Neonatal Nutrition

Growth Expectations, Parenteral & Enteral Nutrition Considerations

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Selected Criteria for Preterm Infants at Highest Nutrition Risk in the NICU setting

- < 1000 grams
- <30 weeks gestation
- IUGR / SGA
- Multiple gestation, (discordance between multiples)
- >15% weight loss from birth
- > 1-2 weeks with continued weight loss / poor weight gain
- Unable to advance enteral feedings, prolonged need for IV nutrition
- Conjugated Bilirubin > 2 mg/dL
- Chronic lung disease
- NEC
- Gastrointestinal issues
- Risk for or development of osteopenia

(unable to tolerate fortified human milk or premature formula, serum phosphorus < 4 mg/dL, serum alkaline phosphate > 600 U/L)

Classification Definitions

**Gestation**
- **Preterm**: <37 weeks gestation
- **Term**: 37-42 weeks gestation
- **Post term**: >42 weeks gestation

**Birth weight**
- **Low Birth Weight**: <2500 grams
- **Very Low Birth Weight**: <1500 grams
- **Extremely Low Birth Weight**: <1000 grams
- **Micro-preemies**: < 750 grams

**Small for gestation age**
- **Small**: Weight <10th%
- **Appropriate**: Weight > 10th% & ≤ 90th%
- **Large**: Weight > 90th%

Anthropometrics - Weight

- Weight
  - Reflects the total mass of body compartments, including lean tissue, fat, and extra/intracellular fluid.
  - Initial weight loss of ≤10% in term infant and ≤15% in the preterm infant is expected
  - Weight loss is attributed to contraction of body water compartments and catabolism of endogenous stores (glycogen, lipid, lean tissue) before energy and nutrient needs are met
  - Initial weight loss reaches its nadir by ~4-6 DOL
  - Birth weight should be regained by 2-3 weeks of life

Age Related Changes in Body Composition

Anthropometrics - Weight

- Weight gain is based on normal intrauterine growth averages.
- Weight needs to be assessed daily.
  - Preterm
    - Infant <2000 grams: 15-20 grams/kg/day
    - Infant >2000 grams: 25-35 grams per day
  - Term Infants
    - First 3 months of life: 20-30 grams per day
- Averaging weight gain over past 7 days
  - [Monday’s weight – last Monday’s weight / 7 / today’s wt in kg]
- Thinking Point → Weight gain is not always an accurate measure of growth 2° changes in fluid status.

Anthropometrics - Weight

- Use birth weight for first 7 days of life for ALL calculations
- Use current or daily weight after DOL 7
- If there is a big fluctuation in birth weight vs. current weight, an analysis weight may need to be used
- Monitor for unusual weights 2° fluid, scales, or equipment
Anthropometrics - Length

- Length measurements more accurately reflect lean body mass and is not influenced by fluid status.
- Length is more difficult to accurately measure.

**Preterm**
- Based on normal intrauterine growth.
- Incremental gain in crown-heel length 0.8-1.1 cm/week.

**Term**
- First 3 months of life, infants grow 0.69-0.75 cm/week.

Head growth correlates well with brain growth during fetal development, infancy, and childhood and with later developmental achievement in preterm infants.

**Pre-term**
- Recommended growth: 0.5-1.0 cm/week

**Term**
- First 3 months of life: 0.5 cm/week

Growth Charts

- 2 types available
  - Intrauterine growth data
  - Postnatal growth data

- Located in Serner, Neodata, & Paper Chart

- Ideal growth chart to use in NICU = Fenton
  as it is based on fetal growth data

- Thinking Point → Which is more concerning:
  Symmetric or Asymmetric SGA?

Reporting Infant’s Growth During Rounds

- Sunday evening all growth parameters are obtained
- Report growth parameters on Monday morning rounds
  - Weight, rate of gain over past 7 days
    - < 2 kg = report weight gain/per kg over the past 7 days
    - If infant is not back to birth weight, express weight loss as a % of birth weight
  - Use Fenton Growth Charts to document growth percentiles
  - Length, rate of growth and percentile
  - HC, rate of growth and percentile
Indications for TPN

