Nutrition Support in Pediatric Critical Illness

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Objectives

- Understand the impact of critical illness and its effect on nutritional status
- Review key components of the nutrition screening and assessment
- Provide guidelines for the indication, selection and prescribing of nutrition support delivery

Pediatric Critical Illness and Malnutrition

- Critically ill infants and children are at highest risk of developing malnutrition due to their limited energy reserves and demands for growth
- Despite improvements in ICU technology, nutrition support protocols, the prevalence of malnutrition is high - up to 45%

Hulst J, Joosten K, Zimmermann L, et al. Malnutrition in critically ill children: from admission to 6 months after discharge. *Nutrition.* 2012;28(3):267-270.

Impact of MalNutrition

- Compromised immune function
- Delayed wound healing
- Reduced gut function
- Longer dependency on mechanical ventilation
- Increased length of hospital stay

Mehta N, Skillman H, Irving S et al. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Pediatric Critically Ill Patient. *Journal of Parenteral and Enteral Nutrition. 2017; 41: 706-742*

Nutrition Screen

- Completed by the Registered Dietitian on all patients within the first 24 hours of admission to the PICU
- Identifies preexisting or risk of developing malnutrition utilizing a questionnaire, anthropometric data and admit problem
- Triggers timely assessment and intervention in high malnutrition risk patients

White M, Lawson K. Simple Nutrition Screening Tool for Pediatric Inpatients. *J Parenter Enteral Nutr*. 2016 Mar; 40(3):392-8. doi: 10.1177/0148607114544321. Epub 2014 Aug 5

Nutrition Assessment Components

- Evaluation of oral, enteral or parenteral intake adequacy on and throughout admission
- Nutrition-focused physical exam
- Anthropometric Measures (weight, height/length, HC, weight for length/BMI) with evaluation of velocity and z score change
- Pertinent or Recommended Biochemical Indices (electrolytes, CRP pre albumin, LFTs, CBC)
- Prescription for Fluid, Energy and Protein
- Nutrition support recommendations and monitoring guidelines

Fluid in Critical Illness

- Fluid goals are to maintain intravascular volume, ensure adequate organ perfusion and minimize risk of pulmonary edema
- Electrolyte composition of IVF must have equal consideration based on clinical status and disruption in H2O and electrolyte homeostasis

Composition of Prescribed Fluid Solutions

Solution	Osmolality mOsm/L	Sodium meq/L	Potassium meq/L	Chloride mEq/L	Dextrose mOsm/L
0.9% Isotonic saline (normal saline)	308	154		154	
0.45% Isotonic saline (1/2 normal saline)	154	77		77	
5% Dextrose in water (D5W)					278
5% Dextrose + .33% isotonic saline (D5 1/3 NS)	378	50		50	278
5% + 0.45% isotonic saline	432	77		77	278

Source: Feld, L and Kaskel, F. *Fluid and Electrolytes in Pediatrics.* 2010 Springer, NY. Pg. 14

Fluid Prescription Equation

Weight * (kilograms)	Milliliters per kilogram (mL/kg)	Example Calculation
1-10kg	100mL/kg	Weight dose: 8 kg 800mL/day 33mL/hour
10-20kg	1,000mL + 50mL/kg for each kg above 10kg	Weight dose: 16kg 1,300mL/day 54mL/hour
> 20kg	1,500mL + 20mL/kg for each kg above 20kg	Weight dose: 24kg 1,580mL/day 66mL/hour

* Use dry weight for calculation, consider sensible and insensible water loss and additional IV medication input

Adapted from: Johnson KB. Fluid and Electrolytes. The Harriet Lane Handbook. Mosby 1993

Energy Needs in Critical Illness

Measured

- Measures energy expenditure through gas exchange VCO_2 produced/ VO_2 uptake and calculates Respiratory quotient (RQ)
- RQ reflects rate of substrate (CHO, Pro, Fat) metabolism
- RQ of 0.85-1 (normal); RQ > 1 (excess substrate); RQ = 0.7 (inadequate substrate)
- Requires constant FiO_2 below 60% and holding feedings/fasting prior to measure; metabolic cart equipment is expensive

