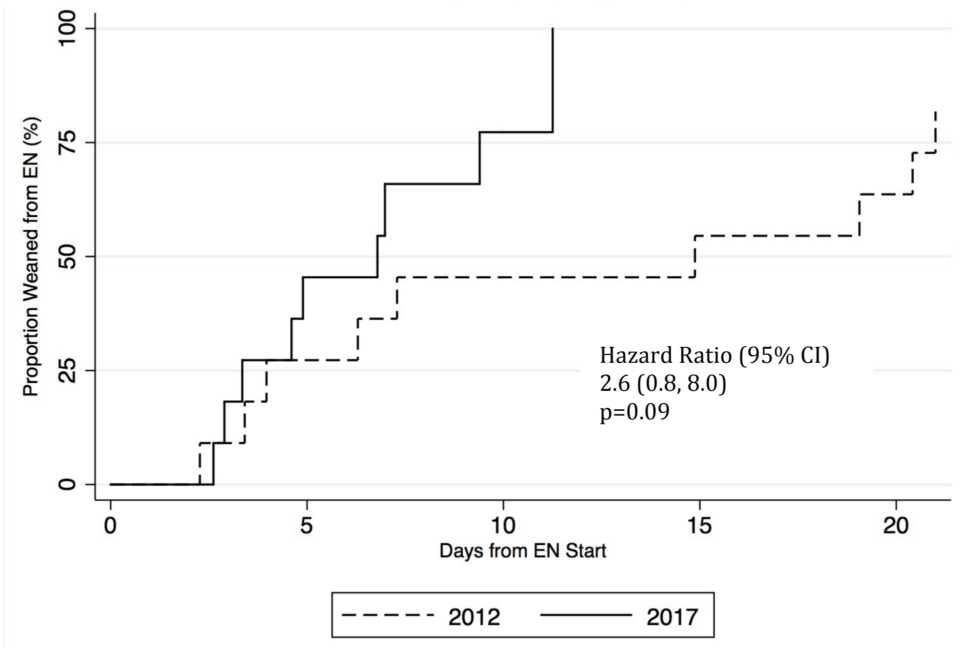
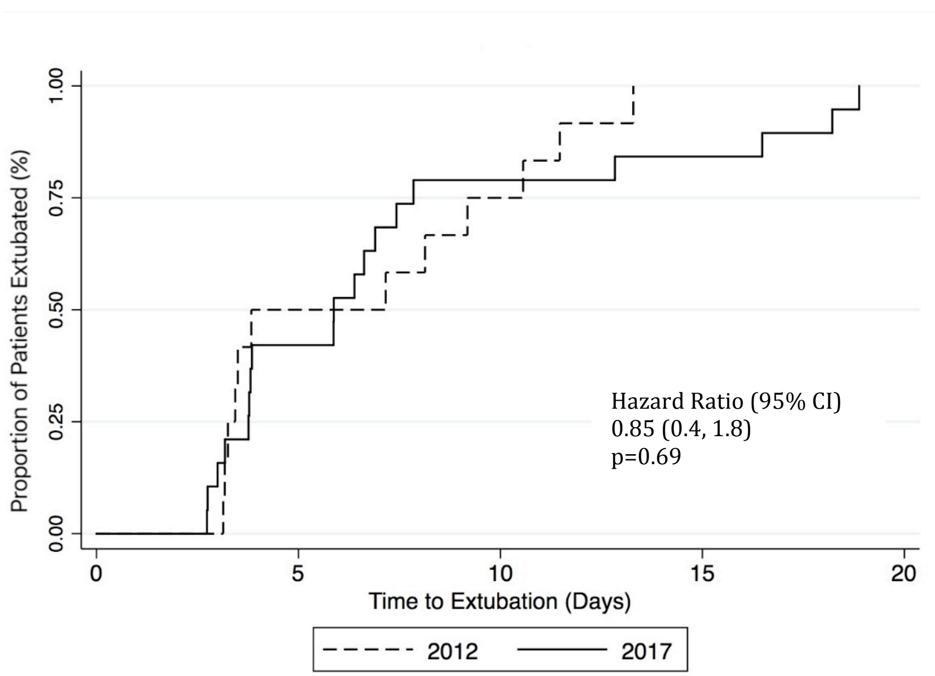



Figure 4. Total time to extubation in days (Kaplan-Meier survival curve)



Log rank tests and hazard models were used to evaluate days to discharge from the ICU and hospital (Table 9). Neither PICU nor hospital lengths of stay were significantly different from 2012 to 2017 based on log rank tests. Based on the hazard models patients did not tend to discharge earlier in 2012 than in 2017 (Figures 5 and 6).

Table 9. Survival analyses for length of stay

| | | 25%(95%CI) | 50%(95%CI) | p-value[1] |
|---|---|---|---|---|
| **Time to discharge from ICU (in days)** | | | | |
| | 2012 (n=22) | 5.0(2.5, 7.7) | 10.4(5.1, 12.4) | p=0.76(l) |
| | 2017 (n=28) | 4.3(2.5, 6.0) | 7.1 (5.1, 9.9) | |
| **Time to discharge from hospital (in days)** | | | | |
| | 2012 (n=22) | 7.7(4.5, 9.9) | 10.4 (7.7, 15.8) | p=0.95(l) |
| | 2017 (n=28) | 6.4(3.6, 10.8) | 12.1(6.7, 16.7) | |

[1]*(l)= Log rank test*

Figure 5. Time to discharge from PICU in days (Kaplan-Meier survival curve)

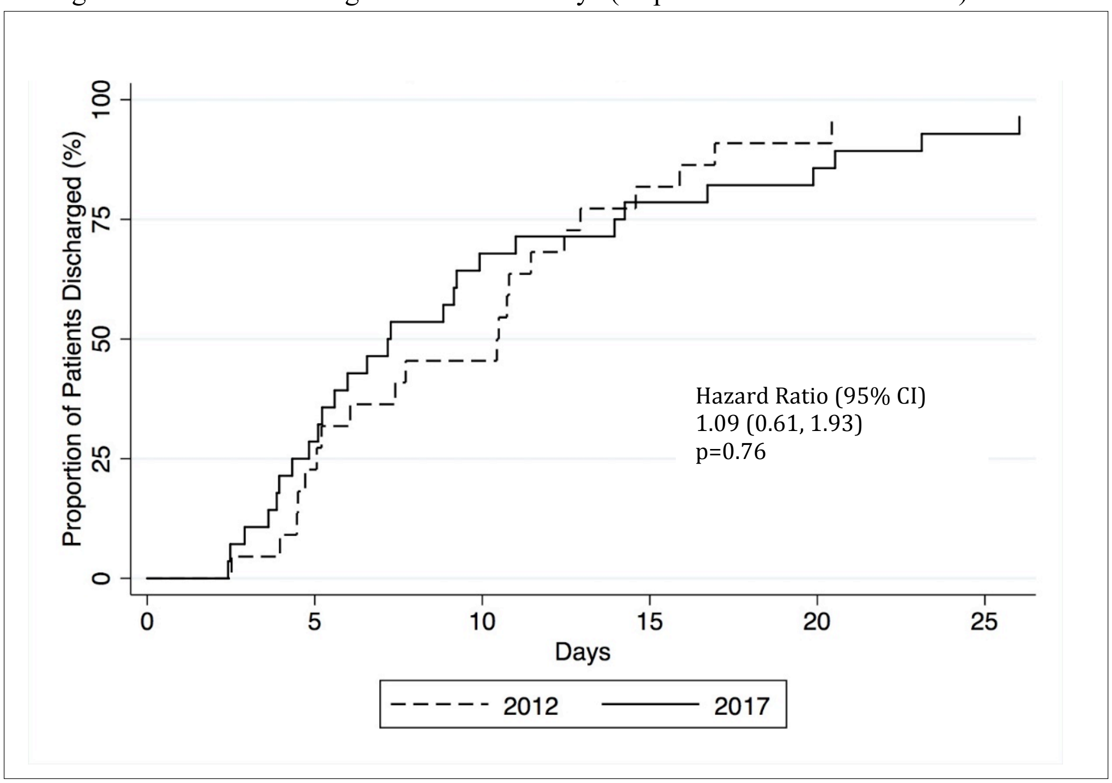
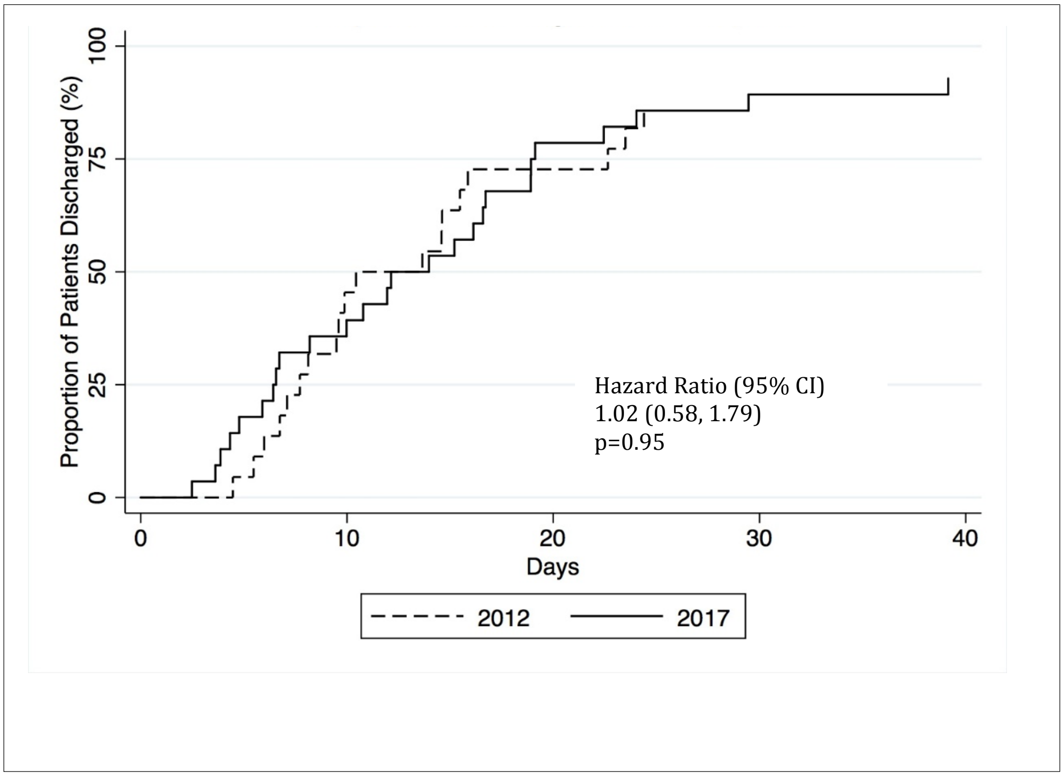


