UC DAVIS HEALTH | CHILDREN'S HOSPITAL

UCD NICU Nutrition Guidelines

Contents

Enteral Nutrition

There is convincing evidence that the application of a standardized feeding protocol reduces the incidence of NEC. Risk of NEC is greatest in infants born < 32 weeks gestation and with a birth weight <1500 gm. For this reason, it is recommended to follow the NICU feeding guidelines for this population as medically appropriate (highlighted in "preemie purple" below). Careful consideration should be taken prior to deviating from these guidelines.

Trophic feeds of mother's own milk should be initiated as soon as medically appropriate after birth, but no later than 24-48 hours unless feeds are contraindicated. If a family intends to provide breast milk to their infant, the provider can consider allowing up to 24 hr for mother's breast milk (EBM) before initiation of feeds. If parent chooses not to provide EBM, then initiate trophic feeds with donor breast milk (DBM) after obtaining parental assent.

Nutrition needs for infants born >1500 gm may vary. The guidelines may be used as a tool to determine appropriate feeding advances and fortification needs, though they are not prescriptive and may be adjusted as needed pending individual need and clinical status. Individual patient nutrition needs may be discussed with the NICU dietitian.

NICU Enteral Feeding Advancement Guidelines

BW (gm)	Initial Feeding	Duration of trophic feeds	Advancement	Fortification
<750	10 mL/kg	3-5 days	10-20 mL/kg daily	• When tolerating 40 mL/kg x 24hr, fortify to 24 kcal/oz w/HMF • Ensure fortified feeds tolerated x 24 hr prior to further advances.
750-1000	10-20 mL/kg	Up to 3 days	20 mL/kg daily	
1000-1500	20 mL/kg	24-48 hr	30 mL/kg daily	
1500-2000	20 mL/kg	At least 24 hr	15-20 mL/kg BID	Likely needed pending GA & clinical status: • May fortify w/HMF if majority of feeds via NG. • If progressing toward discharge, may add supplemental feeds of PDF 22-24 kcal/oz.
2000-2500	20-30 mL/kg	Up to 24 hr	20 mL/kg BID	Likely need supplemental feeds of PDF 22-24 kcal/oz at least 1-2x/d.
>2500	40-60 mL/kg/d or ad lib with minimum	Up to 24 hr	20 mL/kg BID	Only if needed. Evaluate need after tolerating goal volumes.

HMF = human milk fortifier (product used: Similac HMF Hydrolyzed Protein Concentrated Liquid)
PDF = preterm discharge formula (i.e. Similac Neosure or Enfamil Enfacare)

Notes on fluid requirements for infants on enteral feeds:

- Goal hydration for most stable, growing infants is 100-120 mL/kg/d. Consider adding this as a shift minimum (i.e. 50-60 mL/kg/shift) when writing PO ad lib feeding orders.
- Goal *enteral* feeding volume for most infants is 150-160 mL/kg/d. If fluid restriction is warranted, additional fortification may be required to meet caloric goals to support growth.

Additional Enteral Nutrition Guidelines for Cubs (< 27 weeks or < 1000 grams)

- Colostrum should be provided as soon as possible. If it is not yet safe to initiate feeds, may provide as buccal swabs with cares.
- Encourage MOC to begin expressing breast milk within 6 hours of delivery. Prioritize lactation consultation as soon as possible.
- **Goal:** initiate trophic feeds (10-20 mL/kg; starting volume based on weight) within 48 hours of life using maternal EBM if available or high protein DBM if clinically appropriate (i.e. demonstrating adequate perfusion, stable BP off vasoactive support, etc.).
- Trophic volumes may be maintained during initial stabilization phase ~ DOL 0-3. Thereafter, may advance feeds 10-20 mL/kg (volume advancement based on weight) daily as tolerated.
- Can consider empirically extending feeds over 1 hr in infants <24 weeks GA in effort to promote tolerance in setting of slowed gut motility in this population.
- If infant has not stooled within 72 hours of life, a 3-day course of glycerin slivers should be initiated q AM. Ongoing need for glycerin will be evaluated after the initial 3-day course is complete.

Lab Monitoring on Full Enteral Feeds

	Frequency	**Lab Test**	**Notes**
≤34 weeks	q2 weeks (starting at 4 weeks)	Alk phos, serum Ca, serum Phos	If Alk phos <600 IU/L and serum phos >4.5 mg/dL, no need to repeat
	q2 weeks when on enteral iron supplementation	H/H, retic	
	q1 week PRN	BMP, spot urine sodium	Check if concern for poor growth or when receiving electrolyte supplementation
> 34 weeks and at risk for osteopenia*	q2 weeks (starting at 4 weeks)	Alk phos, serum Ca, serum Phos	If Alk phos <600 IU/L and serum phos >4.5 mg/dL, no need to repeat

*Patients at risk for osteopenia/rickets = BW < 1500 g, IUGR, history of long-term TPN (> 1 month), history of diuretics or corticosteroids, history of NEC or intestinal failure, presence of underlying endocrine pathology, or suboptimal mineral intake.

Parenteral Nutrition

These guidelines contain pertinent information that may be used to help care for neonatal patients admitted to the NICU who need parenteral nutrition support. Separate guidelines for pediatric and adult populations are available elsewhere.

Indications for Use:

Parenteral Nutrition (PN) is the intravenous provision of nutrients, including fluids, electrolytes, macronutrients, vitamins, and minerals for patients who are unable to receive or tolerate adequate enteral nutrition to support their metabolic demands. Parenteral nutrition is commonly utilized in the neonatal intensive care unit (NICU) for the following reasons:

- Functional immaturity of the GI tract due to GA
- Congenital GI conditions, anomalies, or injury (ex: gastroschisis, omphalocele, intestinal atresia, SIP, NEC, SBS)
- Bowel obstruction
- Concern for enteral malabsorption
- Critical illness requiring vasoactive medications or other medications that decrease perfusion to GI tract
- Congenital heart disease with compromised hemodynamics (risk of altered gut perfusion)
- Clinical status necessitating NPO or inability to provide EN
- Inability to meet energy needs and/or maintain appropriate growth via EN alone

Contraindications:

While PN is a life-saving therapy, its use is not without risks and may not be appropriate for all patients. Benefits vs. risks must be weighed and compared to the patient's medical condition(s) and clinical status. Contraindications to PN support are as follows:

- Ability to provide/optimize EN
- Severe metabolic derangements
- Transition to comfort care

Venous Access:

Peripheral: Peripheral parenteral nutrition (PPN) is delivered via a PIV and is intended for short-term nutrition support only. PPN concentration must be less than 900 mOsm due to risk of thrombophlebitis. Standard macronutrient composition of PPN is D10% AA2%; this may be adjusted slightly in collaboration with RD and PharmD, pending electrolyte needs.

Central: Total parenteral nutrition (TPN) is delivered via central venous catheter with tip in confirmed central location and is intended for long-term PN support and/or patients requiring fluid restriction.

Dosing Weight

PN is dosed for neonates according to body weight, thus determination of a "nutrition dosing weight" is important. Care should be taken in selecting an appropriate nutrition dosing weight to avoid excessive doses of nutrients to patients with edema or significant adiposity, which are less metabolically active tissues than lean body mass.