- Functional immaturity of GI tract
- Necrotizing Enterocolitis
- Congenital GI anomalies
  - Gastroschisis, omphalocele, bowel obstruction, bowel atresia
- Malabsorption syndromes
  - SBS, CF, meconium ileus
- Impaired GI motility
  - Prematurity, ileus from surgery/sepsis, Hirschsprung’s disease
- Impaired GI perfusion that decreases GI motility
  - Congenital heart disease, PDA, hypotension
- Inadequate enteral nutrient intake

The Role of TPN in the NICU

Initially, the role of TPN is to provide sufficient calories and AA to prevent negative energy and nitrogen balance

- Minimum intake of 60 non-protein kcal/kg/day and 2.5 g AA/kg/day

The rate of catabolism is higher in smaller infants and the need for positive nitrogen balance is more pronounced

Secondary, the role of TPN is to provide enough energy to support adequate growth and weight gain

- Provide 70-80 non-protein kcal/kg/day and 3.5-4g/kg/day of protein
IV Access

- **Peripheral** (osmolarity <1000 mOsm/L)
  - Maximum Dextrose 11%
    - >11% associated with ↑ incidence of phlebitis and skin sloughing secondary to osmolarity
  - Midline

- **Central**
  - Maximum Dextrose 25% - *try not to go >D15*
  - UVC

- **PICC / PCVC**
  - Maximum Dextrose 25% - *try not to go >D15*
Initial Fluid Status

**General Guidelines**
- **<750 grams**: 80-100 mL/kg/day
- **>751 grams**: 80 mL/kg/day
- **Term Infants**: 60 mL/kg/day

Postnatal fluid restriction during the first 1-3 days is associated with reduced incidence of CLD.

Increase fluids by 10-20 mL/kg daily until you reach ~130 mL/kg/d for PN.

EN fluid goal is ~150ml/kg/d

Factors that increase IWL

- Increased Activity
- RDS
- Low Relative Humidity
- High Ambient Temperature
- Fever
- ELBW
- Metabolic Acidosis (↑respiratory loss)
- Cardiac Disease (↑respiratory loss)
- Skin Breakdown, Injury, or Congenital Defects
- Phototherapy
- Radiant Warmers

Factors that decrease IWL

- Humidified Incubator
- Humidified Inspired Gas
- Double Wall Incubator
- Topical Agents

Miscellaneous Fluid Losses

- Chest Tube Drainage
- Gastric Suction
- Vomiting
- Third Spacing Loss
- Diarrhea
- Phototherapy (↑stool water losses)
- Glycosuria (↑urinary water losses)
- High Renal Solute Load (↑urine fluid loss)
- Infants with abdominal wall defects

Indications for Fluid Restriction

- Renal Failure
- CHF, significant PDA
- Meningitis
- Postoperative status - inappropriate antidiuretic hormone secretion with decreased urine output

Components of TPN

- Macronutrients
  - Dextrose
  - Amino Acids
  - Lipids

- Micronutrients
  - Electrolytes
  - Vitamins & Minerals
  - Trace Elements
Dextrose

GIR - Glucose Infusion Rate - mg/kg/min

\[ \text{[mL/kg/d} \times \frac{\text{dextrose}\%}{100} \times 0.7] \]

- Preterm start at 4-6 mg/kg/min
- Try not to run GIR < 4 mg/kg/min for more than 1-2 days - brain needs at least a GIR of 4
- Advance by 1 mg/kg/min if glucose is stable
- Maximize GIR at:
  - < 10 if infant is < 1000 grams
  - 10-12 mg/kg/min if infant is > 1000 grams

Glucose > 150 = consider ↓ GIR

Glucose > 200 results in osmotic diuresis and E-disturbances

Functions of Glucose

- Glucose functions as an energy source for all cells, and is essential for:
  - CNS
  - Erythrocytes
  - Retinal tissue and renal medulla
- Brain uses 90% of total glucose consumption
- Endogenous glucose production may provide only 1/3 of the total glucose needed by preterm infants

## Causes of Hypoglycemia
- SGA
- LGA
- Indomethacin therapy
- Rapid discontinuation of IV dextrose
- Extreme Prematurity
  - Gluconeogenesis
  - Glucogenesis
  - Glycogenolysis
- IDM
- Inadequate exogenous dextrose delivery

## Causes of Hyperglycemia
- Sepsis
- Extreme prematurity
  - Glycogenesis
  - Glycolysis
- Surgery / stress
- Malnutrition
- Renal disease
- Excessive dextrose infusion
- Glucocorticoid therapy
- Thiazide diuretic therapy
- Excessive exogenous dextrose delivery

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**Protein**

- **Written as** *gm/kg/day*
  - Preterm start at 3.0 *gm/kg/day*
  - Advance by 0.5-1.0 *gm/kg/day*
  - Maximum of 4.0 *gm/kg/day*

- Protein is essential for:
  - Cell Maturation
  - Remodeling
  - Growth
  - Functional activity of enzymes and transport proteins

- The average well LBW infant receiving no exogenous protein source loses 1% of endogenous protein stores daily.