Figure 6. Time to discharge from hospital in days (Kaplan-Meier survival curve)



## Chapter VI: Discussion

The Doernbecher PICU feeding protocol was designed to promote early and adequate nutrition for critically ill children, and incorporates ASPEN practice recommendations to optimize care in an evidence-based manner.[25] Feeding protocols are becoming more widely used in hospital settings, but there have been limited studies examining nutrition-related outcomes before and after feeding protocol implementation at a single PICU. In our study, we demonstrated that EN was initiated almost twice as quickly in 2017 compared to 2012, the year before the feeding protocol was implemented. Despite this change, calorie and protein provision were about the same, and nutrition-related outcomes of interest including duration of intubation and length of PICU and hospital stay were unchanged. The results of the present study inform clinical practices at Doernbecher Children's Hospital, including areas for improvement and further study, and add to the currently limited body of knowledge regarding feeding protocols.

### *Time to Initiate Enteral Nutrition*

The joint ASPEN and SCCM 2017 guidelines for nutrition care for critically ill children states use of aggressive feeding protocols may reduce time to initiate EN and reach goal rate of feeds, and reduce use of PN, but that more research (especially randomized controlled trials) need to be performed to demonstrate whether they truly can affect outcomes.[40] In our study, time to initiation of enteral nutrition decreased dramatically over the 5 years in between study cohorts. The improvement in time to initiate enteral nutrition (Table 3) suggests the feeding protocol has affected nutrition practices in the PICU, and is reflective of evidence that feeding protocols encourage the habit of placing feeding tubes earlier and starting feeds more quickly.[2,13,57] Given the observational nature of this study, a causal association between the feeding protocol and time to initiate EN cannot be established. However, given that the protocol encourages clinicians to place feeding tubes and start EN prior to initial nutrition assessment by the dietitian, and is now part of routine clinical practice in the PICU, it is hypothesized to have played a role in this improvement. Other factors that may have influenced this outcome are general changes in clinical practice over the 5-year period and increased knowledge among clinicians of the importance of early and adequate nutrition for pediatric patients. Decreased use of PN over the 5-year period fits with this pattern, although a larger sample size in a future study would help to establish any statistical significance.

Notably, in 2012 over half of patients had started enteral nutrition within 48 hours, but by 2017, that proportion increased to 75% (Table 3). The Doernbecher PICU feeding protocol recommends feeds start within 24 hours of admission where oral intake is unavailable, and to re-evaluate candidacy for enteral nutrition every 12 hours if it is initially contraindicated (Appendix B). Various studies have defined early enteral nutrition as starting before 24 hours[35,58,59] 48-72 hours,[6,12,49] or reaching a certain percentage of nutrition needs by an early point in admission;[5,18,34,60] early EN is associated with improved clinical outcomes including decreased length of stay and reduced infectious complications, reduced mortality, improved tolerance of feeds, and lower hospital costs.[5,6,10,13,35,41,58,60] This effect may be related to the trophic nature of enteral feeds, and to delivery of energy and protein required for metabolism.[2,61] Future research is needed to examine whether time to achieve goal rate, or provision of a certain percentage of nutrition needs within an early period of time, is associated with improved clinical outcomes.

*Calorie and Protein Provision*

In studies examining nutrition provision in pediatric critical care, earlier EN initiation has been associated with an increase in the percentage of estimated nutrition needs met.[18,61] In the current study, however, this did not appear to be the case, refuting our hypothesis that nutrition needs would be better met in the 2017 group than in the 2012 group (Tables 4 and 5). This finding is unexpected considering that if nutrition is provided earlier, there should be less of a cumulative deficit with goal feeding rate being reached earlier, as has been found in similar studies.[2,14,57]

There are several possibilities why this may have occurred. Firstly, since we were primarily interested in how patient's overall nutrition needs for calories and protein were being met compared to estimated needs, PN was counted in addition to EN. In 2012, there was a trend toward more patients having received PN at any time; (36% of patients received PN in 2012, compared to 14% in 2017 (Table 1). This may have resulted in patients who would otherwise have not been meeting nutrition needs via EN receiving a larger percentage of their nutritional requirements via supplemental PN, affecting results. That children were more likely to have been given parenteral nutrition (PN) in 2012 than in 2017 may be reflective of changes in clinical practice, as awareness of cost, risk for infection, and altered nutrition-related labs such as blood glucose and triglycerides when PN is provided are more widely understood. Though the present study's finding only approached statistical significance, if the trend toward a decrease in the use of PN in this study is reflective of actual changes in practice, it may be attributable to the feeding protocol, increased awareness of the risks of parenteral nutrition in critically ill children, or fewer clinical barriers to using enteral nutrition in 2017 versus 2012.

Secondly, interruptions of enteral nutrition (including periods of nil-by-mouth around procedures, signs of gastrointestinal intolerance, fluid restrictions, and resuming feeds at a slow rate instead of at previously tolerated rate after an interruption) may have been more prevalent in one group than another, though these instances were not recorded in the current study. The Doernbecher PICU feeding protocol recommends holding nasogastric feeds six hours prior and postpyloric feeds two hours prior to extubation, with the aim of minimizing the effect of this common procedure on nutrition provision. It also provides guidance for signs of feeding intolerance, recommending that feeds be held for 2 hours, then reassessing whether feeds can be restarted. It also provides guidelines in the case of constipation or diarrhea that do not include stopping enteral feeds. In a follow up study, evaluating interruptions of enteral nutrition for intolerance and around procedures in pre- and post- feeding protocol implementation groups would provide insight into how these guidelines are being used in practice.

Finally, there may have been no actual change in nutrition provision between 2012 and 2017. We were not able to assess compliance with use of the feeding protocol as this was a retrospective chart review, and though some studies have shown improvement in nutrition provision when feeding protocols are implemented,[2,10,13,62] a large multicenter study by Martinez et al. showed no change.[57]

In 2012, Mehta et al. demonstrated that meeting a higher percentage of goal calories prescription from EN alone (defined by an increase from 33.3% to 66.6%, as an average of daily percentage of estimated needs obtained) was associated with a significant reduction in mortality, as was receiving EN alone instead of any PN.[2] Our study used a somewhat different analysis for nutrition provision – we measured the median of percentage of daily calories prescribed for each individual (as measured by the area under the curve) to limit the effect of daily outliers, then, we evaluated the cohorts as a whole using means as the resultant data were normally distributed (Tables 4 and 5). Patients met around two-thirds of prescribed calories from both EN and PN in both cohorts, with a higher percentage of protein provision in 2017, though no significant difference between the groups was demonstrated. Follow up research is needed to evaluate if measuring EN separately from PN would better illustrate how and by what method nutrition needs are being met in the PICU, and whether we are meeting the goal of two-thirds of calorie needs that has been associated with reduced mortality.