Appropriate growth & weight/length	**Significant edema present**	**Disproportionate weight/length and/or excessive adiposity**
Use birthweight for first 1-2 weeks of life or until infant surpasses birthweight For stably growing neonate, adjust nutrition dosing weight weekly to account for growth	Use birthweight for the first 1-2 weeks of life Estimate "dry weight" by following expected growth trajectory on growth chart	Collaborate with RD to determine appropriate ideal body weight

Typical Fluid Requirements for Critically Ill Neonates

BW (gm)	Day 0-1	Day 2	Day 3+
<750	130+ mL/kg	140-150+ mL/kg	150+ mL/kg
750-1000	100-130 mL/kg	130+ mL/kg	130-150+ mL/kg
1000-1500	80-100 mL/kg	100-120 mL/kg	120-150+ mL/kg
>1500	60-80 mL/kg	100 mL/kg	120+ mL/kg

Neonatal fluid requirements can vary based on infant's clinical status, body weight, gestational age, and physical environment. Total fluids include enteral feeds, parenteral nutrition, ILE, IVF, IV drips, medications (ex: antibiotics), blood products, colloids, etc.

Cub Fluid Management and the 3-Fluid Approach

ELBW and/or extremely preterm infants have dynamic fluid needs that require close monitoring and adjustments. To best meet the fluctuating needs and preserve nutrition for infants born <750 gm and/or

<24 weeks gestation, it is recommended to utilize 3 different IV fluids to allow titration of specific components without sacrificing protein provision. The 3 fluids are TPN, 0.45% sodium acetate, and IV dextrose. In general, TPN volume should not exceed 130-140 mL/kg/d maximum. The 3-Fluid Approach should also be considered for patients 24-27 weeks gestation with risk factors for hyperglycemia or refeeding syndrome.

Risk Factors for Hyperglycemia	**Risk Factors for Refeeding Syndrome and Low Phosphorus**

• IUGR
• Critically ill
  ○ Catecholamine infusions
  ○ Seizures
  ○ Physiologic stress (surgery, hypoxia, sepsis, etc.)
• SGA
• Maternal diazoxide
	• SGA (less than 10th percentile on standard growth curve)
	• IUGR
	• Placental insufficiency
	• Maternal comorbidities (e.g., preeclampsia)

Rationale for 3-Fluid Approach

The goal of providing 3 IVF rather than relying on PN as a sole source of fluids, electrolytes, and nutrition is to allow for greater flexibility in adjusting fluids to meet the changing needs of this dynamic population during the initial stabilization phase. This approach is aimed to tighten glycemic control, minimize hypernatremia, and improve nutrition provision to extremely preterm and extremely low birth weight infants. Use of the following fluids is recommended during the first 72 hours (or until fluid status has stabilized) in new Cub admissions.

PARENTERAL NUTRITION & LIPIDS

PN is essential for all ELBW infants given the functional immaturity of the GI tract and anticipated slow progression of enteral feeds. The primary goal of early PN during the stabilization phase is to minimize catabolism by providing an exogenous source of protein and glucose given limited endogenous stores. In this subpopulation, concentrated PN volumes during the initial 72hr of life is desirable, with the goal to provide ~50-100 mL/kg/d of the total fluid goal as PN. This volume of PN is sufficient to provide adequate protein intake, as well as provide appropriate amounts of electrolytes and minerals. Additionally, higher concentrations of macronutrients allow for improved calcium/phosphorus solubility in comparison to high-volume, diluted PN. PN rate should not be manipulated unless it is clinically essential to do so. IV lipid emulsions (ILE) are also included with PN, which provide a source of essential fatty acids.

0.45% SODIUM ACETATE

0.45% sodium acetate is used as a source of free water to meet total fluid goals while also providing a source of bicarbonate to compensate for renal losses in the setting of renal tubular acidosis, which is common in extremely premature infants. Our unit guidelines suggest an initial rate of 0.5 mL/hr, which provides ~ 20 mL/kg fluid for most of our Cub admissions. This rate may be adjusted throughout the day to target changes in fluid needs, such as titrating accordingly with IV dextrose to target ideal BG range or adjusting total fluid goals in the setting of changing urine output.

IV DEXTROSE

IV Dextrose is used to make up the remaining fluid volume needed to target the total fluid goal. Usually, a 5% dextrose solution (D5W) or lower concentration (D3.5W is also available) is used, given the propensity for hyperglycemia in this population. However, the concentration may be adjusted as needed depending on product availability to target the desired GIR.

Starter PN

"Starter PN" (sPN) is a stock solution that is available in the NICU for use in neonates with high nutrition risk (see "target populations" below). It should be provided as soon as feasible after birth (goal within 2 hours of delivery) to provide minimum calorie (30-40 kcal/kg) and protein (1.5-2.5 gm/kg) intake to prevent or limit catabolism. Goal infusion rates (listed below) are specified by subpopulation to ensure these goals are met while minimizing risk of hyperglycemia while the NICU is limited to a single starter solution (see "Orders"). ELBW infants require additional fluids (dextrose and sodium acetate) in addition to starter PN to target higher total fluid goals without providing excessive protein and GIR (see "Cub Fluid Management" section above).

Target population for routine use:

Starter PN is a limited resource and should be reserved for infants are highest nutritional risk. Current literature has shown that the following populations benefit most from starter PN:

- VLBW infants (<1500 gm)
- <32 weeks GA

If starter PN supply on the unit is abundant, providers can consider ordering starter PN for infants who meet ALL the following criteria:

- Diagnosis expected to require early surgical intervention and ongoing PN support (e.g., gastroschisis or other congenital anomaly of the GI tract, CDH, ductal-dependent CHD)

- IUGR or <35 weeks GA or <2 kg

Orders

- Order name: “Pre-mixed Starter Solution-Dextrose 10%/Amino Acid 3% with Calcium and Heparin”
- IV access: peripheral or central (osmolarity ~770)

Goal sPN infusion rates:

- BW </= 750 g: “3-Fluid Plan” with TPN at 50-60 mL/kg/d
- BW 750-1500 g: “Standard Fluid Plan” with TPN at 80-100 mL/kg/d
- Maximum rate: 100 mL/kg/d

Starting IVF for Cub Patients using the 3-Fluid Approach

Initial IVF should be ordered as follows per the *Small Baby Admission Guideline*. Minimum total fluid goal for this population is 100 mL/kg/d. For infants < 750 grams, target total fluid is typically higher.

1. sPN at 50-60 mL/kg/hr (GIR 3.5-4.2 mg/kg/min and 1.5-1.8 gm/kg protein)
2. 0.45% sodium acetate with heparin at 0.5 mL/hr
3. Dextrose* infusion to achieve total fluid

**May use D3.5-D10, as needed to target normal blood glucose and fluid requirement.*

Summary: Nutritional intake of Starter PN at various infusion rates (osmolarity ~770)

Volume (mL/kg/d)	Energy intake (kcal/kg/d)	Protein Intake (g/kg/d)	GIR (mg/kg/min)
50 (minimum rate)	23	1.5	3.5
60	28	2	4.2
70	32	2.1	4.9
80	37	2.4	5.6
90	41	2.7	6.3
100 (max rate)	46	3.0	6.9

Custom TPN

Custom PN orders are placed by the provider and sent to UCDMC pharmacy by 1200, are evaluated by pharmacist, and then sent to Central Pharmacy Admixture Services (CAPS) for compounding. PN solutions are prepared offsite and delivered to the NICU to be available for infusion by 2200.