Predictive

- Derived from resting energy expenditure measures of healthy children
- Does not factor body composition
- WHO equation includes age, sex and weight
- Schofield equation includes age, sex, weight and height
- Inaccurate weight or height can skew energy needs
- Risk of over or underfeeding calories in certain disease states
- Recommended in the absence of IC, use dry weight and WHO equation in critical illness

Predictive Energy Equations

Age	Gender	Schofield Equation Weight (kg), Height (cm)	WHO Equation Weight (kg)
0-3yrs	Male	0.167(W)+ 15.174(H) - 617.6	60.9 (W) -54
	Female	16.252(W) + 10.232(H) – 413.5	61 (W) - 51
3-10yrs	Male	19.59(W) + 1.303(H) – 414.9	22.7 (W) + 495
	Female	16.969(W) + 1.618(H) + 371.2	22.5 (W) + 499
10-18yrs	Male	16.25 (W) + 1.372 (H) + 515.5	17.5 (W) + 651
	Female	8.365(W) + 4.65(H) + 200	12.2 (W) + 746

Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr* 1985; 39 (Supple. 1) 5-41.
Carpenter A, Pencharz P, Mouzaki M. Accurate Estimation of Energy Requirements in Young Patients. *JPGN. 2015; 60: 4-10.*

Protein in Critical Illness

- Associated with rapid catabolism due to starvation, immobility, stress and inflammation
- Recommended Dietary Allowances (RDA) for protein in critical illness is often an underestimate of protein needs in the pediatric population
- Protein intake through Enteral or Parenteral delivery provides 1.5 x RDA at full energy provision

Protein Requirements

Life stage	Age	RDA/Adequate Intake g/d (g/kg/d)
Infants	0 - 6 months	9.1
	7 – 12 months	11.0 (1.5)
Children	1 – 3 years	13 (1.1)
	4 - 8 years	19 (1.0)
	9 - 13 years	34 (1.0)
Adolescent Males	14 – 18 years	52 (0.9)
Adolescent Females	14 – 18 years	46 (0.9)

Source: Food and Nutrition Board, Institute of Medicine. National Academy of Science. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids* (2002/2005).

Nutrition Support Modalities

Enteral Nutrition (EN)

- Preferred route of feeding in critical illness
- Maintains integrity and function of GI tract
- Time to initiate
  - In Preterm infants or malnourished children within 24 hr
  - In well-nourished, term infant within 3 – 4 days
  - In well-nourished child/adolescent within 5 -7 days