Our feeding protocol suggests goal rates for EN delivery based on weight and age, but recent studies have explored the use of volume-based goals, with rates managed primarily by clinical staff. In a single-center randomized prospective study of critically ill adults, a volume-based feeding protocol better met calorie needs than did a rate-based protocol (92.9% of needs compared to 80.9%, p=0.01).[63] Research in pediatric critical care on this topic is currently scarce. In one observational study of 40 patients by Bixia et al., implementation of a volume-based feeding protocol in a PICU showed no improvement in nutrition provision. [64] A prospective study on volume-based goals compared to rate-based goals at our site would provide information on whether our feeding goals are better achieved using goal volumes instead of rates.

*Anthropometrics and Malnutrition*

Overall, demographic and clinical characteristics showed the groups were without significant differences that would affect the comparison's validity. Though there were a greater number of patients in the 2017 cohort than in the 2012 cohort, groups were adequately comparable in size for the statistical analyses performed. Age and sex of the cohort was similar to that of the international multicenter study of PICU feeding practices by Mehta et al.,[2] whose subjects were a mean age of 4.5 years and of whom 48% were females.

Z-scores are used to assess deviation from the average weight, length, or weight-for-length/BMI. However, though these measures of central tendency were useful for ascertaining whether the groups were comparable overall, they are not as useful for describing the nutrition status of the cohorts, because there are a large range of z-scores among patients both above and below the mean. For this reason, a separate assessment of malnutrition in the study population was performed. In order to make a valid diagnosis of malnutrition, it is necessary to assess whether standard growth charts are actually appropriate for the child in question, as children admitted to the PICU frequently have non-nutrition related growth abnormalities, and cannot be reliably compared to growth charts used for typical children. For example, anthropometrics of children with cerebral palsy are plotted on disease-specific growth charts, which take into account mobility and feeding method, and do not use z-scores. Some studies that have aimed to include information on malnutrition as determined by z-score have included all patients rather than stratifying them by whether or not standard growth charts are appropriate.[2,9,17]

In the present study, when patients were categorized according to whether or not standard growth charts were applicable, trends in z-scores between the groups emerged. Weight and length z-scores were lower in children for whom standard growth charts were not valid, and the difference between groups trended toward statistical significance (Table 6). The mean and median length z-scores observed for these children (which are more likely primarily reflective of a growth-affecting disorder rather than nutritional status) when seen in typical children would suggest nutrition-related stunting. We used the Doernbecher Children's Hospital Criteria for Pediatric Malnutrition to diagnose malnutrition in our study population, which is designed for use with standard growth charts and incorporates ASPEN guidelines. ASPEN guidelines incorporate categories for point-in-time z-scores and address changes in z-scores over time, among other parameters. Prevalence of malnutrition in our study was similar to results of a study of children admitted to a single PICU performed by Pollack et al. in 1981, which excluded children with growth-affecting diseases, and estimated that 15% of children admitted were malnourished.[16] There was a lower prevalence of malnutrition in our study compared to the estimates of more recent studies that did include children with growth-affecting diseases, which ranged from 24-48% of admissions, although differing parameters were used in each study.[9,17,18,56]

A limitation of our method is that children with diseases related to congenital or chromosomal abnormalities may be at greater risk for malnutrition,[17,65,66] so it is possible that by excluding children with growth-affecting disorders, some children who were actually malnourished were missed. On the other hand, many of these excluded children were tube fed at home, and so would likely to have their nutritional requirements and growth monitored by a dietitian or pediatrician (Table 6).

In order to more thoroughly assess the nutrition status of children admitted to the PICU, a future study could screen every child admitted to the PICU for malnutrition, and would include specific parameters that could be used to diagnose malnutrition objectively in children with growth-affecting disorders. As of this time, however, such parameters have not been developed due to the breadth of pediatric disorders and the diversity of associated growth patterns. Potentially, such guidelines might include categories of anthropometric measurements and weight trends along with supporting information such as nutrition-focused physical examination and feeding history. Some pediatric assessment tools, such as the STRONGkids score,[33] are currently used in these populations as they incorporate subjective assessments of nutritional status that can be performed by trained clinicians, but more objective measures are needed. Standardized methods for diagnosing pediatric malnutrition that take into account diverse disease states and conditions would help to better illustrate true prevalence of malnutrition in critically ill children admitted to PICUs in future studies.

### *Other Exploratory Analyses*

Nutrition-related clinical outcomes including infectious complications, duration of mechanical ventilation, time to wean from enteral nutrition, and lengths of hospital and PICU stay were collected for all patients. Only 1 patient in the entire study population experienced infectious complications (both nosocomial pneumonia and a urinary tract infection), and so infectious outcomes were not further analyzed, and no patients passed away in the PICU or before hospital discharge up until 60 days. In a large multicenter study, receiving higher percentages of prescribed calories and protein from enteral nutrition and early enteral nutrition initiation was associated with decreased risk for infectious complications.[2] Duration of mechanical ventilation and length of stay, which in some studies have been shown to be decrease when nutrition needs are better met,[44] were similar between groups (Tables 8 and 9). An effect would not necessarily be expected here as calorie and protein provision were similar between 2012 and 2017, although it is unclear what percentage of nutrition needs were met via EN.

There was not a significant difference in total length of time receiving EN in each group as measured by a survival analysis (Table 8), though there was a trend toward a shorter duration of EN in 2017. This may have been due to a shorter course of illness or faster progression to oral diet. Since EN started significantly earlier in the 2017 group, this information suggests that feeds may have both started and ended earlier in 2017. A repeat study with a greater number of subjects would be needed to further investigate this outcome.

Early EN, implementation of feeding protocols, and meeting a greater percentage of estimated nutrition needs has been associated in some studies with decreased length of stay and time on mechanical ventilation.[4,6,67,68] In our study, patients met about the same percentage of protein and calorie needs from both enteral and parenteral nutrition in both the 2012 and 2017 cohorts (Table 4); and time to wean from mechanical ventilation (Table 8) as well as PICU and hospital length of stay were about the same (Table 9). This outcome is similar to findings from Petrillo-Albarano et al., who did not find a relationship between implementation of a feeding protocol and ICU length of stay,[10] and those of Mikhailov et al., who did not find a relationship between mechanical ventilation or length of stay when early enteral nutrition was provided.[5] Whether there are any causal factors between nutrition provision (including implementation of feeding protocols) and these clinical outcomes continues to be investigated.

*Strengths and Limitations*

Strengths of our study included the completeness of information available in the electronic medical record, despite over 5 years having passed since the earlier portion of the information was entered. Minimal values for anthropometrics, nutrition records, and timing of relevant events were missing, supporting the validity of the findings. Trained pediatric clinical dietitians performed the nutrition assessments used to determine estimated nutrition needs.

Limitations of the study included the small sample size, which lead to wide confidence intervals. Energy needs, although performed by a clinical dietitian, were not calculated using the gold standard of IC. However, IC is not readily available at most sites; rather, predictive equations are generally used, which may result in an over or underestimation of nutrition needs. Another limitation was that there may have been differences between what was prescribed and recorded from what was actually provided, which is a typical limitation of chart reviews. Another limitation was the validity of anthropometric measurements – PICU weights may be inaccurate due to use of patient reported or estimated weights (though these were not used in our study); altered fluid status related to dehydration, intravenous fluid use, or dehydration; or use of bed weights, which are less accurate and may be falsely elevated if medical equipment is on the bed at time of measurement. Lengths can be difficult to measure in the PICU, and may be inaccurate due to inconsistent methods of measurement or bodily contractures.

## Chapter VII: Summary and Conclusions

The findings of our study suggest implementation of the PICU feeding protocol resulted in a marked improvement in time to initiate enteral nutrition, but did not result in an increased percentage of estimated nutrition needs being met, nor was it associated with decreased duration of mechanical ventilation or length of stay. Our study also revealed that malnutrition is a significant issue in our PICU, as a high percentage of patients were found to be at risk for or with already present malnourishment.

Our research demonstrates that feeding protocols may improve nutrition practices in the critical care setting, especially with regard to routine early placement of feeding tubes and time to start EN, but that earlier EN was not associated with time on mechanical ventilation or length of stay. A future study with a larger sample size and separate comparisons of EN and PN use would help to illustrate whether there have been changes in EN provision since the protocol was implemented. Additionally, a prospective study comparing interventions such as volume-based goals with rate-based goals may provide further insight into improving the percentage of prescribed calories and protein that patients are provided. The findings of our study add to a limited body of information on feeding protocols in PICUs, inform our clinical practice and the use of the feeding protocol, and highlight areas where additional research is needed.