Energy requirements

Parenteral energy requirements are ~10-30% less than estimated enteral requirements, as nutrients provided parenterally bypass digestive, absorptive, and excretion processes that contribute to the total enteral energy requirement. Calorie goals via PN may generally be estimated as follows, though may vary pending infant's gestational age and clinical status:

- Starter PN and/or initial IVF: 30-45 kcal/kg
- Early PN: 45-60 kcal/kg
- Goal PN: 80-100 kcal/kg

Custom TPN/IVF Orders for Cub Patients

It is expected that most Cub patients will benefit from the 3 IVF approach for at least the first 72 hours of life. Once the patient's total fluid goals have normalized to ~140-180 mL/kg/d and BG levels are consistently trending <150 mg/dL, it is reasonable to begin consolidating from 3 IVF to utilizing PN as the sole source of IV fluid/nutrition. It is anticipated that enteral feeds will likely begin to advance per the *Enteral Feeding Guideline* (pages 3-4 of this document) during this time as well.

Cubs that are of older gestations, higher BW, and are clinically well-appearing may stabilize faster and be able to transition off 3 IVF management earlier than outlined above.

Given lack of solubility curves for PN with dextrose concentrations less than 10% and the importance of optimizing calcium and phosphorus intake to ELBW infants, it is recommended to aim for a minimum dextrose concentration of D10% in custom PN orders if clinically appropriate. In the setting of significant hyperglycemia and rising total fluid goals, this may not always be feasible. For this reason, continuing a low PN volume to allow for higher dextrose concentration in the PN while continuing Y-in fluids to target lower GIRs is often helpful, and may be desirable for a longer period in patients with ongoing hyperglycemia to help reduce risk of osteopenia of prematurity.

MACRONUTRIENTS

Dextrose (Carbohydrates)

- An initial GIR of 4-6 mg/kg/min is appropriate for most infants admitted to the NICU.
    - Term and larger preterm infants may tolerate an initial GIR ~5-8 mg/kg/min.
    - ELBW infants are prone to hyperglycemia and may only tolerate an initial GIR ~3.5-4 mg/kg/min.
- Minimum recommended GIR for neonates is 3.5-4 mg/kg/min
- Maximum recommended GIR in TPN is 14 mg/kg/min
- Advance GIR by 0.5-3 mg/kg/min daily to goal. See table below for specific guidance on GIR adjustments based on BG levels. Goal GIR for most stable/growing neonates is ~10-12 mg/kg/min.
- GIR from all dextrose-containing IVF should be considered
- Goal: Target BG 70-180 mg/dL (up to 220 mg/dL may be acceptable). If hyperglycemic >220 mg/dL, refer to separate *Hyperglycemia in Preterm Infants* guideline.

Outside fluids (both dextrose and non-dextrose containing) can be used to titrate to goal GIR. *Do not* manipulate PN rate to target goal BG unless it is clinically essential to do so.

Target GIR for custom TPN order based on BG values

Blood Glucose Value	Recommended GIR adjustment
<120 mg/dL	If term/late preterm: increase by 2-3 mg/kg/min If VLBW/stable preterm: increase by 1-2 mg/kg/min If ELBW or <24 weeks, consider more cautious advance 0.5-1 mg/kg/min
120-150 mg/dL	If term/late preterm: may increase by 1-2 mg/kg/min or maintain GIR If VLBW/stable preterm: may increase by 0.5-1 mg/kg/min or maintain GIR If ELBW: increase by no more than 0.5 mg/kg/min or maintain GIR
150-180 mg/dL	Maintain same GIR or reduce GIR by 1-2 mg/kg/min; goal to maintain minimum 3.5-4 mg/kg/min GIR
>180 mg/dL	Reduce GIR by 1-2 mg/kg/min; goal to maintain minimum 3.5-4 mg/kg/min GIR

Amino Acids (Protein)

- Initiate minimum 1.5-2 gm/kg protein to prevent catabolism. Do not provide more than 3 gm/kg protein in the first 24 hours of life.
- Increase to goal protein within first days of life. The goal for term infants is typically 2-3 gm/kg and ~3.5 gm/kg for preterm infants. Up to 4 gm/kg protein may be required for some preterm infants (e.g., post-surgical, growth failure with PN dependence requiring Omegaven, etc.).

- The maximum recommended protein provision via PN is 4 gm/kg/d. Potential risks associated with excessive protein provision include acidosis, elevated BUN, and hyperammonemia.

SUMMARY: NICU PN Macronutrient Initiation & Advancement Guidelines

	Initiation		Advancement		Goal	
	Preterm	Term	Preterm	Term	Preterm	Term
PROTEIN (gm/kg/d)	Min: 1.5-2 Max: 3	2-3	0.5-1	--	3-3.5 Max: 4	2-3
DEXTROSE (GIR mg/kg/min)	ELBW: 3.5-4 Stable preterm: 5-7	6-8	ELBW: 0.5-1 Stable preterm: 1-2	2-3	10-12 (max: 12-14)	

Lipids

For patients unable to meet their full nutrition needs via oral or enteral route and need parenteral nutrition (PN) support, intravenous lipid emulsions (ILE) are provided as a concentrated source of calories and essential fatty acids. ILE should be initiated promptly, ideally within the first 24-48 hr of life, as preterm infants may develop essential fatty acid deficiency (EFAD) within 2-3 days if dietary fat is not provided. Available ILEs vary in caloric density and fatty acid composition to meet the needs of specific patient populations. These guidelines aim to outline the specific indications for ILE use and monitoring parameters for infants admitted to the NICU.

Intravenous Lipid Emulsions (ILE)

The following ILE are FDA-approved for use in pediatric/neonatal patients and are available at UCDMC.

- Intralipid® (100% soybean oil)
- SMOFlipid® (30% soybean oil, 30% MCT oil, 25% olive oil, 15% fish oil)
- Omegaven® (100% fish oil)

Indications for Use

- Intralipid: Preferred lipid source for ELBW/VLBW preterm infants following feeding protocol, preterm/term infants with expected short-term duration of TPN (<7-14 days), or infants with hypertriglyceridemia requiring ILE restriction. Intralipid may also be used with restricted dosing of 1 gm/kg in cases of limited IV access or compatibility issues with alternative ILE.
- SMOFlipid: Preferred lipid source for infants who are expected to require PN support greater than 21 days or who have a rising direct bilirubin while on PN. Must be able to tolerate dose of 2.5-3 gm/kg given risk of EFAD with restricted dose. ELBW/VLBW preterm infants who have

early injury to their gut (e.g., NEC, SIP) who are likely to require prolonged TPN support should be transitioned to SMOFlipid as soon as they are able to tolerate at least 2.5 gm/kg dose and have appropriate IV access.

- Omegaven: Preferred lipid source for infants with intestinal failure associated liver disease (IFALD) or parenteral nutrition-associated cholestasis (PNAC); must have direct bilirubin >2.0 mg/dL and expected duration of PN >2 weeks. Not indicated for *prevention* of IFALD/PNAC. Continue Omegaven until direct bilirubin levels <2 gm/dL or until patient no longer requires PN/ILE.
    - *Based on available literature, the following causes of direct hyperbilirubinemia are not indications to transition to Omegaven lipids: hepatotoxic medications, sepsis, congenital infections including syphilis.*

Lipid Use in Special Populations

Surgical GI Population, including Congenital GI Anomalies or Short Bowel Syndrome (SBS)

1. Initiate SMOF lipids as initial ILE for all infants with GI anomaly expected to require PN support > 14 days OR for infants with acquired GI injury receiving support with rising direct bilirubin (1-1.9 gm/dL) with goal of providing 2.5-3 gm/kg SMOF daily.
2. If direct bilirubin rises > 2 mg/kg/d, transition infant to 1 gm/kg Omegaven.
3. If growth trend is poor and GIR optimized, may consider increasing to 1.5 gm/kg Omegaven.
4. If significant concern for EFAD, recommend addition of 0.5-1 gm/kg/d Intralipid.