Intravenous Lipids

- Written in \textit{gm/kg/day}
  - Preterm start at 1.5 \textit{gm/kg/day}
  - Advance by 0.5-1.0 \textit{gm/kg/day}
  - \textbf{Maximum} Lipid 3.0 \textit{gm/kg/day}

- Concentrated energy source
- Essential for normal growth and development, including retinal development and function, brain development, and cell structures and function
- Essential to prevent fatty acid deficiency
  - Can develop w/in 72 hours of birth

Non-Protein Calorie : Nitrogen Ratio

- **NPC:N Ratio** = Non-protein calories / nitrogen from PRO
  - Non-Protein Calories:
    - calories from CHO (GIR x 4.9) + calories from Fat (gm/kg Fat x 10)
  - Nitrogen:
    - grams/kg of protein / 6.25

- **Ratio** indicates if you are providing enough calories from non-protein substrates so that the baby does not use the protein for energy - rather endogenous deposition of lean body mass

- **Ratios**
  - Optimal > 130
  - Low < 130 Give more dextrose or lipid
  - High > 200 Give more protein and less dextrose

Composition of TPN

Calculating TPN Calories

- CHO (50-55%)
  - Gm/kg CHO X 3.4 or GIR X 4.9
- Protein (10-20%)
  - Gm/kg/d of PRO X 4
- Fat (30-50%)
  - Gm/kg/d of FAT X 10

Combine to get total calories from TPN per kg

Lower energy requirements for PN than EN b/c there are no requirements for digestion of fecal losses due to incomplete absorption (80-100 kcal/kg)

Electrolytes and Minerals

- Do not need to add on DOL 1-2
- Labs reflect maternal values for the first 12-24 hours of life
- Do not want to make drastic changes to electrolytes
  - want to correct gradually without over correction
  - allow for natural diuresis
Sodium

- Normal value 136-143 mEq/L
- Start at 2 mEq/kg/day
- Goal is 2-5 mEq/kg/day based on infant needs
- Look at fluid status before correcting sodium levels
- Add once the diuresis phase begins

Sodium Continued

Some clinical conditions affecting exogenous sodium requirements

- Extreme prematurity = limited renal tubular sodium re-absorption
  - Infants with ↑ fractional excretion require more exogenous Na+
- Abdominal wall defects = sodium wasting
- SBS
- Premature skin

Potassium

- Normal value 4.1-5.6 mEq/L
- Start at 1 mEq/kg/day
- Goal is 2-3 mEq/kg/day based on infant needs
- If the level is high, find out if it was a heel stick and if the lab is reporting hemolysis
- Add once the diuresis phase begins

Potassium Continued

- Non-oliguric hyperkalemia is common
  - Extreme prematurity
  - Bruising
  - Catabolism
  - Metabolic acidosis
  - Potassium intake

E- Carriers

- Na
- K

1) Acetate
2) Phosphorus
3) Chloride
Acetate

- Normal values
  - Bicarb 20-24 (on renal)
  - pCO2 35-45 (on blood gas)
  - Base excess –2 to +2 (on blood gas)

- Start at 1mEq/kg/day
- Adjust based on infant needs
- May need to sacrifice phosphorus to provide acetate

Chloride

- Normal value 97-104 mEq/L
- Necessary to correct other electrolyte imbalances
- “left-over”; Na and K added to TPN with acetate and phosphate first, then with chloride

Magnesium

- Normal value 1.5-2.3 mEq/L
- Dosage:
  - Preterm 0.3 mEq/kg/day
  - Term 0.5 mEq/kg/day
- Do NOT add Mg until DOL 4
- If mom was treated with Mg, check infant Mg level on DOL 4 to assess level before adding to TPN