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# Evidence Table

| Author | Year | Citation | Population | Methods | Results | Adult(A) or Peds (P) |
|---|---|---|---|---|---|---|
| Barr | 2004 | Barr, J., Hecht, M., Flavin, K. E., Khorana, A., & Gould, M. K. (2004). Outcomes in Critically Ill Patients Before and After the Implementation of an Evidence-Based Nutritional Management Protocol. *Chest,* 125(4), 1446–1457. http://doi.org/10.1378/chest.125.4.1446 | 200 adult ICU patients. 100 patients enrolled in preimplementation group, and 100 after. | Med-surg ICUs of two teaching hospitals. # of patients who received enteral nutrition, time to initiate nutrition support, and percent caloric target administered on day 4 of nutritional support. Clinical outcomes - duration of mechanical ventailation, ICU and hospital LOS, mortality. | Postimplementation group fed more frequently via enteral adjusted for illness severity, baseline nutritional status. Time to feeding and caloric intake on day 4 not different between groups. Duration of mechanical ventilation short in post group. No difference in LOS. Risk of death lower in post group. | A |
| Delgado | 2008 | Delgado AF, Okay TS, Leone C, Nichols B, Del-Negro GM, Costa-Vaz FA. Hospital malnutrition and inflammatory response in critically ill children and adolescents admitted to a tertiary intensive care unit. *Clinics.* 2008;63:357-62. | 1077 PICU patients (retrospective). Elimintated down to 29 total. 15 pts with severe malnutrition and 14 well-nourished. | Retrospective study to evaluate incidence of hospital malnutrition at a PICU during first 72 hours, y 2002-2005. Nutritional status evaluated by z-score wt for age (-2 or lower as malnutrition, MUAC, alb). IL6 and CRP measured. All received early feeding, enteral or parenteral. Compared mortality, sepsis incidence, and LOS hospital for nourished and malnourished pts. | Of 1077, 53% were malnourished (84% had underlying disease). Similar CRPs and alb. IL-6 decreased by day 10 in well nourished, increased in malnourished. | P |
| Dobson | 2007 | Dobson K, Scott A. Review of ICU nutrition support practices: implementing the nurse-led enteral feeding algorithm. *Nurs Crit Care*. 2007;12(3):114-123. | 106 mixed medical and surgical critically ill adult and adolescent patients receiving nutritional support. | 58 patients followed the nurse-led enteral feeding algorithm, and 48 patients were referred to the dietitian (off- algorithm). A 3-month prospective audit was conducted (June to September 2005) with data collected by specialist dietitians visiting the unit on average three times per week. Patient | Absolute adherence to the algorithm was just 2% (n = 1). Despite this finding 60% (n = 33/55) received the correct type and volume of enteral feed irrespective of the feed prescription or the recorded weight. | A |
| Gurgueira | 2005 | Gurgueira GL, Leite HP, Taddei JA de AC, de Carvalho WB. Outcomes in a pediatric intensive care unit before and after the implementation of a nutrition support team. *JPEN J Parenter Enteral Nutr*. 2005;29(3):176-185. | 323 infants between 0-2 y/o, hospitalized for >72 hours at a PICU from 1992 to 2003. | Evaluated the effect of parenteral nutrition and enteral nutrition on PICU mortality before and after a continuous education program in nutrition support that leads to implementation of a Nutrition Support Team. Used a historical cohort study of infants hospitalized for >72 hoursat the PICU. Samples compared in sex, age, admitting service med/surg, mortality, LOS, duration of ventilation, and percentage of time receiving EN/PN. Bi-and multivariate analyses were performed. | The program motivated an increase in EN from 25% to 67% in medical patients (no difference in surgical patients) and a decrease in PN use, mainly after implementation of NST and reduced in-PICU mortality rate among medical patients. Risk of death 83% lower in pts that received EN for >50% of LOS (OR 0.17, CI 0.066-0.412). | P |
| Hulst | 2004 | Hulst JM, Goudoeve JB, Zimmermann LJI, Hop WCJ, Albers MJI, Tibboel D, et al. The effect of cumulative energy and protein deficiency on anthropometric parameters in a pediatric ICU population. *Clinical Nutrition.* 2004;23(6):1381–1389. | 261 children admitted to a multidisciplinary tertiary pediatric ICU. | Prospective, observational study wherein total energy and protein intakes gathered up to 2 weeks, Actual intakes were subtracted from RDA and cumulative balances were calculated. Relations between cumulative balances, various clinical factors and changes in anthropometry (weight, arm and calf circumference) were analyzed using regression analysis. | At 14 days after admission children showed significant cumulative nutritional deficits compared to RDA. These deficits were on average 27, 20, 12 kcal/ kg and 0.6, 0.3, and 0.2 g protein/kg per day for preterm neonates (n ¼ 103), term neonates (n ¼ 91) and older children (n ¼ 67), respectively. Age at admission, length of ICU-stay and days on mechanical ventilation were negatively related to cumulative balances. Cumulative energy and protein deficits were associated with declines in SD-scores for weight and arm circumference. | P |
| Hulst | 2004 | Hulst, J., Joosten, K., Zimmermann, L., Hop, W., van Buuren, S., Büller, H., van Goudoever, J. (2004). Malnutrition in critically ill children: from admission to 6 months after discharge. *Clinical Nutrition*. 2004;23(2), 223–232. http://doi.org/10.1016/S0261-5614(03)00130-4 | 293 children (104 preterm neonates, 96 term neonates and 93 older children) admitted to PICU/NICU. | Nutritional status evaluated by anthropometry at admit, at discharge, 6 weeks after discharge, 6 months after discharge. ECMO were excluded. Naked Weight, recumbent length or stadiometer, HC, calf c, biceps skinfold, triceps skinfold. | 24% were undernourished at admit. Neonates showed decline in nutritional status during admission. At 6 months after discharge almost all children showed recovery of nutrition status. LOS and disease history affected adversely status of preterm and term neonates. Concluded most children have good long term outcome in terms of nutritional status after discharge. | P |

| | | | | | | |
|---|---|---|---|---|---|---|
| Kim | 2017 | Kim SH, Park CM, Seo JM, Choi M, Lee DS, Chang DK, et al. The impact of implementation of an enteral feeding protocol on the improvement of enteral nutrition in critically ill adults. *Asia Pac J Clin Nutr* 2017;26(1), 27–35. http://doi.org/10.6133/apjcn.122015.01 | 270 patients in a med surg ICU (134 before feeding protocol implementation and 136 after implementation) receiving EN for >24h. | Retrospective study with prospectively collected data. Multidisciplinary working group including RDs developed an EN protocol. Subjects included patients consecutively admitted to the ICU who received EN for more than 24 hours. EN practices and clinical outcomes (time to initiation, time to reach caloric goal, reaching caloric goal, prokinetics, PN, GI symtpoms, mortality, LOS in hospital/ICU) were compared before and after implementation of the protocol. | EN was initiated earlier (35.8 vs 87.1 hours, p=0.001) and more patients received EN within 24 hours (59.6% vs 41.0%, p=0.002) after implementation of the protocol. The interval between start- ing EN and reaching the caloric goal was not different, but more patients reached the caloric goal after implemen- tation (52.2% vs 38.3%, p=0.037). The post-implementation group was given more prokinetics and less parenter- al nutrition. The incidences of diarrhea and gastrointestinal bleeding significantly decreased following implemen- tation of the protocol. There was no difference in clinical outcomes including in-hospital mortality and length of hospital and ICU stay. Conclusion: The implementation of the EN protocol significantly improved the practices of EN and decreased complications in critically ill patients. Clinical outcomes were not different before and after implementation. | A |
| Kyle | 2012 | Kyle UG, Jaimon N, Coss-Bu JA. Nutrition Support in Critically Ill Children: Underdelivery of Energy and Protein Compared with Current Recommendations. *Journal of the Academy of Nutrition and Dietetics*, 2012;112(12). http://doi.org/10.1016/j.jand.2012.07.038 | 240 PICU patients admitted >48h. | Retrospective chart review. Documented all IV, PN, EN energy/protein for the first 8 days. BMR using Schofield and ASPEN guidelines. Moderate/severe acute malnutrition was defined as weight for age greater than ?2 z scores, and moderate/severe chronic malnutrition (growth stunting) was defined as height for age greater than ?2 z scores, using 2000 Centers for Disease Control and Prevention growth charts. | During the first 8 days of PICU stay, the actual energy intake for all patient-days was an average of 75.7%?56.7% of basal metabolic rate and was significantly lower than basal metabolic rate (P?0.001); the actual protein intake for all patient-days met an average of 40.4%?44.2% of protein requirements and was signifi- cantly lower than the American Society for Parenteral and Enteral Nutrition guidelines (P?0.001). Delivery of energy and protein were inadequate on 60% and 85% of patient- days, respectively. Only 75% of estimated energy and 40% of protein requirements were metin the first8days of PICU stay. These data demonstrate a high prevalence of critically ill children who are not meeting their recommended levels of protein and energy. In | P |
| Mehta | 2012 | Mehta NM, Bechard LJ, Cahill N, et al. Nutritional practices and their relationship to clinical outcomes in critically ill children--an international multicenter cohort study. *Crit Care Med*. 2012;40(7):2204-2211 | International prospective cohort study of consecutive children (ages 1 month to 18 yrs) requiring mechanical ventilation longer than 48 hrs in 31 PICUs in 8 countries. | Multivariate analysis, accounting for pediatric intensive care unit clustering and important confounding variables, was used to examine the impact of nutritional variables and pediatric intensive care unit characteristics on 60-day mortality and the prevalence of acquired infections. Main | Over 30% of patients had severe malnutrition. Mean prescribed goals for daily energy and protein intake were 64 kcals/kg and 1.7 g/kg respectively. Enteral nutrition was used in 67% of the patients and was initiated within 48 hrs of admission in the majority of patients. Enteral nutrition was subsequently interrupted on average for at least 2 days in 357 of 500 (71%) patients. Mean (SD) percentage daily nutritional in- take (enteral nutrition) compared to prescribed goals was 38% (34) for energy and 43% (44) for protein. A higher percentage of goal energy intake via enteral nutrition route was significantly associ- ated with lower 60-day mortality. | P |
| Mehta | 2010 | Mehta NM, McAleer D, Hamilton S, et al. Challenges to optimal enteral nutrition in a multidisciplinary pediatric intensive care unit. *J Parenter Enter Nutr*. 2010;34(1):38-45. | 117 patients with PICU stay >24 hours. | Daily nutrient intake and factors responsible for avoidable interruptions to EN were recorded in patients admitted to a 29-bed medical and surgical PICU over 4 weeks. Clinical characteristics, time to reach caloric goal, and parenteral nutrition (PN) use were compared between patients with and without avoidable interruptions to EN. Results: | Eighty (68%) patients received EN (20% postpyloric).EN was subsequently interrupted in 24 (30%) patients at an average of 3.7 ± 3.1 times per patient. Mechanically ventilated subjects were at the highest risk of EN interruptions. Avoidable EN interruption was associated with increased reliance on PN and impaired ability to reach caloric goal. | P |