Contraindications

All available ILE are contraindicated in cases of severe hyperlipidemia or severe disorders of lipid metabolism with serum TG >1000 gm/dL OR if there is a known allergy/hypersensitivity to any ingredient in the product (see below). Additionally, Omegaven is contraindicated for patients with severe hemorrhagic disorders.

- Intralipid: soybean or egg protein
- SMOFlipid: fish, egg, soybean, or peanut protein
- Omegaven: fish or egg protein

NICU Lipid Dosing Guidelines

	Initial Dose	Advancement	Maximum Dose^	Minimum Dose to Prevent EFAD
Intralipid	<750 gm: 0.5 gm/kg 750-1000 gm or SGA, IUGR, or septic: 1 gm/kg >1000 gm: 2 gm/kg/d	<750 gm: 0.5 gm/kg/d* 750-1000 gm or SGA, IUGR, sepsis: 1 gm/kg/d >1000 gm: 1 gm/kg/d	3 gm/kg	0.5-1 gm/kg (2.5-5 mL/kg)
SMOFlipid	2-2.5 gm/kg**	0.5-1 gm/kg	3 gm/kg	2.5-3 gm/kg ** (12.5-15 mL/kg)
Omegaven	1 gm/kg	N/A	1 gm/kg *May consider up to 1.5 gm/kg if IFALD + growth failure (off-label)*	1 gm/kg (10 mL/kg)

** Consider holding advancement if hyperglycemic with BG persistently > 150 mg/dL*
***SMOFlipid dose restriction can result in EFAD and is discouraged. Goal to start at 2-2.5 gm/kg and advance to goal dose within 24-48 hr. Infants who develop IFALD/PNAC should be transitioned to Omegaven for rescue treatment*
^Do not exceed 60% of total kcal due to risk of ketosis. Do not exceed infusion rate >0.15 gm/kg/hr.

Hypertriglyceridemia Algorithm for Neonates Receiving Intralipid

Triglyceride Value	Recommended IL adjustment
<250 mg/dL	Continue to advance as scheduled or maintain goal dose
250-400 mg/dL	Reduce dose by 0.5-1 gm/kg Ensure levocarnitine in PN (starting dose 10 mg/kg/d)
>400 mg/dL	Consider holding up to 24-48 hr Optimize levocarnitine in PN (up to 20 mg/kg/d) Do not withhold IL for >3 days in preterm infants due to risk of EFAD. If TG remains grossly elevated, provide minimum 0.5-1 gm/kg IL.

ILE Drug Compatibility

Type of Lipid	Intralipid	SMOFlipid	Omegaven
Compatible	Most drug compatibility data available	Fentanyl Morphine Fluconazole Furosemide Amikacin Ampicillin Ceftazidime Erythromycin Meropenem Metronidazole Propofol Tobramycin Vancomycin	No compatibility data
Incompatible		Famotidine Dopamine Hydrocortisone * Lack of drug compatibility data on commonly used medications (caffeine, steroids, antibiotics, diuril). These should be considered incompatible until further testing performed.	All drugs incompatible with Omegaven until further testing can be completed. Should not be infused with other IV lipids.

Note compatibility data is rapidly evolving. Check tertiary online resources to the most up-to-date information.

Please contact the NICU Pharmacist for any questions regarding medication combability.

If compatibility issues arise for an infant whom SMOF or Omegaven is indicated, please contact the pharmacist to determine if there may be a work-around solution. If unable to provide alternative ILE, recommend providing restricted dose of Intralipid at 1 gm/kg in the interim, with goal to resume most appropriate ILE when the appropriate access is available.

ELECTROLYTES

Phase 1: Birth to weight nadir

- Relative oliguria followed by diuretic phase, evaporative losses in the Cubs via immature skin.
- Goals: Allow normal contraction without compromising intravascular volume and maintain normal electrolyte concentrations.

Phae 2: Intermediate

- Goals: Replete the body of electrolyte losses, replace actual water and electrolytes.

Phase 3: Stable Growth

- Goals: Replace losses of water and electrolytes (maintain water and electrolyte homeostasis).

- Cub Specific: provide enough extra water and electrolytes to build up new tissue at intrauterine growth rates.

Summary of Electrolyte Needs

	Sodium	Potassium	Magnesium	Calcium	Phosphate
Phase 1	1-5 mEq/kg/day	0-2 mEq/kg/day Generally, add when urine output established at 0.5-1 ml/kg/hr	0-0.2 mEq/kg/day If *in utero* Mg exposure, hold until serum Mg is within normal limits	0.8-2 mEq/kg	0.7-2 mmol/kg
Phase 2	6-12 mEq/kg/day	2-3 mEq/kg/day	0.2-0.4 mEq/kg/day	0.7-3.5 mEq/kg	0.7-3.5 mmol/kg
Phase 3	3-6 mEq/kg/day	2-5 mEq/kg/day	0.1-0.5 mEq/kg/day	1-4 mEq/kg	1-2 mmol/kg

Sodium

Considerations:

- Renin-angiotensin-aldosterone system (RAAS) is very active in the first week, resulting in increased vascular tone. After birth, renal blood flow increases due to increased blood pressure, resulting in a secondary increase in GFR.
- Elevated levels of aldosterone lead to enhanced distal tubular reabsorption of sodium.
- Antidiuretic hormone (i.e., ADH, AVP) levels rise after birth and may increase due to stress (birth trauma, RDS, positive pressure ventilation, IVH, etc.)
- The neonatal kidney is less efficient at excreting an acute sodium or volume load.
- In general, it is predicted that urinary sodium losses decrease with increasing gestational age (sodium needs decrease as gestational age increases and renal function matures).
- Conditions that may increase sodium needs include diuretic use, extreme prematurity, gastric losses (e.g., Replogle to suction, significant emesis, ostomy losses pending bowel adaptation with distal feeding). See *Ostomy replacement document* for replacement fluid recommendations.
- Remember to evaluate fluid and volume status when assessing labs. Hyponatremia is best managed with volume restriction rather than increased sodium intake.