### Calcium and Phosphate

#### Calcium
- **Normal**
  - <1 week: 6-10 mg/dL
  - 3-7 wks: 8-11 mg/dL
  - 3mo-1yr: 9-12 mg/dL
- **Start at 2 mEq/kg/day**
- **Advance to 2.5-3.0 mEq/kg/day**
- **Maintain a 1.3-1.7:1 ratio with phosphorus**
- **Can start on day 1 w/o PO4**

#### Phosphorus
- **Normal**
  - <1 wk: 6.1-11.7 mg/dL
  - 3-7 wk: 5.3-8.3 mg/dL
  - 1 mo: 5.0-9.5 mg/dL
- **Start at 1.3 mmol/kg/day**
- **Advance to 1.5-2 mmol/kg/day**
- **Maintain a 2:1 Calcium:Phos ratio for solubility**

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Clinical Case Study

- Neonate receiving sub-optimal TPN
- Laboratory Studies Reveal:
  - ↓ P04
  - ↑ AlkPhos
  - ↑ Ca

What do you do?
Inversing Ca:PO4 Ratio

- Neonate receiving sub-optimal TPN with ↓ P04, and ↑ Ca

Rational:
- Hormonal Control of Calcium
  - 1) PTH
  - 2) Calcitriol \([1,25(OH)_{2}D_{3}]\)
  - 3) Calcitonin

TPN Prescription:
- Inverse Ca:PO4 Ratio for 48-72 hours

Trace Elements

- **Standard Trace Minerals**
  - Chromium 0.26mcg/kg
  - Copper 26mcg/kg
  - Manganese 7.8mcg/kg
  - Selenium 3.1mcg/kg
  - Zinc 400 mcg/kg

- **Hepatic Trace Minerals**

- **Renal Trace Minerals**


Cholestasis

**Hepatic Trace Minerals (direct bili >2.0mg/dL)**
- Copper is excreted through the liver and infants with limited Cu excretion secondary to cholestasis or other conditions that reduce bile excretion should not receive full dosing
- D/C supplemental Manganese
- Chromium 0.2mcg/kg, Copper 10 mcg/kg, Selenium 2mcg/kg, Zinc 400 mcg/kg

**Consider reducing lipids to 1-2 gm/kg**

**Reinshagen et al 2008 >1 gm of lipid during bouts of cholestasis ↑oxidant load and tissue damage.**


Enterohepatic Circulation of Bile

Hunt & Groff, 1990

[Diagram of the enterohepatic circulation of bile with labels for various parts of the digestive system including the gall bladder, liver, hepatic portal vein, duodenum, jejunum, ileum, and lymphatic system.]
How does the PN cause liver damage?

Enteral lipids

- Enteral lipids are absorbed by the enterocytes in the form of a micelle and packed into chylomicrons.
- The chylomicrons acquire apolipoproteins from the circulating HDL and then are metabolized by the liver.

Parenteral lipids

- The Intravenous lipid (IL) emulsions such as Intra-Lipids mimic the size and structure of chylomicrons but contain only W6 FA and TGs.
- devoid of cholesterol and protein.
- IL depend on apolipoprotein E, lipoprotein lipase and LDL-receptors for clearance.
- IL may be cleared as whole particles not by the liver but by other tissues thereby causing TPN induced steatosis.

Renal Insufficiency

Renal Trace Minerals (urine output is <1.0mL/kg/hr for >2 days and/or with elevated creatinine)
- Selenium and Chromium is excreted through the kidney and supplementation should be decreased or D/C if renal function is impaired
- Chromium 0.1mcg/kg, Copper 20mcg/kg, Manganese 1mcg/kg, Selenium 1mcg/kg, Zinc 400 mcg/kg

Carnitine

- Added to enhance β-oxidation by transporting LCFA groups and acetyl-CoA across the mitochondrial membrane
- Clinical intolerance is 2°:
  - Lack of endogenous carnitine along with altered synthesis and storage
  - Lower levels of lipoprotein lipase
- Can be synthesized from lysine and methionine in the liver and kidney in term infants
- Prophylactically add 20 mg/kg when infants are <2000 grams birth weight
- Add 30-40mg/kg when TG are >200


Preterm infants lack the ability to synthesize cysteine from methionine. Can create a small metabolic acidosis in very small infants - give acetate to buffer ↑ Ca/PO4 solubility Helps to ↓ incidence of PNALD Always add 40 mg/gm protein