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| Meyer | 2009 | Meyer R, Harrison S, Sargent S, Ramnarayan P, Habibi P, Labadarios D. The impact of enteral feeding protocols on nutritional support in critically ill children. *J Hum Nutr Diet*. 2009;22(5):428-436. | 353 patients age 0-16 years of age admitted to the PICU in St. Mary's Hospital, London. | A prospective audit on nutritional practice was initiated in 1994–1995 on all ventilated patients who were admitted for > 24 to the PICU. The audit was repeated 1997–1998, 2001 and 2005. The collection of data on outcomes included the time taken to initiate nutritional support, the proportion of patients fed via the enteral versus parenteral route, and the proportion of children reaching 50% and 70% of the estimated average requirement (EAR) by day 3. | Over the study period, time taken to initiate nutrition support was reduced from 15 h (1994–1995), 8 h (1997–1998), 5.5 h (2001) to 4.5 h (2005). The proportion of patients on parenteral feeds was reduced from 11% (1994–1995) to 4% (2005). An increase was also documented in the percentage of patients receiving a daily energy provision of 50% and 70% of the EAR by day 3 after the initiation of nutritional support (6% in 1994–1995 to 21% in 2005 for 70% of EAR). | P |
| Mikhailov | 2014 | Mikhailov TA, Kuhn EM, Manzi J, et al. Early Enteral Nutrition Is Associated With Lower Mortality in Critically Ill Children. *J Parenter Enter Nutr*. 2014;38(4):459-466. | 5105 patients in 12 PICUs, included patients aged 1 month to 18 years who had a PICU length of stay (LOS) of ≥96 hours for the years 2007–2008. | Analyzed demographics, weight, Pediatric Index of Mortality–2 (PIM2) score, LOS, duration of mechanical ventilation (MV), mortality data, and nutrition intake data in the first 4 days after admission. | Mortality was 5.3%. EEN was achieved by 27.1% of patients. Children receiving EEN were less likely to die than those who did not (odds ratio, 0.51; 95% confidence interval, 0.34–0.76; P = .001 [adjusted for propensity score, PIM2 score, age, and center]). | P |
| Pawellek | 2008 | Pawellek I, Dokoupil K, Koletzko B. Prevalence of malnutrition in paediatric hospital patients. *Clin Nutr*. 2008;27(1):72-76. doi:10.1016/j.clnu.2007.11.001 | 475 unselected children aged 7.975 years (mean) admitted to a pediatric hospital in Germany. | Data for weight and height upon admission were recorded. Weight for height 81–90 of median values were considered to indicate mild malnutrition, 70–80% moderate malnutrition and 70% severe malnutrition according to cut-off points defined by Waterlow. | Some 24.1% of the patients were malnourished, with 17.7% of all patients who were mildly, 4.4% who were moderately and 1.7% who were severely malnourished. The largest proportion of malnourished patients was found among patients with multiple diagnoses (42.8% malnourished), mental retardation (40.0%), infectious diseases (34.5%) and cystic fibrosis (33.3%). Conclusions: | P |
| Petrill-Albarano | 2006 | Petrillo-Albarano T, Pettignano R, Asfaw M, Easley K. Use of a feeding protocol to improve nutritional support through early, aggressive, enteral nutrition in the pediatric intensive care unit. *Pediatr Crit Care Med*. 2006;7(4):340-344. | 91 PICU patients before protocol (2000), 93 PICU patients after protocol (2002) | Patients were selected for review if they received nasogastric tube feedings while in the pediatric intensive care unit. Data reviewed through LOS 7 days of goal feeding or discharge. Data examined included: days in the pediatric intensive care unit and hospital, time to goal feedings, concomitant use of cardiovascular medications, sedation, analgesia, episodes of feedings held, vomiting, diarrhea, and constipation | Protocol group achieved goal nutrition in an average of 18.5 hrs and a median of 14 hrs. The retrospective group achieved goal feedings at an average of 57.8 hrs and a median of 32 hrs (p<.0001). Also noted were a reduction in the percentage of patients vomiting from 20% to 11% and a reduction in constipation from 51% to 33%. This comparison study suggests that the institution of a feeding protocol will not only achieve goal feedings at a substantially reduced time but also improve tolerance of enteral feedings in patients admitted to the pediatric intensive care unit. | P |
| Rogers | 2003 | Rogers, E. J., Gilbertson, H. R., Heine, R. G., & Henning, R. (2003). Barriers to adequate nutrition in critically ill children. *Nutrition,* 19(10), 865–868. http://doi.org/10.1016/S0899-9007(03)00170-9 | 42 children (median age, 6.6 mo; range, 0–198) admitted to a tertiary-level PICU studied prospectively over a 6-mo period. | Patients staying in the PICU longer than a full 3 d and who received enteral or a combination of enteral and parenteral nutrition were eligible for inclusion. Patients were assigned to one of two groups: patients after cardiac surgery (n = 18) and all other diagnoses (n = 24). EERs were compared with actual energy intake, and clinical information was collected throughout the PICU admission. Wt for z score and barriers to nutrition recorded. | Patients in the PICU received a median of 37.7% (range, 0.2–130.2%) of their EERs. The cardiac group achieved significantly lower energy intakes than did the non-cardiac group (P?0.02). Only 22 of 42 patients (52%) achieved full EERs at any time during their admission, and this was more likely in non-cardiac patients (67% versus 33%, P?0.03) Children undergoing cardiac surgery had a significant fall in weight-for-age Z scores (WAZ) from PICU admission to discharge (median WAZ, ?1.44 versus ?2.14; P ? 0.001). In both groups, the major barrier to achieving EER was fluid volume restriction. Interruption of feeding for procedures and feeding intolerance reduced energy intake to a lesser degree. | P |

