1

Objectives

- Review the components of neonatal nutrition assessment
- Discuss nutrition needs in preterm and term neonates
- Explore nutrition interventions for neonates including:
  - Parenteral Nutrition
  - Enteral Nutrition
  - Oral feeding and breastfeeding
  - Vitamin and Mineral Supplements
- Identify nutritional related complications of prematurity and discuss management
- BONUS: example feeding and fluid calculation

2

"The goal of nutritional management in VLBW infants is the achievement of growth at a rate that approximates the intrauterine growth of a normal fetus at the same post conceptual age"

AAP Committee on Nutrition

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Impact of Prematurity on Nutrition Status

Cardiovascular
- Altered circulatory pathways (PDA)
- Impaired organ perfusion
- Hemodynamic instability

Respiratory
- Immature lung development
- Apnea of prematurity

Skin
- Extremely fragile
- Large body surface area

Neurologic
- Inability to coordinate suck, swallow, breathe

Musculoskeletal
- Minimal subcutaneous and brown fat
- Higher total body water
- Limited bone mineralization

Gastrointestinal
- Immature motility patterns
- Decreased enzyme production
- Altered microbiome

Renal
- Immature function
- High losses of water, sodium, bicarbonate
- Decreased excretion of nitrogenous waste and potassium

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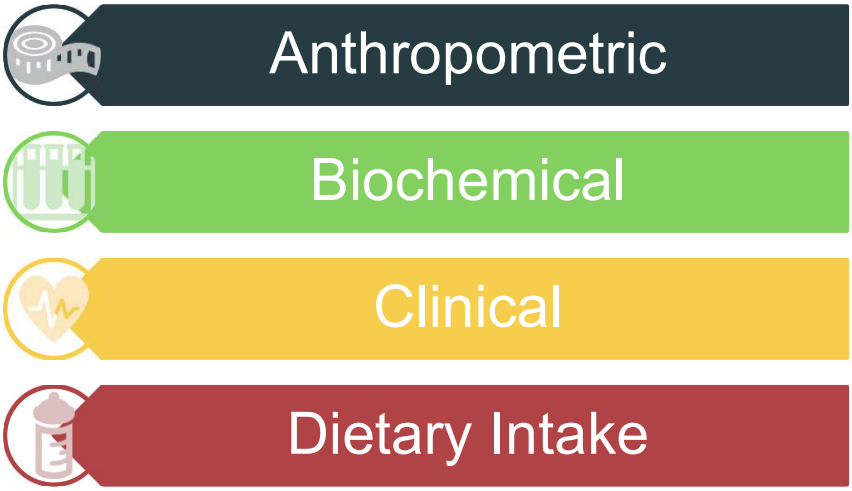
Neonatal Nutrition Assessment



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Classification of Preterm Infants

Gestational Age (GA)	Birth weight (BW)	Size for Age

• **Term**
37 to 42 weeks GA
• **Preterm**
< 37 weeks GA
• **Late Preterm (LPT)**
≥ 34 to < 37 weeks GA
• **Extremely Preterm (EPT)**
< 28 weeks GA
  • Micro preemie: <26 weeks
  • Nano preemie: <23 weeks
	• **Normal BW**
	2500-4500 g (5 lb, 8 oz - 8 lb, 8 oz)
	• **Low birth weight (LBW)**
	< 2500 g (5 lb, 8 oz)
	• **Very low birth weight (VLBW)**
	< 1500 g (3 lb, 5 oz)
	• **Extremely low birth weight (ELBW)**
	< 1000 g (2 lb, 3 oz)
		• **Small for GA (SGA)**
		< 10th %ile BW for GA
		• **Appropriate for GA (AGA)**
		10th to 90th %ile BW for GA
		• **Large for GA (LGA)**
		> 90th %ile BW for GA
		• **Intrauterine growth restriction (IUGR) or fetal growth restriction (FGR)**
		< 10th %ile estimated fetal weight
		• **Extrauterine growth restriction (EUGR)**
		< 10th %ile weight for corrected GA at discharge

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Key Anthropometric Measures

- Weight (daily)
- Length (weekly)
- Head Circumference (weekly)
- Other Measures
  - BMI or Weight for length
  - MUAC (limited reference standard)
  - Body Composition measures (in research)
    - Air Displacement Plethysmography (PEA POD)
    - Bioelectrical Impedance
    - DEXA

Images from: Pepin H et al, *Nutr Clin Pract*, 2025

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Weight Assessment

- Weight loss after birth is expected
  - 5-14% weight loss after birth
  - Nadir DOL#5
  - Regain by 2 weeks, ideally sooner
- Calculation of growth velocity (g/kg/d)
  - g/kg/d = weight change in g / average weight in kg / # days
  - 15-20 g/kg/d associated with improved outcomes for preterm infants
- Comparison to growth charts
  - Intrauterine Growth Curves: Fenton 2025 (preterm), Olsen 2010 (preterm)
  - Postnatal Growth Curves: WHO 2006 (term), INTERGROWTH 21st 2015 (preterm)

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Calculation of Growth Velocity