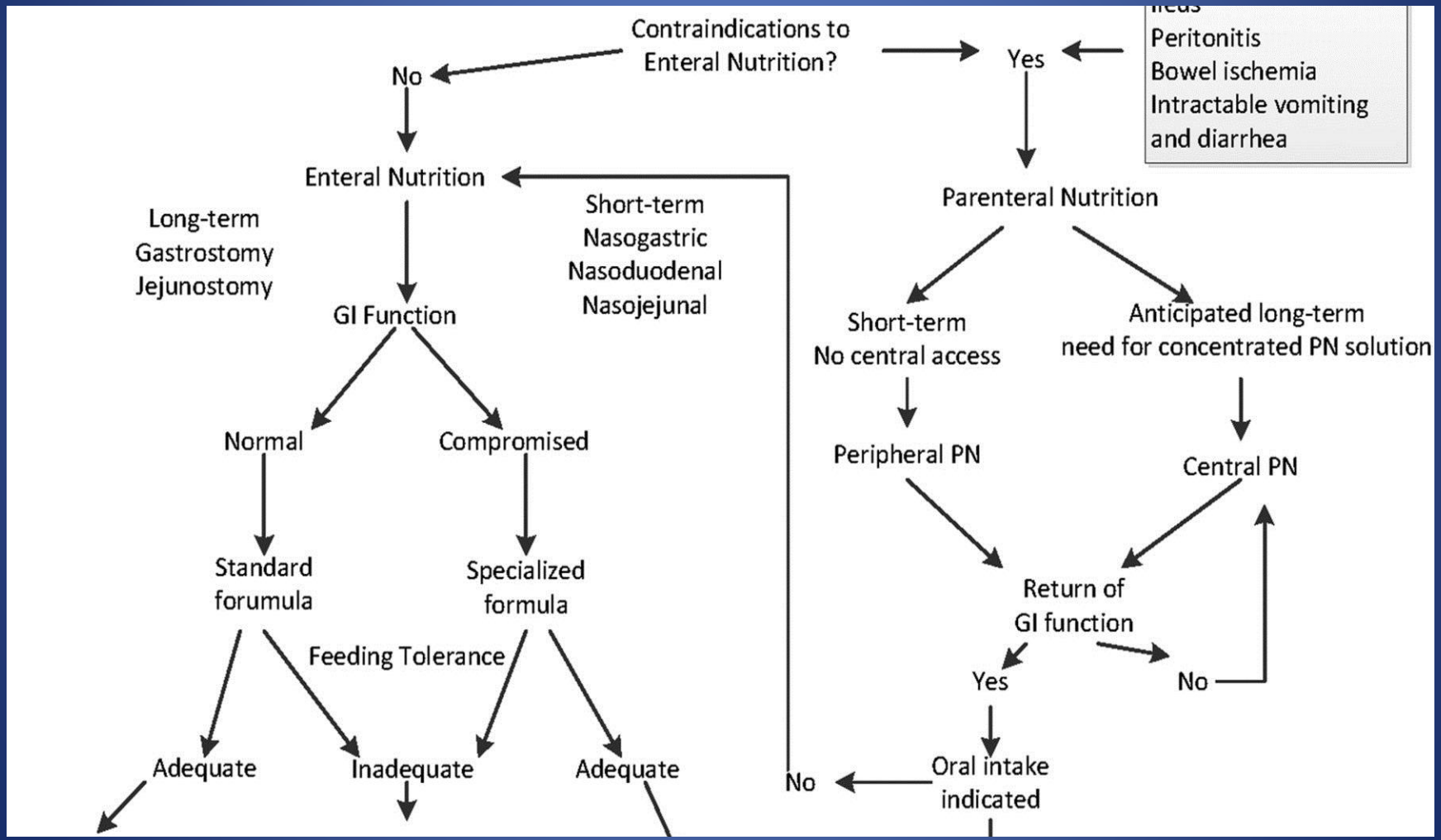
Standards for Nutrition Support: Pediatric Hospitalized Patients. Corkins, M R. et al and Task Force on Standards for Nutrition Support: Pediatric Hospitalized Patients; and the American Society for Parenteral and Enteral Nutrition Board of Directors. *Nutr Clin Pract* 2013 28: 263

Nutrition Support Modalities

Parenteral Nutrition (PN)

- Can serve as supportive therapy in combination with EN therapy in clinical conditions
- Higher risk of infection
- More expensive therapy
- Not physiologic
- Indications for primary support include:
  - Prolonged paralytic ileus
  - Bowel ischemia/poor perfusion
  - Small bowel obstruction
  - VLBW premature infants <1500g

Algorithm for Determining Route of Nutrition Support



Corkins M R et al. Nutr Clin Pract 2013;28:263-276

Enteral Feeding Options in Pediatrics

- Expressed Breast milk
- Preterm enriched formula (age ≤ 37 weeks and 2.5 kg)
- Infant formula (age ≥ 38 weeks and < 12 months)
- Toddler/school age formula (age > 1 year – 11 years)
- Adolescent/Adult formulas (age ≥ 12 years and 40kg)

Initiating and Advancing EN Feedings

Method	Administration	Initiate	Advance	Goal rate
*Continuous - delivered at a set rate per hour over 24 hours	Infusion pump set at an hourly rate to deliver volume over 24 hours	1-2mL/kg/hour for the first 24 hours	0.5-1mL/kg/hour every 4-8 hours	Desired mL per hour rate to achieve daily caloric needs
Bolus - established number of feedings delivered over a short duration of time	Infusion pump or syringe delivered over 15-60 minutes in 3-4 hour intervals	25% of the goal caloric needs divided into 5-8 feedings per day depending on patient's age, tolerance and nutrition needs	25% of goal caloric needs each day or every other based on tolerance	100% of caloric goal