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| Woien | 2005 | Wøien, H., & Bjørk, I. T. (2006). Nutrition of the critically ill patient and effects of implementing a nutritional support algorithm in ICU. *Journal of Clinical Nursing*, 15(2), 168–177. http://doi.org/10.1111/j.1365-2702.2006.01262.x | 21 patients during first 3 days after ICU admission. | A nutritional support algorithm was then implemented and nutritional data were collected from critically ill patients who participated in this intervention (intervention group, n ¼ 21). Data collected included the total amount of calories prescribed vs. received, onset of delivery of enteral nutrition, enteral vs. parenteral nutrition, and the use and size of enteral feeding tubes. | Patients in the intervention group were both prescribed and actually received significantly larger amounts of nutrients than patients in the control group. They also received a larger proportion of their nutrients in the form of enteral nutrition. In addition, the nutritional support algorithm led to greater consistency in nursing practices with respect to aspiration of gastric content and rate of increment in enteral feeding. | A |
| Briassoulis | 2001 | Briassoulis G, Zavras N, Hatzis T. Malnutrition, nutritional indices, and early enteral feeding in critically ill children. *Nutrition.* 2001;17(7-8):548-557. doi:10.1016/S0899-9007(01)00578-0. | Seventy-one, consecutively enrolled, critically ill children. | Children received early enteral feeding (energy intakes equal to 0.50, 1, 1.25, 1.5, and 1.5 of the predicted basal metabolic rates on days 1 through 5, respectively) through nasogastric tubes. | On the first day of the study, 16.7% of the patients already were depleted of protein and 31% of fat stores. Overall, 16.9% were at risk for chronic protein-energy malnutrition and 21.1% for acute protein-energy malnutrition, whereas 4.2% and 5.6% already had chronic and acute, respectively protein-energy malnutrition. Only 22.7% of patients without protein deficiencies versus 37% of those at risk or already deficient developed multiple-organ system failure. Survivors had higher prealbumin levels than non-survivors (22.3 versus 15.5 mg/dL). With logistic regression analysis, only repleted energy, not anthropometric or nutrition indices, was independently associated with survival (P = 0.05). | P |
| Rutan | 1990 | Rutan RL, Herndon DN. Growth Delay in Postburn Pediatric Patients. *Arch Surg*. 1990;125(3):392. doi:10.1001/archsurg.1990.01410150114021. | Medical records of 80 patients who had sustained a greater than 40% total body surface area burn, were older than 2 years of age at the time of the burn, and were at least 1 year post burn were reviewed. | Yearly growth velocities were calculated for up to 3 years after the burn. | Despite adequate nutritional support and maximal exercise and/or long-bone stresses, a profound growth arrest was noted during postburn year 1, which slowly resolved to near normal distribution by postburn year 3. | P |
| Martinez | 2014 | Martinez EE, Bechard LJ, Mehta NM. Nutrition Algorithms and Bedside Nutrient Delivery Practices in Pediatric Intensive Care Units. *Nutr Clin Pract*. 2014;29(3):360-367. doi:10.1177/0884533614530762. | 524 mechanically ventilated pediatric patients, 1 month to 18 years old | Available EN algorithm details from 31 international PICUs were obtained. Daily nutrient intake data from 524 mechanically ventilated patients, 1 month to 18 years old, were prospectively documented, including EN delivery, adjunct therapies, and energy prescription. Practices associated with higher percentage adequacy of EN delivery were determined by regression analysis. | Nine EN algorithms were available. All algorithms defined advancement and EN intolerance; 7 of 9 defined intolerance by gastric residual volume; 3 of 9 recommended nutrition screening and fasting guidelines. Few elements were in agreement with the American Society for Parenteral and Enteral Nutrition and the European Society of Paediatric Gastroenterology, Hepatology, and Nutrition guidelines. Of the 341 patients who received EN exclusively 32.9% received ≥66.6% of prescribed energy on day 7. Percentage adequacy of EN delivered was inversely associated with days to EN initiation (-8.92; P < .001) and hours per EN interruption (-1.65; P = .001) and was not associated with the use of algorithms, promotility agents, or postpyloric feeding. | P |

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| Hamilton | 2014 | Hamilton S, McAleer DM, Ariagno K, et al. A stepwise enteral nutrition algorithm for critically ill children helps achieve nutrient delivery goals. *Pediatr Crit Care Med*. 2014;15(7):583-589. doi:10.1097/PCC.0000000000000179. | Consecutive patients admitted to the PICU over two 4-week periods pre and post implementation, with a stay of more than 24 hours who received enteral nutrition. Eighty patients were eligible for this study and were compared to a cohort of 80 patients in the preimplementation audit. | Investigators developed and systematically implemented a stepwise, evidence and consensus-based algorithm for initiating, advancing, and maintaining enteral nutrition in critically ill children. Three months after implementation, they prospectively recorded clinical characteristics, nutrient delivery, enteral nutrition interruptions, parenteral nutrition use, and ability to reach energy goal in eligible children over a 4-week period. Clinical and nutritional variables were compared between the pre and postintervention cohorts | There were no significant differences in median age, gender, need for mechanical ventilation, time to initiating enteral nutrition, or use of postpyloric feeding between the two cohorts. They recorded a significant decrease in the number of avoidable episodes of enteral nutrition interruption (3 vs 51, $p < 0.0001$) and the prevalence and duration of parenteral nutrition dependence in patients with avoidable enteral nutrition interruptions in the postintervention cohort. Median time to reach energy goal decreased from 4 days to 1 day ($p < 0.0001$), with a higher proportion of patients reaching this goal (99% vs 61%, $p = 0.01$). | P |
| Pollack | 1981 | Pollack MM, Wiley JS, Holbrook PR. Early nutritional depletion in critically ill children. *Crit Care Med*. 1981;9(8):580-583. http://www.ncbi.nlm.nih.gov/pubmed/6790227. Accessed May 29, 2017. | 50 medical PICU admits. | Nutritional assessment included weight/50th percentile weight for length, length/50th percentile length for age, triceps skinfold thickness, and midarm muscle circumference. | Acute protein-energy malnutrition (PEM) occurred in 16% of all children. Chronic PEM also occurred in 16%. The nutrient stores of fat and somatic protein were deficient in 18 and 20% of all children. Acute PEM and deficient somatic protein stores were more frequent in children less than 2 years (p less than 0.05). | P |
| Pollack | 1982 | Pollack M, Wiley J, Kanter R, Holbrook P. Malnutrition in critically ill infants and children. *J Parenter Enter Nutr*. 1982;6(1):20-24. doi:10.1177/014860718200600120. | 108 infants and children in a multidisciplinary intensive care unit. | Nutritional assessments were performed on all patients. | Overall, the prevalence of acute PEM was 19% and chronic PEM was 18%. The prevalence of fat store depletion was 14% and somatic protein store depletion was 21%. In general, children <2 years had poorer nutritional status compared to children ≥2 years. There was not a statistically significant difference between medical and surgical patients. | P |
| Hecht | 2015 | Hecht C, Weber M, Grote V, et al. Disease associated malnutrition correlates with length of hospital stay in children. Clin Nutr. 2015;34(1):53-59. doi:10.1016/j.clnu.2014.01.003. | 2567 patients aged 1 month to 18 years were assessed in 14 centres in 12 countries. | Patients were assessed using standardised anthropometry within the first 24 h after admission. Body mass index (BMI) and height/length <−2 standard deviation scores (SDS, WHO reference) were related to LOS (primary outcome), frequency of gastrointestinal (diarrhoea and vomiting) and infectious complications (antibiotic use), weight change during stay (secondary outcomes) and quality of life. | A BMI <−2 SDS was present in 7.0% of the patients at hospital admission (range 4.0–9.3% across countries) with a higher prevalence in infants (10.8%) and toddlers aged 1–2 years (8.3%). A BMI <−2 to ≥−3 SDS (moderate malnutrition) and a BMI <−3 SDS (severe malnutrition) was associated with a 1.3 (CI95: 1.01, 1.55) and 1.6 (CI95: 1.27, 2.10) days longer LOS, respectively ($p = 0.04$ and $p < 0.001$). Reduced BMI <−2 SDS was also associated to lower quality of life, and more frequent occurrence of diarrhoea (22% vs 12%, $p < 0.001$) and vomiting (26% vs 14%, $p < 0.001$). | P |