Estimated Sodium Needs Based Age (mEq/kg/day)

Age	Day 1	Day 2	Day 3	Day 4	Day 5	Phase 2	Phase 3
Preterm < 1500 g	0-2	0-2	0-5	2-5	2-5	2-5	3-5
Preterm > 1500 g	0-2	0-2	0-3	2-5	2-5	2-5	3-5
Term	0-2	0-2	0-2	1-3	1-3	2-3	2-3

Preterm infants, especially those < 28 weeks GA, can have very high sodium requirements (up to 12 mEq/kg/day) during the first 1-2 weeks of life due to renal sodium losses in this population. Estimated needs by GA are as follows:

GA	DOL 1-2	DOL 3	DOL 7	DOL 14	DOL 30
< 28 wk	3 mEq/kg/day	6-12 mEq/kg/day	4-8 mEq/kg/day	3-6 mEq/kg/day	2-4 mEq/kg/day
29-31	2 mEq/kg/day	4-7 mEq/kg/day	2-4 mEq/kg/day	2-4 mEq/kg/day	1-2 mEq/kg/day
32-36	1 mEq/kg/day	3-5 mEq/kg/day	2-3 mEq/kg/day	1-2 mEq/kg/day	1-2 mEq/kg/day

See Appendix for guidance on how to adjust sodium in TPN

Potassium

General considerations:

- Potassium is the major intracellular cation; therefore, serum levels do not reflect the total body stores.
- Extracellular potassium concentration is not always related to intracellular concentration.
- Potassium can shift from the intracellular space to the extracellular space when there is acidemia through exchange with hydrogen ions.
- Intracellular potassium concentration depends on Na/K-ATPase activity, which can be impaired during hypoxia or catabolism.
- Ten percent of the potassium body stores are not exchangeable (bone, connective tissue, cartilage).

Consider risk factors for HYPERkalemia:

- Hold off on adding extra potassium to PN until adequate urine output is established (> 1-2 ml/kg/hr) in Phase 1.
- Consider risk for non-oliguric hyperkalemia VLBW infants with additional risk factors (lack of antenatal steroids, systemic acidosis, birth asphyxia, massive hematoma, hemolysis, catabolic state, etc.).

- Consider holding potassium with acute changes in renal function, such as AKI.
- Anticipate reduced potassium needs in patients with chronic kidney disease.

Consider risk factors for HYPOkalemia:

- Refeeding-like syndrome may be seen in growth-restricted and ELBW premature infants who have low mineral stores and high requirements. Upon refeeding, elevated insulin levels facilitate protein synthesis and can also lead to hypokalemia (and hypophosphatemia) due to intracellular shift of potassium (and phosphorus). During the oliguric phase, consider the risk of adding extra potassium to PN vs. monitoring and repletion if indicated.
- Patients with increased losses (loop diuretics, increased gastric losses) may have increased potassium needs. Consider empiric adjustment to potassium supplementation as these factors are changing.
- Magnesium deficiency can lead to hypokalemia by increasing renal potassium excretion, and magnesium deficiency can render hypokalemia refractory to treatment with potassium supplementation. Consider repleting Mg prior to K repletion.

Estimated Potassium Needs Based on Age (mEq/kg/day)

	Day 1-3	Day 4-5	Phase 2	Phase 3
Preterm < 1500 g	0-3	2-3	1-3	2-5
Preterm > 1500 g	0-3	2-3	1-3	1-3
Term	0-3	2-3	1-3	1.5-3

See Appendix for guidance on how to adjust potassium in TPN

Chloride (and Chloride/Acetate Balance)

- Chloride is the major extracellular anion. It is involved maintaining osmotic pressure, hydration, and ionic neutrality.
- Chloride losses and excretion can occur independently from sodium, mainly in equilibrium with bicarbonate.
- Daily chloride turnover is high. Sixty to seventy percent of filtered chloride is reabsorbed by the renal tubules.
- Acetate is utilized to provide a source of bicarbonate. A bicarbonate source is often needed to compensate for the renal losses secondary to renal tubular acidosis.
- In EBLW infants during phase 1, hyperchloremia should be minimized due to risk for IVH and other comorbidities.

- Chloride-reduced or chloride-free parenteral nutrition should be considered during this phase.
- Note that amino acids, saline flushes, and many IV medications will provide chloride.

Estimated Chloride Needs by Age (mEq/kg/day)

	Day 1-3	Day 4-5	Phase 2	Phase 3
Preterm < 1500 g	0-3	2-5	2-5	3-5
Preterm > 1500 g	0-3	2-5	2-5	3-5
Term	0-3	2-5	2-3	2-3

See Appendix for guidance on how to adjust chloride and acetate in TPN

Calcium

- Calcium is the most abundant mineral in the body. In blood, calcium exists in three fractions:
  - Ionized calcium (~50%) – physiologically active component, responsible for hypocalcemia symptoms
  - Protein-bound calcium (~40%)
  - Small amount of calcium that is complexed with other molecules such as citrate and phosphate
- Transfusion of citrated blood products can lower ionized Ca by increasing the anion-complexed fraction
- Note that with hypoalbuminemia, the total serum calcium concentration will be lower (generally decreased by 0.8 mg/dL for each 1 g/dL decrease in albumin), but the ionized fraction should remain normal.
- Alterations in acid-base status can impact ionized calcium. An elevation in extracellular pH, for example, increases the binding of Ca to albumin, thereby lowering the plasma ionized Ca concentration (usually 0.04 mmoL/L for each 0.1 change in pH).
- Therefore, respiratory *acidosis* reduces albumin binding and *increases ionized calcium*.
- Acute respiratory *alkalosis* increases albumin binding and can result in *hypocalcemia* symptoms.
- Bone calcium homeostasis is controlled by PTH, calcitonin, and $1,25(OH)_2$-vitamin D.
- Magnesium is necessary for PTH production, so magnesium deficiency can lead to secondary hypocalcemia.
- In addition to bone health, calcium is essential for coagulation, muscle function, neural transmission, cellular membrane integrity, and enzymatic function.

- Renal reabsorption depends on plasma concentrations, calcium requirements, renal tubular function, and availability of phosphorus for microcrystalline apatite formation in growing infants.
- Due to interruption of placental calcium transfer and relative hormonal immaturity (delayed PTH surge), hypocalcemia is common in the first 72 hours of life. *See table below for definitions of hypocalcemia.*
- Infants at risk for early hypocalcemia who may benefit from early addition of calcium to IV fluids even if not candidates for starter PN include:
    - Less than 32 wk GA at birth
    - IUGR
    - Sepsis
    - Asphyxia
    - Born to mothers with:
        - Preeclampsia
        - Diabetes
        - Severe vitamin D deficiency
        - Hyperparathyroidism/hypercalcemia
        - Hypocalcemia
        - AED use (phenobarbital, phenytoin, topiramate)
        - High-dose antacid (calcium carbonate) use
        - Aminoglycoside use
- Late-onset hypocalcemia (after the first 72 hours) is associated with more severe iCa derangements, and patients are more likely to be symptomatic.

Hypocalcemia thresholds (2 standard deviations below the mean nadir)

	Total Ca (mg/dL)	Ionized Ca (mmol/L)
Preterm with BW ≤ 1500 g	< 7	< 1.0
Term or preterm with BW > 1500 g	< 8	< 1.1

Estimated Calcium Needs based on Age

	mEq/kg/day	mmol/kg/day	mg/kg/day
Preterm during first days of life	1.6-4	0.8-2	32-80
Growing preterm	3.5-7	1.6-3.5	64-140
Term – 6 months	1.6-3	0.8-1.5	30-60

See Appendix for guidance on how to adjust calcium in TPN

Phosphate

- Phosphate is the primary intracellular anion. It is also present in bone and has critical roles in energy metabolism, nucleic acid synthesis and structure, and membrane formation.
- Phosphate deficiency can result in muscle weakness, impaired glucose tolerance, and prolonged respiratory insufficiency. Extreme hypophosphatemia can result in respiratory failure, cardiac dysfunction, and death.
- VLBW and SGA infants are at increased risk for early hypophosphatemia due to high phosphate needs for growth.
- As a result of hypophosphatemia:
    - Renal tubular phosphate reabsorption, which is usually 85–90%, increases to its maximum.
    - Calcium cannot be fixed in the bone, resulting in hypercalcemia and hypercalciuria.
    - If prolonged, this can result in in bone demineralization, osteopenia, and nephrocalcinosis.
- Hypophosphatemia has been observed in preterm infants on PN with inappropriately low phosphorus intake, high amino acid dosage, and a refeeding-like syndrome.