*preferred method of administration in critical illness until gut perfusion improves and medically stable when time off of the infusion pump can allow for physical therapy/development

Nutrition Support Case Example

3m.o. former full term infant female admitted with hypoxia in respiratory failure. Intubated, sedated, HD # 2 of PICU admit and NPO. NG tube in place. Prior to admission feeding maternal breast milk. Pertinent medical info: Temp 38.3, uo 1.8mL/kg/hr, HR 144, IV meds contributing 5mL/kg. IVF D5 ½ NS at 19mL/hr (providing 89mL/kg, GIR 3.1).

Pertinent Anthropometrics:

Admit (dry) weight: 5.125kg Birth weight: 3kg

Admit length: 57.25cm

RD Assessment:

Energy 61-104 kcals/kg (WHO x 1.2 intubated - EER 0-3m.o. extubated/growth)

Protein minimum DRI – RDA 1.5 - 2.2g/kg/day

Fluid maintenance – 100mL/kg (nutritional fluids per team limited to < 100mL/kg)

RD recommended interventions:

1. Initiate continuous NG tube feedings of expressed breast milk feeding at 5 mL per hour and advance by 5 mL every 4 hours (per PICU protocol) to a goal of 20mL/hour (provides: 480mL, 93.7mL/kg, 62.8kcals/kg and 1.0g protein/kg)
2. Once reached 20mL/hour, advance caloric density to ~24 calories per ounce using infant formula powder at 1 tsp./90mL to fortify breast milk (provides: 75kcals/kg, 1.3g protein/kg. *Need at least 110mL/kg/day deliver 88 kcals/kg and 1.5g protein/kg *

Enteral Nutrition Order Writing Tips

1. Select route of administration based on access
   - Ng, Og, ND, G-tube, J-tube
2. Determine method of delivery continuous vs. bolus
   - Continuous preferred in critical illness
3. Select feeding type breast milk and/or formula
4. Determine starting infusion rate and advance, based on PICU protocol
5. Determine goal rate based on nutrition assessment targets for energy and protein needs, considering fluid as a possible rate limiting factor for nutrition delivery

Nutrition Support Case Example

3m.o. remains intubated, sedated, HD # 5 of PICU admission. Initiated NG tube feedings on HD #2 but unable to advance enteral rate beyond 10mL per hour and by HD # 5 developed bloody stools.

Pertinent medical info: Temp 37-38, UO 1.5 mL/kg/hr, HR 135-145, IV meds contributing 5mL/kg. IVF of D5 ½ NS at 19mL/hr providing 89mL/kg. I/) 482/500 (urine and stool mix)

Admit weight: 5.125kg

Pertinent labs: 148 / 109 / 3 Gluc- 75 Mg- 1.8, albumin – 2.6
3.6/ 19 / < 0.2 Ca- 7.9 Phos – 3.8 triglycerides - 48

Based on patient's deteriorating clinical status, risk of acute malnutrition and ongoing need for electrolyte and hydration support, PICU team decides to place PICC based on length of need (> 7 days) for supporting hydration, electrolyte and nutrition

Components of Parenteral Nutrition Solution

- Dextrose (3.4 calories/gram)
- Amino acids (4 calories/gram)
- Lipid (10 calories/gram) - 10% emulsion (1.1kcals/mL) or 20% emulsion (2kcals/mL)
- Electrolytes
- Vitamins
- Trace elements
- Sterile Water
- Miscellaneous: compatible medications (Famotidine, Erythromycin), cysteine, carnitine

Parenteral Dextrose Dosing

Age	Initiate GIR mg/kg/min (g/kg)	Advance GIR mg/kg/min	Goal GIR mg/kg/min (g/kg)
Preterm infant	6-8 (8.6-13)	1-2	10-14 (14.4-20.2)
Term infant < 1 year	6-8 (8.6-13)	1-2	10-14 (14.4-20.2)
Children 1-10 years	3-6 (4.3-8.6)	1-2	8-10 (11.5-14.4)
Adolescents	2.5-3 (3.6-4.3)	1-2	5-6 (7.2-8.6)

Corkins, MR. *Pediatric Nutrition Support Core Curriculum*. 2nd edition. Silver Springs MD: ASPEN, 2015
Koletzko B. Pointdexter B, Uauy R. *Nutrition Care of Preterm Infants: Scientific Basis and Practical Guidelines (World Review of Nutrition and Dietetics, Volume 110)*. 1st ed. Karger; 2014.