Heparin & Multivitamin

**Heparin**
- If a PCVC has been ordered, add to TPN – watch osmolarity
- Automatically calculated by computerized TPN program
- 1 unit / mL

**Multivitamin**
- Automatically dosed by computerized TPN program based on infant’s weight
- MVI includes:
  - Vitamin A, B1, B2, B12, C, D, E, K, biotin, dextanhemol, folic acid, niacinamine
TPN Considerations with Clinical Conditions - SBS

- Protocol posted in office
- TPN @ 130 ml/kg/d
  - GIR 12-14
  - PRO 4 g/kg/d
  - Lipid 0.5-2 g/kg/d
  - Hepatic Trace Elements When Direct Bili is >2
  - Zantac 2mg/kg/d (debatable)
  - Monitor serum sodium closely 2° ↑exogenous requirements

Wound Healing

**Nutrient/Vitamin For Wound Healing**

- Zinc: up to 1000mg per day
- Vitamin C: 150 mg per day
- Protein: 4-4.5 g/kg/d
- Arginine, Glutamine

TPN Monitoring

Check with Neonatologist....generally:

- RFP after birth
- If 50% of TFV is from TPN
  - Q Monday & Thursday (unless something abnormal)
    - RFP
    - TGs (if abnormal)
  - Q 2 weeks
    - LFTs
- If an infant is on full Enteral Feeds
  - Neonatologist will decide
    - RFP (only if following something abnormal)
    - LFT (only if following ALk phos/direct bili)
    - Hct/Hgb weekly
TFV = PN + EN

- When to incorporate enteral feeds in total fluid volume
- Typically EN volume is included in TFV when feeding advancement is written
- Discontinuing TPN
  - If an infant has access issues, determine the cost:benefit ratio of the line placement
  - Generally discontinue TPN when EN reaches 100-120mL/kg/d
Restarting TPN (i.e. NPO) after Being on EN

What do you do with your TPN when an infant is made NPO after being on EN?

- Generally… prescribe maximized amounts of macro- & micronutrients

- GIR = 8-10
- PRO = 4
- Lipid = 3
- Na = 3
- K = 2
- Ca/PO4 = 2:1
Promote BM for all infants unless contraindicated

Infants born <1500 grams can receive donor milk; must sign consent form

Infants start on 20 kcal per ounce of breastmilk.

Generally feeds are started Q3 hours NG for preemies not able to po

Refer to feeding protocol for volume and advancement
Enteral Nutrition Information

- Fortify feeds of breast milk once infant is taking 100-120 ml/kg/d
  - Fortify breast milk with HMF (in-patient) to 22 kcal/oz - if tolerated after 24-48 hours increase to 24 kcal/oz using HMF if warranted
    - 22 kcal/oz = 1 pkt HMF + 50 mL of breast milk
    - 24 kcal/oz = 1 pkt HMF + 25 mL of breast milk

- D/c Recipe / All po feeds / >34 weeks
  - 22 kcal/oz =
    - ½ teaspoon of Enfacare/Neosure powder + 90 mL of BM
  - 24 kcal/oz =
    - 1 teaspoon of Enfacare/Neosure powder + 90 mL of BM
How Much…How Long…How Often

- Universal recommendations to be made to mothers by staff during lactogenesis
- Pump dependent mothers should be at 500ml by end of week one. There are 2 weeks of hormonal assistance to establish a mother’s milk supply, so we need to recognize there is a problem prior to this time.
  - Volumes (HOW MUCH)
    Day 4 350 mL Q Day
    Day 7 500 mL Q Day
  - Time (HOW LONG)
    10-15 minutes per side
    2 min past last drop or 10-15 minutes per side on day 3
  - Frequency (HOW OFTEN)
    Every 2-3 hours
Formula Choices

Infants <2000 g birth weight
- Enfamil Premature 24
- Special Care 24, 30

Infants >2000g and <36 weeks
- Enfacare 22 or Neosure 22

Term infants >36 weeks
- Enfamil or Similac
MVI and Vitamin D

AAP Recommendation

- Breast fed infant  400IU Q day
- Formula fed infant taking <1L formula Q day  400IU Q day

Start MVI with iron once infant achieves full feeds

- <2kg  0.5 mL Q day
- >2 kg  1 mL Q day