Estimated Phosphate Needs based on Age

	mmol/kg/day	mg/kg/day
Preterm during first days of life	1-2	31-62
Growing preterm	1.6-3.5	50-108
Term – 6 months	0.7-1.3	20-40

Minimizing Risk for Metabolic Bone Disease

- Majority of mineral accretion occurs during the third trimester of pregnancy. Therefore, Cub babies are at increased risk for low bone mass and metabolic bone disease.
- Threshold for calcium and phosphorus precipitation limits optimal delivery in PN.
- Factors that lower risk of precipitation:
    - Lower pH of the final solution (higher concentrations of dextrose and amino acids and addition of cysteine lowers the pH of the PN solution)
    - Prevention of excessive warming of the solution
    - Using PN within 24 hours of formulation
- Optimal calcium/phosphate ratio:

- ASPEN recommends 1.3:1 (molar ratio) or 1.7:1 (mg/mg, or mass ratio)
- Other experts have recommended somewhat lower Ca:P ratios, ranging from 1.1:1 to 1.5:1 (mg/mg).

Magnesium

- Magnesium sulfate is commonly used in the immediate antenatal period for prevention or treatment of eclampsia or for neuroprotection of the fetus.
- Magnesium sulfate freely crosses the placenta and can result in hypermagnesemia in the neonate.
- Reported clinical effects of hypermagnesemia in the newborn include:
  - Apnea, cyanosis, hypotonia, and/or hyporeflexia (i.e., magnesium 'toxicity' or 'intoxication')
  - Additive paralysis with aminoglycosides or neuromuscular blockers
  - Microcolon or 'meconium-plug syndrome'
- Hold magnesium in all infants with *in utero* magnesium exposure until serum magnesium level is normal or near normal with adequate renal function.
- Outside the early neonatal period, magnesium is primarily an intracellular ion, and serum levels do not necessarily reflect total body stores.
- In the blood, 1/3 of magnesium is bound to plasma proteins, and the remaining 2/3 is filtered by the kidney. About 1/3 of filtered magnesium is excreted in urine, and 5-15% is reabsorbed.
- Mg-dependent adenyl cyclase participates in both PTH release and activity. Therefore, magnesium deficiency can result in impaired PTH release and hypocalcemia.

Estimated Magnesium needs Based on Age

	mEq/kg/day	mmol/kg/day	mg/kg/day
Preterm during first days of life	0.2-0.4	0.1-0.2	2.5–5.0
Growing preterm	0.4-0.6	0.2-0.3	5-7.5
Term – 6 months	0.2-0.4	0.1-0.2	2.4–5

See Appendix for guidance on how to adjust magnesium in TPN

VITAMINS

Vitamins are essential for a variety of physiologic functions. In parenteral nutrition vitamins are provided based on patient weight through a multivitamin product. Based on limited parenteral dosages of individual vitamins few can be supplemented individually.

See Appendix for standard MVI Formulations

TRACE ELEMENTS

Trace elements (TE) are present in the body in very small amounts but provide vital physiologic functions. Recommended parenteral intake based on gestation/age are listed in the table below. Certain clinical conditions, including cholestasis, significant GI losses, renal failure/insufficiency, lymphatic disorders, and/or wounds affect TE needs and may warrant adjustment from standard doses; the NICU RD may be consulted for recommendations. Currently, there is no multi-trace element product that provides 100% of the requirements for all TE in the neonatal population, thus individual trace element supplementation may be required. If clinically appropriate, the multi-trace product may be removed and replaced with individually dosed TE.

Iron is not recommended as a routine additive to neonatal PN given concern for compatibility and toxicity and should be provided enterally if possible. Optimal route of iron supplementation for infants requiring long-term PN unable to receive enteral iron supplementation should be discussed with the pharmacist and peds GI team.

If PN support is required for 1 month or more, zinc, copper/ceruloplasmin, and selenium levels should be checked to assess status *(see PN Lab Monitoring Guidelines* below*).* Zinc and copper compete for intestinal absorption, thus should be checked together whenever possible to aid in dosing recommendations.

NICU TPN Trace Element Requirements

Trace Elements	Preterm Requirements (*from birth to term*) (mcg/kg/d)	Term Requirements (mcg/kg/d)
Zinc	400-500	<3 months: 250 >3 months: 50
Copper (cupric chloride)	20-40	20
Selenium	2-7	2

UCD Children's Hospital Standard Pediatric PN Trace Elements Guide (2022)

Multrys®	Patient weight (kg)	Zinc	Copper	Selenium	Manganese
Standard dose: 0.35 mL/kg	2.5-3 kg	350 mcg/kg	21 mcg/kg	2.1 mcg/kg	1 mcg/kg
1 mL/d (max dose)	3+ kg	1000 mcg	60 mcg	6 mcg	3 mcg
- Preterm infants <2.5 kg will receive individually dosed TE (400 mcg/kg Zn, 3 mcg/kg Se, 20 mcg/kg Cu) - Preterm infants that are 2.5-3 kg will need an additional 50 mcg/kg zinc added to meet needs. - For infants >3 kg who require TPN >7-14 days, assess if actual TE intake is appropriate to meet requirements for gestation & clinical status. Consult RD for assistance.					

ADDITIVES

*Cysteine: C*onditionally essential AA added to PN for preterm infants, increases Ca/PO4 solubility by lowering pH and appears to improve nitrogen retention. Dose is typically 40 mg per gm of AA.

L-carnitine: Aids in fatty acid transport into mitochondria for beta oxidation. Add 10-20 mg/kg to PN if expected to require 2+ weeks of PN support or to treat elevated TG.

Heparin: add if running via central line (UVC, UAC, PICC)

Lab Monitoring Guidelines

	Initiation and/or Advancing PN	Stable PN
Blood Glucose (BG)	Per unit guidelines	Per unit guidelines
BMP	Daily	1-2x/week
Minerals (Ca, PO4, Mg)	Daily	Every 1-2 weeks
Triglycerides (TG)	With increasing IL dose	PRN
CMP, direct bilirubin	Weekly	Weekly
Urine sodium	N/A	Weekly (if VLBW or increased GI losses)
Trace Minerals (zinc, copper, selenium)	N/A	- Check if on PN x 30 days - Repeat q 1-3 months pending status - Do not check during inflammatory state (CRP >2)
Essential Fatty Acid Panel Misc lab order: ARUP #2013518	N/A	- Check after 30 days on PN if receiving SMOF, Omegaven, or dose-limited IL. - Repeat PRN

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Appendices

Appendix 1: Conversion Factors and Formulas

Conversion Factors

	mmol	mEq	mg (elemental)
Sodium (Na)	1	1	23
Potassium (K)	1	1	39
Chloride (Cl)	1	1	35
Magnesium (Mg)	1	0.5	12
Calcium (Ca)	1	2	20
Phosphorus (P)	1	2 (HPO3)	31

Formulas

Sodium deficit (mEq) = 0.6 × weight (kg) × (desired [Na^+] – measured [Na^+])