How to Calculate the GIR

Example: 3 month old infant, weight of 5kg; IV fluids D5 at 19mL/hour x 24 hours (480mL/day)

1. Determine total grams of dextrose infused over 24 hours
   - % dextrose 5g/100mL x 480mL= 24g
2. Convert from total grams to milligrams
   - 24g x 1,000mg dextrose = 24,000mg
3. Divide total mg of dextrose by infants weight
   - 24,000 ÷ 5 kg = 4,800mg/kg
4. Divide mg of dextrose by the total minutes of infusion time (24 hrs = 1440 minutes)
   - 4,800mg/kg ÷ 1440min = 3.3mg/kg/min

* Online tool available for calculating http://www.nicutools.org > glucose delivery

Parenteral Amino Acid Dosing

Age	Initiate g/kg	Advance g/kg/day	Goal g/kg/day
Preterm infant	1-3	-	3.0-4.0
Term infant < 1 year	2.5 - 3	-	2.5–3
Child (1-10yrs)	1.5-2.5	-	1.5-2.5
Adolescent	0.8-2	-	0.8-2.0

Corkins, MR. *Pediatric Nutrition Support Core Curriculum*. 2nd edition. Silver Springs MD: ASPEN, 2015
Koletzko B. Pointdexter B, Uauy R. *Nutrition Care of Preterm Infants: Scientific Basis and Practical Guidelines (World Review of Nutrition and Dietetics, Volume 110)*. 1st ed. Karger; 2014.

Parenteral Lipid Dosing

Age	Initiate g/kg	Advance g/kg/day	Goal g/kg/day
Preterm	0.5-1	0.5-1	3* (15mL/kg volume)
Term infant < 1 year	0.5-1	0.5-1	2.5 -3* (12.5-15mL/kg volume)
Children (1-10yrs)	1-2	0.5-1	2 -2.5
Adolescents	1	1	1-2

* Max lipid infusion rate 0.15mL/kg/hour at 3g/kg dose, minimum infusion time required is 20 hours

Corkins, MR. *Pediatric Nutrition Support Core Curriculum*. 2nd edition. Silver Springs MD: ASPEN, 2015
Koletzko B. Pointdexter B, Uauy R. *Nutrition Care of Preterm Infants: Scientific Basis and Practical Guidelines (World Review of Nutrition and Dietetics, Volume 110)*. 1st ed. Karger; 2014.

Parenteral Electrolyte Dosing

Electrolyte/Salt	Preterm Infant Requirement	Infants/Children Requirement	Adolescents and Children > 50kg Requirement
Sodium	2-5mEq/kg	2-5mEq/kg	1-2meq/kg
Potassium	2-4mEq/kg	2-4mEq/kg	1-2meq/kg
Calcium	2-4mEq/kg	0.5-4meq/kg	10-20mEq/day
Phosphorus	1-2mmol/kg	0.5-2mmol/kg	10-40mmol/day
Magnesium	0.3-0.5mEq/kg	0.3-0.5mEq/kg	10-30mmol/day
Chloride	As needed to	maintain	acid base balance
Acetate	As needed to	maintain	acid base balance

Mirtallo J, Canada T, Johnson D et al. Safe practices for parenteral nutrition. *J Parenter Enteral Nutr.* 2004;28 (6): S39-S70.