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| Fivez | 2016 | Fivez T, Kerklaan D, Mesotten D, et al. Early versus Late Parenteral Nutrition in Critically Ill Children. *N Engl J Med*. 2016;374(12):1111-1122. | 1440 critically ill children. | This was a multicenter, randomized, controlled trial investiating whether withholding parenteral nutrition for 1 week (i.e., providing late parenteral nutrition) in the pediatric intensive care unit (ICU) is clinically superior to providing early parenteral nutrition. Fluid loading was similar in the two groups. The two primary end points were new infection acquired during the ICU stay and the adjusted duration of ICU dependency, as assessed by the number of days in the ICU and as time to discharge alive from ICU. | Mortality was similar in the two groups. The percentage of patients with a new infection was 10.7% in the group receiving late parenteral nutrition, as compared with 18.5% in the group receiving early parenteral nutrition. The mean (+/-SE) duration of ICU stay was 6.5+/-0.4 days in the group receiving late parenteral nutrition, as compared with 9.2+/-0.8 days in the group receiving early parenteral nutrition; there was also a higher likelihood of an earlier live discharge from the ICU at any time in the late-parenteral-nutrition group (adjusted hazard ratio, 1.23; 95% CI, 1.11 to 1.37). Late parenteral nutrition was associated with a shorter duration of mechanical ventilatory support than was early parenteral nutrition (P=0.001), as well as a smaller proportion of patients receiving renal-replacement therapy (P=0.04) and a shorter duration of hospital stay (P=0.001). Late parenteral nutrition was also associated with lower plasma levels of gamma-glutamyltransferase and alkaline phosphatase than was early parenteral nutrition (P=0.001 and P=0.04, respectively), as well as higher levels of bilirubin (P=0.004) and C-reactive protein (P=0.006). | P |
| Chellis | 1996 | Chellis MJ, Sanders S V., Webster H, Dean JM, Jackson D. Early Enteral Feeding in the Pediatric Intensive Care Unit. *J Parenter Enter Nutr*. 1996;20(1):71-73. doi:10.1177/014860719602000171. | 42 critically ill patients ranged in age from 5 days to 18 years (mean 5.8 years), mean weight 17 kg. | Transpyloric nasoenteric tubes were placed in all patients by a nonfluoroscopic bedside technique. All subjects were mechanically ventilated; 32 (76%) were on one or more vasoactive medications. Six (15%) patients were fed for more than 13 days while on vasoactive support and pharmacological paralysis. | There were no documented complications of early enteral feeding, including aspiration. All patients were able to achieve caloric goals within 48 hours of beginning enteral feedings. All patients developed regular stool patterns despite periodic absence of bowel sounds. Enteral feedings replaced 256 days of total parenteral nutrition. Estimated patient charge savings averaged $425 for each day of enteral feedings. | P |
| Sanchez | 2007 | Sánchez C, López-Herce J, Carrillo A, Mencía S, Vigil D. Early transpyloric enteral nutrition in critically ill children. *Nutrition.* 2007;23(1):16-22. doi:10.1016/j.nut.2006.10.002. | 526 critically ill children. | This was a prospective observational study including all critically ill children fed using transpyloric enteral nutrition. The clinical characteristics, energy intake, tolerance, and complications of nutritional delivery between the children with early (first 24 h) and late (after 24 h, range 1-43 d) transpyloric enteral nutrition were compared. | Transpyloric nutrition was started within the first 24 h in 202 (38.5%) of the 526 children. There were no differences in the diagnoses, incidence of organ disturbances, doses of vasoactive drugs, or mortality between the two groups. There were no differences in the maximum number of calories delivered or in the duration of the nutrition between children with early and late transpyloric nutrition. | P |
| King | 2004 | King W, Petrillo T, Pettignano R. Enteral nutrition and cardiovascular medications in the pediatric intensive care unit. *J Parenter Enteral Nutr*. 2004;28(5):334-338. | 52 pediatric patients aged 1 month to 20 years old receiving cardiovascular medications. | Retrospective chart review. Feeding characteristics were recorded and analyzed. Included feed interruptions, reasons documented for interruptions (GI intolerance, constipation, vomiting, GI bleeding). | Although a large number (71%) of patients experienced at least 1 feeding interruption, the majority (70%) of reasons cited for stopping or slowing feedings were not related to gastrointestinal (GI) tolerance. Only 29% of patients had feedings held for perceived intolerance. Vomiting was the most often-cited reason for these interruptions. Constipation was reported in 36% of patients but cited only 4 times as a reason for feeding interruption. Four patients exhibited evidence of GI bleeding. This bleeding was considered clinically insignificant in 2 patients and appeared unrelated to enteral feedings in the others. | P |

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| Framson | 2007 | Framson CMH, LeLeiko NS, Dallal GE, Roubenoff R, Snelling LK, Dwyer JT. Energy expenditure in critically ill children. *Pediatr Crit Care Med*. 2007;8(3):264-267. doi:10.1097/01.PCC.0000262802.81164.03. | Forty-four children (29 males, 15 females) ages 2 wks to 17 yrs in a pediatric intensive care unit of a tertiary care medical center. | During the course of their stay in the pediatric intensive care unit, 44 patients' measured resting energy expenditure was assessed using indirect calorimetry 94 times at up to three time points. | Measured energy expenditure varied only slightly (7% to 10%) from the first to second and the second to third measurements. The hypermetabolic response apparent in adults was not evident in these critically ill children. | P |
| Mehta | 2015 | Mehta NM, Bechard LJ, Zurakowski D, Duggan CP, Heyland DK. Adequate enteral protein intake is inversely associated with 60-d mortality in critically ill children: a multicenter, prospective, cohort study. *Am J Clin Nutr*. 2015;102(1):199-206. doi:10.3945/ajcn.114.104893. | Study included 59 pediatric intensive care units (PICUs) from 15 countries, which enrolled 1245 children (age: 1 mo to 18 y) who were mechanically ventilated for ≥48 h. | Prospective, multicenter, cohort study. Daily and cumulative mean adequacies of energy and protein delivery as a percentage of the prescribed daily goal during the PICU stay ≤10 d were recorded. Researchers examined the association of the adequacy of protein delivery with 60-d mortality and determined variables that predicted protein intake adequacy. | A total of 985 subjects received enteral nutrition, 354 (36%) of whom received enteral nutrition via the postpyloric route. The mean delivery of enteral energy and protein was 36 ± 35% and 37 ± 38%, respectively, of the prescribed goal. The adequacy of enteral protein intake was significantly associated with 60-d mortality ($P < 0.001$) after adjustment for disease severity, site, PICU days, and energy intake. In relation to mean enteral protein intake <20%, intake ≥60% of the prescribed goal was associated with an OR of 0.14 (95% CI: 0.04, 0.52; $P = 0.003$) for 60-d mortality. Early initiation, postpyloric route, shorter interruptions, larger PICU size, and a dedicated dietitian in the PICU were associated with higher enteral protein delivery. | P |
| Moreno | 2016 | Moreno YMF, Hauschild DB, Barbosa E, Bresolin NL, Mehta NM. Problems With Optimal Energy and Protein Delivery in the Pediatric Intensive Care Unit. *Nutr Clin Pract*. 2016;31(5):673-680. doi:10.1177/0884533616639125. | 130 children (age: 1 month to 15 years) admitted to the PICU in southern Brazil. | Demographics, clinical characteristics, and NT details were recorded. | Median predicted energy expenditure by Schofield equation and prescribed and actual energy intake were 47.13 kcal/kg/d (38.60, 55.38), 31.94 kcal/kg/d (13.99, 51.90), and 25.06 kcal/kg/d (10.21, 46.92), respectively. On average, actual energy intake was 47% of the predicted energy expenditure, and 68% of patients were underfed. Actual protein intake was 49% of the estimated requirement. NT was interrupted in 64% of patients. | P |
| Rogers | 2003 | Rogers EJ, Gilbertson HR, Heine RG, Henning R. Barriers to adequate nutrition in critically ill children. *Nutrition*. 2003;19(10):865-868. doi:10.1016/S0899-9007(03)00170-9. | Forty-two children (median age, 6.6 mo; range, 0-198) who were admitted to a tertiary-level pediatric intensive care unit (PICU). | Patients staying in the PICU longer than a full 3 d and who received enteral or a combination of enteral and parenteral nutrition were eligible for inclusion. Patients were assigned to one of two groups: patients after cardiac surgery (n = 18) and all other diagnoses (n = 24). EERs were compared with actual energy intake, and clinical information was collected throughout the PICU admission. | Patients in the PICU received a median of 37.7% (range, 0.2-130.2%) of their EERs. The cardiac group achieved significantly lower energy intakes than did the non-cardiac group ($P = 0.02$). Only 22 of 42 patients (52%) achieved full EERs at any time during their admission, and this was more likely in non-cardiac patients (67% versus 33%, $P = 0.03$) Children undergoing cardiac surgery had a significant fall in weight-for-age Z scores (WAZ) from PICU admission to discharge (median WAZ, -1.44 versus -2.14; $P < 0.001$). In both groups, the major barrier to achieving EER was fluid volume restriction. | P |
| Taylor | 2003 | Taylor RM, Preedy VR, Baker AJ, Grimble G. Nutritional support in critically ill children. *Clin Nutr*. 2003;22(4):365-369. http://www.ncbi.nlm.nih.gov/pubmed/12880603. | 95 children over the age of 1 year who were in PICU>or=3 days. | The chart notes children who were in PICUwere reviewed and information related to the delivery of nutrition was obtained. | Fifty-nine per cent were fed within 24h of admission. Enteral nutrition was administered 54% of the time, 10% required parenteral nutrition and 9.5% received no nutritional support. Children only received a median 58.8 (range 0-277)% of their energy requirements, which could not be optimised until the 10th intensive care day. Energy intake was greater when supplemented with parenteral nutrition. | P |