Chloride deficit (mEq) = 0.2 × weight (kg) × [103 – measured serum chloride (mEq/L)]

Corrected Ca = Measured Ca + [0.8 × (4 – albumin)]

PN Calculations:

GIR (Glucose Infusion Rate): ___ % dextrose x _____mL/kg/d ÷ 144 = ___ mg/kg/min

Protein (4 kcal/g) = ___ mL/kg PN x ____g/100 mL amino acid = ___ g protein/kg/d

Dextrose (3.4 kcal/g) = _____ mL/kg PN x _____% dextrose = ___ g dextrose/kg/d

20% Lipid (IL or SMOF) provides 5 mL/gm → 2 kcal/mL → 10 kcal/gm

10% Lipid (Omegaven) provides 10 mL/gm → 1.1 kcal/mL → 11 kcal/gm

Calories from MCT oil = 7.7 kcal/mL

Example: Calculate nutrition provision of standard TPN (D12.5% + AA3%) at 130 mL/kg + 10 mL/kg IL

Dextrose calculations:

130 mL/kg x 0.125 g/dL dextrose x 3.4 kcal/g = 55 kcal/kg
130 mL/kg x 0.125 g/dL dextrose + 1.44 mg/min = 11.3 GIR

Amino acid calculations:

130 mL/kg x 0.3 g/dL AA = 3.9 g/kg AA
3.9 g/kg AA x 4 kcal/g = 15.6 kcal/kg

Lipid calculations:

10 mL/kg x 2 kcal/mL = 20 kcal/kg

TPN provides ~ 140 mL/kg, 91 kcal/kg, 3.9 kcal/kg, & 11.3 mg/kg/min GIR

Enteral Nutrition Calculations:

EBM/Formula Calorie Concentration (kcal/oz)	Conversion to kcal/mL
20	0.67
22	0.73
24	0.8
26	0.87
27	0.9
28	0.93
30	1.0

Example: Calculate calories provided for 1.5 kg infant receiving 30 mL q3hr of EBM 24 kcal/oz.

30 mL x 8 feeds = 240 mL

240 mL / 1.5 kg = 160 mL/kg

160 mL/kg x 0.8 = 128 kcal/kg

OR 160 mL/kg x 24 kcal/oz / 30 mL/oz = 128 kcal/kg

Example: Calculate calories provided for 1.5 kg infant receiving 1 mL of MCT oil BID.

1 mL x 2 x 7.7 kcal/mL = 15.4 kcal

15.4 kcal / 1.5 kg = 10.3 kcal

Appendix 2: Further detail of 3-Fluid Approach

The multi-fluid approach greatly improves our ability to meet the ever-changing needs of our Cubs without compromising the nutrition we are able to provide.

This population requires frequent adjustments to IVF in the first 72 hours of life as they transition to extra uterine life. Fluid volume may be adjusted in increments ~ 10-20 mL/kg based on trends in electrolytes and urine output. In the initial transition period, it is common for infants to undergo significant diuresis resulting in hypernatremia and metabolic acidosis that warrant adjustments to IVF. These patients also have poor glycemic control, which necessitates careful titration of GIR to maintain BG within a targeted goal range.

Furthermore, while PN can theoretically provide all the fluids, electrolytes, and nutrients that extremely premature infants need, it is logistically challenging, if not impossible to do so. PN is a complex, multi-component fluid. It requires careful evaluation of the patient's clinical status and review of laboratory data prior to writing a custom PN order. Providers are often making a best guess at what the patient's needs will be 10+ hours from when the order is written. This often results in the patient receiving a solution that may not appropriately meet their needs at the time the PN bag hangs, which can result in either reducing the PN rate and adding additional IVF or discarding the bag entirely. In either scenario – nutrition provision, particularly protein, calcium, and phosphorus, intake is compromised. This process is often cyclical in the first days to week of life, which can cause the patient to fall far behind in their nutrition and contribute to early malnutrition.

Given the dynamic nature of this population, the use of 3 IVF, each with its distinct purpose, allows for greater flexibility to better achieve the targeted fluid, sodium, and glucose goals. Communication between members of the NICU team, including the ordering provider, bedside RN, dietitian, and pharmacist is key to the success of the 3 IVF approach.

Appendix 3: Parenteral MVI Pediatric Standard dosing

Vitamin	Less than 2.5 kg Dose 2 ml/kg	Greater than or equal to 2.5 kg Dose 5 ml
Ascorbic acid (vitamin C)	32 mg/kg	80 mg
Vitamin A* (retinol)	0.28 mg/kg	0.7 mg
Ergocalciferol (vitamin D)	4 mcg/kg	10 mcg
Thiamine (Vitamin B1)	0.48 mg/kg	1.2 mg
Riboflavin (Vitamin B2)	0.56 mg/kg	1.4 mg
Pyridoxine (Vitamin B6)	0.2 mg/kg	1 mg
Niacinamide	6.8 mg/kg	17 mg
Dexpanthenol	2 mg/kg	5 mg
Vitamin E	2.8 mcg/kg	7 mcg
Biotin	8 mcg/kg	20 mcg
Folic acid	56 mcg/kg	140 mcg
Cyanocobalamin (vitamin B12)	0.4 mg/kg	1 mcg
Phytonadione (vitamin K)	80 mcg/kg	200 mcg

Appendix 4: Responding to Abnormal Serum Sodium and Adjusting Sodium in Parenteral Nutrition

Serum sodium	Possible interventions	Adjustment to PN
Greater than 150 mmol/L	Reduce other sources of sodium. Consider spot-dose diuretic. Assess for diabetes insipidus. Provide free water (i.e., increase total fluids with a dextrose-containing fluid). *Rapid correction of hypernatremia may cause seizures and permanent neurodevelopmental sequelae. Therefore, do not lower serum [Na+] more rapidly than 10 mEq/L q12h.*	Consider reducing the current PN rate if other interventions are not sufficient.
145-150 mmol/L	Consider volume status and need for additional fluids.	Decrease sodium in PN by 1-3 mEq/kg/day, assuming no other sources of sodium or medications that cause sodium wasting.
135-145 mmol/L		Continue same sodium in PN, assuming no planned changes to medications or volume status.
130-135 mmol/L		Increase PN sodium 1-3 mEq/kg/day.
125-130 mmol/L	Calculate sodium deficit and correct. Hold diuretics if possible. Consider volume restriction.	Increase PN sodium 2-4 mEq/kg/day, assuming no other sources of sodium or medications that cause sodium wasting.
120-125 mmol/L	Calculate sodium deficit and correct. Hold diuretics is possible. Consider volume restriction.	Increase PN sodium by 3-5 mEq/kg/day, assuming no other sources of sodium or medications that cause sodium wasting.
Less than 120 mmol/L	Consider NaCl 3% repletion bolus if symptomatic.	Increase PN sodium by at least 4 mEq/kg/day, depending on correction plan.