Multivitamin Preparation and Dosing

Weight kg	*Pediatric MVI -13 Dose	Adult MVI – 13 Dose
≥ 3 kg	5mL	
12 years and > 40kg		10mL

Baxter Infuvite Pediatric per 5mL dose contains:
0.7mg Vitamin A, 400IU Vitamin D3, 7mg (7 IU) Vitamin E, 0.2mg Vitamin K, 1.2mg Thiamine (B1), 1.4mg Riboflavin (B2), 17mg Niacinamide (B3) , 5mg Dexpanthenol (B5), 1mg Pyridoxine (B6), 1mcg Cyanocobalamin (B12), 20mcg Biotin, 140mcg Folic Acid, 80mg Vitamin C

Vincent V, Borum P, Buchman A, Fessler T et. al. ASPEN Position Paper: Recommendations for Changes in Commercially Available Multivitamin and Multi-Trace Element Products (A.S.P.E.N) Board of Directors. *Nutri Clin Pract* 2012 (27): 440-491

Trace Element Requirements

Trace Element	Preterm Neonates < 3kg	Term Neonates 3kg - 10kg	Children 10kg - < 40kg	Adolescent > 40kg
Zinc	400mcg/kg	250mcg/kg	50mcg/kg (max 5,000mcg/d)	2-5mg/d
Copper	20mcg/kg	20mcg/kg	20mcg/kg (max 500mcg/d)	200-500mcg/d
Chromium	0.05-0.3mcg/kg	0.2mcg/kg	0.2mcg/kg (max 5 mcg/d)	5-15mcg/d
Manganese	1mcg/kg	1mcg/kg	1mcg/kg (max 55mcg/d)	40-100mcg/d
Selenium	2mcg/kg	2mcg/kg	2mcg/kg (max 100mcg/d)	40-60mcg/d

Vanek VW, et al. A call to action to bring safer parenteral micronutrient products to the U.S. market. *Nutr Clin Pract.* 2015;30(4):559-569.

Trace Element Preparation per mL

Trace Element	Multitrace – 4 Neonatal	Multitrace – 4 Pediatric > 3kg	Multitrace – 4 non-concentrate (concentrate)	Multitrace – 5 Adult concentrate > 40kg
Zinc	1.5mg	1mg	1mg (5mg)	5mg
Copper	0.1mg	0.1mg	0.4mg (1mg)	1mg
Chromium	0.85mcg	1mcg	4mcg (10mcg)	10mcg
Manganese	25mcg	25mcg	0.1mg (0.5mg)	0.5mg
Selenium	None	None	None (None)	60mcg

Monitoring Guidelines

Parameter	Initial	Follow Up
BMP	Daily	Every 1-4 weeks
Magnesium	Daily	Every 1-4 weeks
Phosphorus	Daily	Every 1-4 weeks
Triglycerides	Daily	Monthly as needed
CRP with Prealbumin	Weekly	Monthly
CBC differential/platelets	Weekly	Every 1-4 weeks
Trace elements (Zn, Se, Mn, Cu, Cr)	3 months	Every 3-6 months
Iron Studies (Ferritin, TIBC, B12, Folate)	3months	Every 3-6 months
B12/Folate	6months	Yearly
Weight Length HC < 36 months)	Daily Baseline Baseline	Weekly Monthly Monthly

Parenteral Nutrition Order Writing Tips

1. Determine your vascular access based on length of need
2. Use dry weight for determining fluid, energy and electrolyte dosing
3. Correct all electrolyte abnormalities prior to initiating.
4. Prescribe total volume based on maintenance fluid needs considering GI and renal loss
5. Calculate energy needs and determine composition of calorie distribution: 55-60% Dextrose, 30-35% Lipid, 10-15% Amino Acid; this percentage of calorie distribution meets goal per kg guidelines for Dextrose, AA and Lipid for infants and children
6. Convert macronutrient percent calories to grams/day and then divide by weight for goal grams/kg/day.
7. Use macronutrient guidelines for prescribing initial solution and advancing to goal macronutrients (determined in #6) over 1-2 days.