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| Kyle | 2012 | Kyle UG, Jaimon N, Coss-Bu JA. Nutrition Support in Critically Ill Children: Underdelivery of Energy and Protein Compared with Current Recommendations. *J Acad Nutr Diet.* 2012;112(12):1987-1992. doi:10.1016/j.jand.2012.07.038. | Three hundred thirty-five children from August to December 2012 (pre-implementation) and 185 from October to December 2013 (post-implementation). | The retrospective study evaluated changes in the energy and protein intake before and after implementation of nutrition support (NS) guidelines for a pediatric critical care unit (PICU). | The implementation of NS guidelines was associated with improvements in total energy in 2-year-olds and older and protein in younger than 2 and 2 years and older children by days 5 through 8, and protein deficits were significantly lower in the post- vs the pre-implementation period. | P |
| Gurguiera | 2005 | Gurgueira GL, Leite HP, Taddei JA de AC, de Carvalho WB. Outcomes in a pediatric intensive care unit before and after the implementation of a nutrition support team. *J Parenter Enteral Nutr*. 2005;29(3):176-185. | Historical cohort study of infants hospitalized for >72 hours at the PICU from 1992 to 2003. | Five periods were selected (P1 to P5), considering the modifications incorporated into the program. The samples were compared in terms of sex, age, admitting service (ie, medical vs surgical), prognostic index of mortality, length of stay (LOS), duration of mechanical ventilation, in-PICU mortality rate, and percentage of time receiving EN and PN for each | Progressive increase was observed in EN use ($p = .0001$), median values for which were 25% in P1 and rose to 67% by P5 in medical patients; there was no significant difference in surgical patients. A reduction was observed in PN use; in P1 medians were 73% and 69% for medical and surgical patients respectively, and decreased to 0% in P5 for both groups ($p = .0001$). There was significant reduction in-PICU mortality rate during P4 and P5 among medical patients ($p < .001$). The risk of death was 83% lower in patients that received EN for >50% of LOS (odds ratio, 0.17; confidence interval, 0.066-0.412; $p = .000$). | P |

Appendix 1

# Criteria for Pediatric Malnutrition

## Diagnosing Pediatric Malnutrition

- Identify, diagnose, and document the presence of malnutrition in pediatric patents age 1 month to 20 years who plot on standardized growth charts.

- Use serial data points to best evaluate changes from a normal growth pattern.

- Patients diagnosed with malnutrition should meet 2 or more anthropometric criteria.

- If only a single anthropometric data point meets criteria, malnutrition can still be diagnosed by using supporting evidence such as intake or nutrition focused physical exam.

- If a patient meets criteria for more than one degree of malnutrition look at supporting evidence and use clinical judgement. If indicated select the most severe degree.

- Patients <2 years use WHO z scores
- Patients >2 years use CDC z scores
- z scores can be found in EPIC or calculated using www.peditools.org
- For premature infants weight and height should be adjusted until 36 months.

*Weight gain velocity chart based on data from The WHO Child Growth Standards.
**CDC 2012 MUAC percentile reference tables

**Identify Duration of Malnutrition**
Acute is < 3 months duration
Chronic is > 3 months duration

**Identify Etiology of Malnutrition**
Examples- chronic illness, disease state, increased energy expenditure, malabsorption, inadequate intake, inadequate intake, socioeconomic, inflammation

| Anthropometric Criteria | At risk/Mild Malnutrition | Moderate Malnutrition | Severe Malnutrition |
|---|---|---|---|
| **Weight-for-age *z* score** | -1 to -1.9 | -2 to -2.9 | -3 or less |
| **Length/height-for-age *z* score** | No data | No data | -3 or less (May indicate stunting) |
| **Weight-for-length or BMI *z* score** | -1 to -1.9 | -2 to -2.9 | -3 or less |
| **MUAC (3-60 months) *z* score** | -1 to -1.9 | -2 to -2.9 | -3 or less |

| Anthropometric Criteria- Change in Body Weight Over Time | At risk/Mild Malnutrition | Moderate Malnutrition | Severe Malnutrition |
|---|---|---|---|
| **Weight gain velocity * (<2 years of age)** | <75% of expected | <50% of expected | <25% of expected |
| **Deceleration in Weight-for-age z score** | Decline of 1 | Decline of 2 | Decline of 3 |
| **Weight loss (2-20 years of age)** | 5% usual weight | 7.5% usual weight | 10% usual weight |
| **Deceleration in Weight-for-length/BMI z score** | Decline of 1 | Decline of 2 | Decline of 3 |

| Additional Supporting Evidence | At risk/Mild Malnutrition | Moderate Malnutrition | Severe Malnutrition |
|---|---|---|---|
| **Inadequate Intake** | 51-75% of estimated calorie/protein needs | 26-50% of estimated calorie/protein needs | ≤25% of estimated calorie/protein needs |
| **MUAC (>60 months) **** | 5-15% | <5% | |
| **Fat Stores** | | Depleted fat stores- orbital, buccal, triceps, ribs. Bony prominences, loose/hanging skin, defined muscular outlines, minimal space when pinching | |
| **Muscle Stores** | | Depleted muscle stores- temporal, clavicle, scapula, thigh, calf. Bony prominences, muscle atrophy, loss of bulk and tone | |

Appendix 2

# Doernbecher PICU Enteral Feeding Guidelines

- Goal- Place feeding tube and start enteral feedings within 24 hours of admission in patients where oral intake is unavailable.
  - NJ feeds desirable, NG feeds will be considered in patients with low aspiration risk.
- Elevate head of bed 30-45° (unless contraindicated).
- If feedings are contraindicated, re-evaluate every 12 hours. Consider starting TPN.

## Contraindications to Enteral Feeding

| | |
|---|---|
| Intestinal obstruction<br>Ileus<br>Impending procedure or intubation<br>Instability requiring fluid resuscitation or distress<br>Significant respiratory distress | High dose vasopressors<br>-Dopamine gtt >8mcg/kg/min<br>-Epinephrine/norepinephrine gtt > 0.05mcg/kg/min<br>Vasopressin gtt for blood pressure (not DI)<br>NJ feeds for NIPPV with escalating support or HFNC > 5L |

## Initial Formula Selection

| *Age* | *Standard* |
|---|---|
| 0-12 months | Breast milk (20 cal/oz)<br>Home Formula or Similac Advance (19-20 cal/oz) |
| 1-10 years or < 35 kg | Nutren Jr (30 cal/oz, 1 cal/ml) |
| > 10 years or > 35 kg | Replete (30 cal/oz, 1 cal/ml) |

- Allergies or intolerances to milk or dairy products should be verified with parents/care givers.
- If patient is formula fed at home, use usual formula. Please note that not all formulas are on the formulary.

## Feeding Initiation and Advancement

| *Age* | *Start* | *Advancement* | *Initial goal rate* |
|---|---|---|---|
| 0-3 months | 0.5-1 mls/kg/hr | 0.5-1 mls/kg/hr q 2 hrs | 155 mls/kg/day (~6.5 mls/kg/hr) |
| 4-6 months | 0.5-1 mls/kg/hr | 0.5-1 mls/kg/hr q 2 hrs | 125 mls/kg/day (~5.2 mls/kg/hr) |
| 7-12 months | 0.5-1 mls/kg/hr | 0.5-1 mls/kg/hr q 2 hrs | 120 mls/kg/day (~5 mls/kg/hr) |
| 1-10 years<br>or<br>> 10 years and < 35 kg | 10-20 mls/hr | 5-10 mls/hr q 2 hrs | 10-15 kg = 50-55 mls/kg/day (~2.2 mls/kg/hr)<br>16-25 kg = 45-50 mls/kg/day(~2 mls/kg/hr)<br>26-35 kg = 40-45 mls/kg/day(~1.8 mls/kg/hr) |
| > 10 years and 35 kg | 15-25 mls/hr | 10-20 mls/hr q 2 hrs | 35-50 kg = 35-45 mls/kg/day (~1.7 mls/kg/hr)<br>>50 kg = 25-35 mls/kg/day (~1.3 mls/kg/hr) |

- The initial goal rate should provide the patients estimated basal metabolic rate.
- If the patient is tube fed at home, do not exceed the daily home feeding volume.
- Adjustments in the goal rate will be determined by the dietitian after a full nutrition assessment.
- Titrate IV fluids to enteral volumes

## Monitoring

| *Feeding Intolerance* | *Constipation* | *Diarrhea* |
|---|---|---|
| •Monitor for abdominal discomfort, abdominal distention, emesis, or bloody stools<br>•Consider holding feeds for 2 hrs and reassessing | •Senna-*S* or docusate BID on admit (unless contraindicated)<br>•If no stool after 2 days of full feeds, start Miralax<br>•If no stool after 2 days of Miralax doses and feeds, consider suppository or enema<br>•Refer to "Pediatric Bowel Protocol" | •>4 loose stools in 24 hrs<br>•Discontinue laxatives, stool softeners, etc<br>•Review formula and meds osmolarity<br>•Consider changing formula<br>•Consider withdrawal from opioids or benzos<br>•Consider stool studies (*C. difficle*) |

## Extubation

- If patient passes ERT, hold NG feeds 6 hrs prior to extubation or hold NJ feeds 2 hrs prior to extubation
- Evaluate feeding status 2 hrs after extubation and restart feeds if respiratory status is stable