Appendix 5: Responding to Abnormal Serum Potassium and Adjusting Potassium in Parenteral Nutrition

Serum Potassium	Changes to PN	Consideration for IV replacement	Consideration for Enteral supplementation
Greater than 6.5 mmol/L	Follow *Hyperkalemia Guideline*		
5-6.5 mmol/L	Reduce potassium in PN by 25-50%< may need more significant reductions in the setting of AKI or when nearing full feeds		
3.5-5 mmoL/L	Continue same as long as renal function is stable and not adding medications that can cause potassium losses		
2.5-3.2 mmol/L	Increase potassium in PN by 0.5-1 mEq/kg/day may need more if adding medications that increase losses, less in the setting of renal impairment.	Consider potassium chloride 0.5 mEq/kg x 1, if symptomatic or continuing to down trend. Consider smaller dose in the setting of renal impairment.	If nearing full feeds, consider potassium chloride 1 mEq/kg PO/NG/OG/GT BID. Consider smaller dose in the setting of renal impairment.
Less than 2.5 mmol/L	Increase potassium in PN by 1-2 mEq/kg/day following repletion, may need more if adding medications that increase losses, less in the setting of renal impairment.	Potassium chloride 0.5 - 1 mEq/kg IV x 1; consider lower doses in the setting of renal impairment.	

Appendix 6: Adjusting Chloride and Acetate in Parenteral Nutrition

Serum Acetate	Adjustment to PN	Additional considerations
Greater than 29 mmol/L	Shift to more chloride.	Consider diuretic dose.
22-29 mmol/L	No change to acetate needed. Consider shifting to chloride if starting diuretics.	
Less than 22 mmol/L	Shift to more acetate.	
Serum Chloride	**Adjustment to PN**	**Additional considerations**
Greater than 107 mmol/L	If acetate is low to normal, consider shift to more acetate.	Consider volume status.
98-107 mmol/L	No change needed.	
Less than 98 mmol/L	If acetate is also elevated or normal, consider shifting to more chloride. If both chloride and acetate are low, consider if additional cation can be optimized to increase chloride and acetate load.	Consider diuretic tolerance.

Appendix 7: Responding to Abnormal Serum/Ionized Calcium and Adjusting Calcium in Parenteral Nutrition

Lab value	Adjustment to Calcium in PN	IV repletion	Enteral Repletion
Ionized greater than 1.5 mmol/L Serum greater than 12 mg/dL	If phosphorus is normal to mildly elevated, increase the Ca:P ratio. *Examples* If receiving 3 mEq of calcium and 1 mmol of phosphate (1.5:1 molar ratio), change to 2 mEq of calcium and 1 mmol of phosphate (1:1 molar ratio). If receiving greater than 2 mEq of calcium and 1 mmol of phosphorus (1:1 molar ratio), change to 1.6 mEq of calcium and 1 mmol of phosphate (0.8:1 molar ratio)		
Ionized 1.35-1.5 mmol/L Serum 10-12 mg/dL	As above		
Ionized 1.2-1.35 mmol/L Serum 8.5-10 mg/dL	Continue current calcium in PN. Consider adjustment to Ca:P ratio, if there is concomitant HYPO/HYPERphosphatemia, initiation of diuretic therapy, or renal insufficiency.		
Ionized less than 1.1-1.2 mmol/L Serum less than 8-8.5 mg/dL	If serum **phosphorus is normal to mildly elevated**, increase Ca:P ratio. *Examples* If receiving 1.6 mEq of calcium and 1 mmol of phosphate (0.8:1 molar ratio), change to 2 mEq of calcium and 1 mmol phosphate (1:1 molar ratio).	If symptomatic, give calcium gluconate 100 mg/kg IV x 1	If persistent hypocalcemia, asymptomatic, and tolerating enteral feeds: Consider calcium carbonate 31.25-46.8 (12.5-15 elemental) mg/kg/dose q6h

	If receiving greater than 2 mEq of calcium and 1 mmol phosphate (1:1 molar ratio), change to 3 mEq of calcium and 1 mmol of phosphate (1.5:1 molar ratio) If serum **phosphorus is low**: Consider increasing PN volume if able. Optimize as solubility curve allows.		
*Ionized less than 1.1 mmol/L (or less than 1.0 if preterm < 1500 g) *Serum less than 8 mg/dL (or less than 7 if preterm < 1500 g)	As above	Give calcium gluconate 100 mg/kg IV x 1	

Appendix 8: Responding to Abnormal Serum Phosphorus and Adjusting Phosphorus in Parenteral Nutrition

Serum phosphorus	Adjustment to phosphorus in PN	IV phosphorus repletion	Enteral phosphorus repletion
Greater than 8 mg/dL	If non-hemolyzed, especially in the setting of renal dysfunction, consider holding phosphate.		
6.5-8 mg/dL	Continue current phosphate dose or consider reduction of phosphate in PN by 0.2-0.5 mmol/kg.		
4-6.5 mg/dL	Continue current phosphate in PN. Consider adjustment to Ca:P ratio in the setting of hypocalcemia or renal insufficiency.		
2.5-4 mg/dL	If **HYPERcalcemia**, shift Ca:P ratio. *Examples* If receiving greater than 2 mEq of calcium and 1 mmol phosphate, reduce to 2 mEq calcium and 1 mmol phosphate (1:1 molar ratio). If receiving 2 mEq calcium and 1 mmol phosphorus (1:1 molar ratio), reduce to 1.6 mEq calcium and 1 mmol phosphate (0.8:1 molar ratio). If **NORMOcalcemia**, increase phosphorus as solubility curve allows. If **HYPOcalcemia**, consider increasing PN volume if able or increasing phosphorus as solubility curve allows.	If symptomatic, give sodium phosphate 0.25-0.5 mmol/kg. If potassium is less than 3.5 mmol/L with normal renal function for age, can consider potassium phosphate 0.035 mmol/kg x 1 (provides 1 mEq/kg potassium).	If at or near full-volume feeds and unable to supplement IV, consider sodium phosphate 0.5 mmol/kg BID.

	If risk for **refeeding syndrome**, consider restriction of amino acids to max of 3 g/kg/day.		
1.5-2.5 mg/dL	See above	Give sodium phosphate 0.25-0.5 mmol/kg. If potassium is less than 3.5 mmol/L with normal renal function for age, can consider potassium phosphate 0.035 mmol/kg x 1 (provides 1 mEq/kg potassium).	If at or near full-volume feeds and unable to supplement IV, consider sodium phosphate 0.75 mmol/kg BID.
Less than 1.5 mg/dL	See above	Give sodium phosphate 0.5-1 mmol/kg. If potassium is less than 3.5 mmol/L with normal renal function for age, can consider potassium phosphate 0.35-0.7 mmol/kg (provides 0.5-1 mEq/kg of potassium).	If at or near full-volume feeds and unable to supplement IV, consider sodium phosphate 1 mmol/kg BID.

Appendix 9: Responding to Abnormal Serum Magnesium and Adjusting Magnesium in Parenteral Nutrition

Serum magnesium	Adjust magnesium in PN	IV repletion
Greater than 2.4 mg/dL	For neonates with *in utero* magnesium exposure, hold until less than 2.4 mg/dL then start 0.1-0.2 mEq/kg/day. For patients receiving magnesium in PN, reduce by 0.05-0.1 mEq/kg/day.	
2-2.4 mg/dL	Continue same	
1.6-2 mg/dL	Continue same *if targeting magnesium greater than 2 mg/dL, increase as below	Consider magnesium sulfate 25-50 mg/kg x 1 (provides approximately 0.2-0.4 mEq/kg) for patients with a higher goal serum magnesium (e.g., cardiac disease, seizures)
Less than 1.5 mg/dL	Increase magnesium by 0.1-0.2 mEq/kg/day. Consider smaller increases in patients with renal dysfunction.	Consider magnesium sulfate 25-50 mg/kg x 1 (provides approximately 0.2-0.4 mEq/kg)

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