Parenteral Nutrition Case Example

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Parenteral Calculation Example

1. Determine your solutions daily calorie goal by multiplying your prescribed kcals/kg (83kcals/kg) x dosing weight (5.125kg) = 425 total calories
2. Determine percentage of calorie distribution for dextrose, amino acid (AA) and lipid using the following distribution 58% carbohydrate, 30% fat, 12% protein
3. Calculate calorie distribution and convert to total grams then divide by weight to determine grams per kg as follows:
   - **Dextrose:** 425 x .58 = 247 kcals

     divide by 3.4 kcals/g = 72.5 g divide by weight 5.125kg = 14.15g/kg

     calculate the GIR by multiplying 14.15g/kg x 1,000mg = 14,170mg

     divide 14,170mg by 1,440 minutes in 24 hr to calculate **GIR = 9.8**
   - **Lipid:** 425 x .30 = 127.5 kcals

     divide by 10 kcals/g = 12.8g divide by weight 5.125kg = 2.5g/kg

     Calculate lipid rate per kg per hour over 12 hours = 0.2mL/kg/hr
   - **AA:** 425 x .12 = 51 kcals

     divide by 4 kcals/g = 12.8g divide by weight 5.125kg = 2.5g/kg

Parenteral Calculation Example

4. Determine volume and electrolyte dosing based on dry weight, current labs, urine output, GI and renal loss
5. Volume prescription based on maintenance fluid plus considering GI loss and urine output
   - 22mL/hour (528mL; 103mL/kg) 2 in 1 solution for < 1 year of age lipid at goal 2.5g/kg will add 64mL (12.5mL/kg)
6. Electrolyte prescription using maintenance dosing guidelines for age with consideration of acid base balance, renal and GI loss; if no iCa be sure to correct Ca for low albumin (4.0- current albumin x 0.8 + current Ca value)
7. Tips for dosing electrolytes: Dose sodium first (consider a 3 to 1 CL to Acetate or 2 to 1 ratio depending on acid/base status and GI loss), then calcium before phosphorous (ratio of 2.2meq/44mg elemental Ca per 1mMol/31mg elemental Phos for infants) and potassium after phosphorous depending on salt chosen. If choosing KPhos, subtract the total K from your KPhos dose e.g. 0.45meq K per Kg (2meq/kg K target dose – 0.45meq/kg from KPhos = 1.6meq K to add either via CL or Acetate
   - 2meq/kg NaCL
   - 1.5meq/kg NaAcetate
   - 0.5meq/kg Calcium
   - 0.3mMol/kg KPhos (adds 0.45meq/kg K)
   - 1.6meq/kg KCL
   - 0.3meq/kg Magnesium

Parenteral Nutrition Final Solution

- Day # 1 initiating central parenteral nutrition (PICC confirmed in SVC) solution using 2 in 1 with lipid < 1 year order set

  Starting Dextrose 8.6g/kg or GIR 6 (goal is 9.8mg/kg/min or 14.1g/kg)

  Starting AA at 2.5g/kg (goal)

  Starting Lipid at 1g/kg (goal is 2.5g/kg)

  Volume prescription (Dextrose/AA/Electrolytes/MVI and trace) is 22mL/hr (528mL; 103mL/kg)

  Lipid prescription of 1g/kg adds 25.6mL (5mL/kg) total dose infused over 12 hours (0.08g/kg/hr)

  Electrolytes and other:

  2meq/kg NaCL

  1.5meq/kg NaAcetate

  0.5meq/kg Calcium

  0.3mMol/kg KPhos (adds 0.45meq/kg K)

  1.6meq/kg KCL

  0.3meq/kg Magnesium

  5mL multivitamin, pediatric trace element (4) 0.2mL/kg, add 2mcg/kg Selenium

Resources

- Feld L, Kaskel F. Fluid and Electrolytes in Pediatrics. *A Comprehensive Handbook.* Springer, NY; 2010.
- Carpenter A, Pencharz P, Mouzaki M. Accurate Estimation of Energy Requirements in Young Patients. *JPGN. 2015; 60: 4-10.*
- Consensus Statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: Indicators Recommended for the Identification and Documentation of Pediatric Malnutrition (Undernutrition). *Nutrition in Clinical Practice.* 2015; 30 (1):147-161.
- Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Pediatric Critically Ill Patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition. *JPEN. 2017; 41 (5): 706-742.*
- Goday P, Mehta N. *Pediatric Critical Care Nutrition.* 1st edition. New York, NY: McGraw-Hill Companies, Inc; 2015.
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