Weight gain (g/kg/d) = weight change in g / average weight in kg / # days

EXAMPLE: 11/12/25 Weight: 800 g 11/5/25 Weight: 700 g

- Weight Change = 800 g -700 g = + 100 g
- Average Weight in kg = (0.8 kg + 0.7 kg)/2 = 0.75 kg
- # Days 11/12-11/5 = 7 days
- Weight gain (g/kg/d) = 100 g / 0.75 kg / 7 d = 19 g/kg/d

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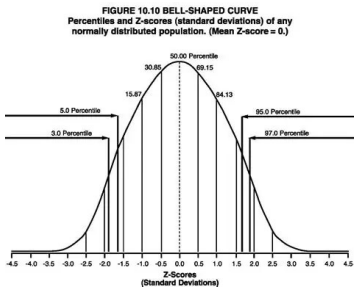
2025 Fenton Growth Charts

Percentile

Comparison to the reference population

Z-score

Standard deviations above or below the reference population mean



Fenton TR, et al. *Paediatr Perinat Epidemiol.* 2025

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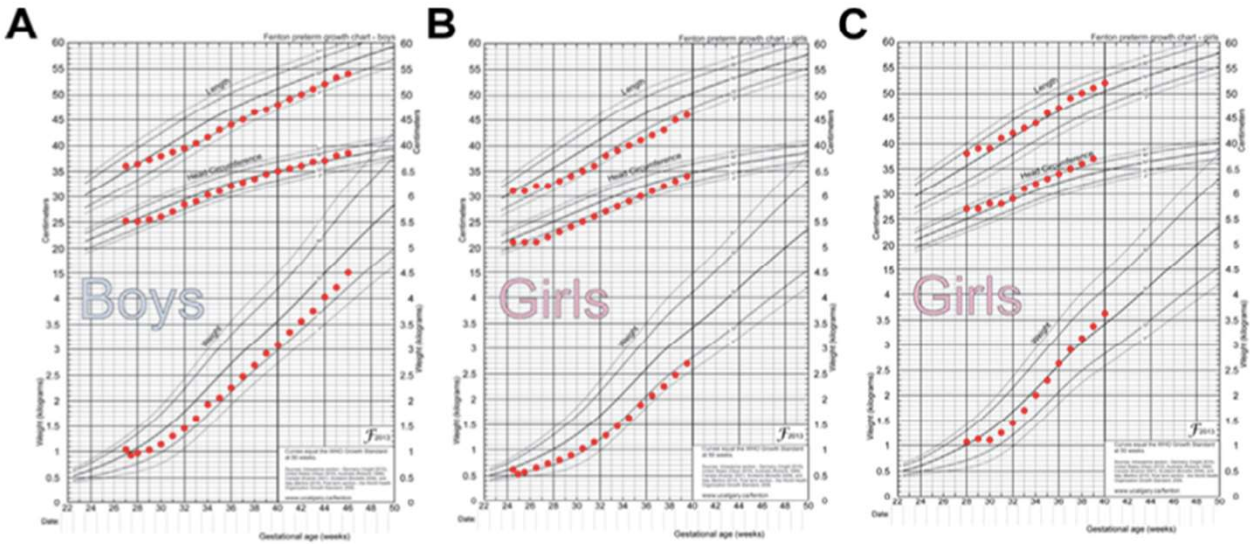
Normal Growth Patterns in Preterm Infants



Fenton T, et al. *Clin Perinatol*, 2022.

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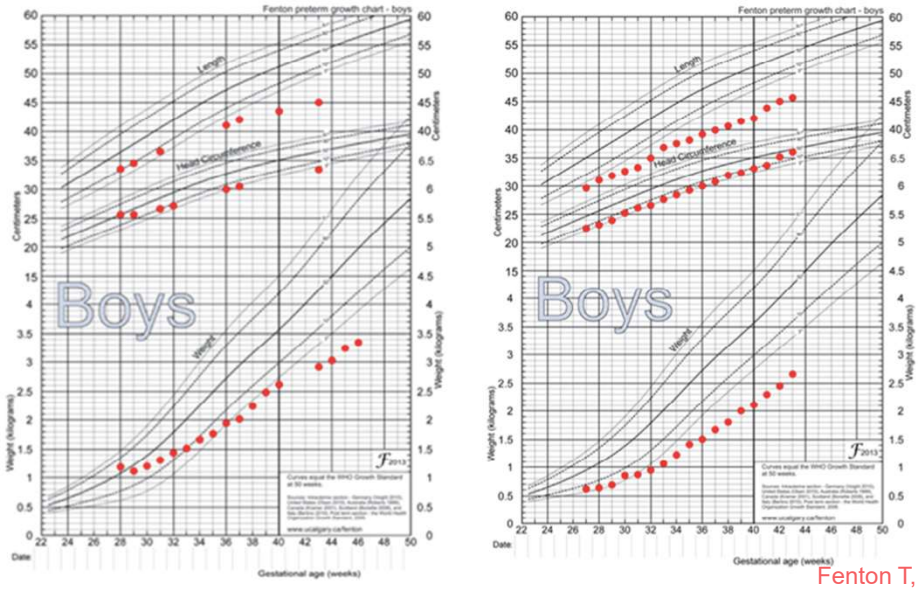
Abnormal Growth Patterns In Preterm Infants



Fenton T, et al. *Clin Perinatol*, 2022.

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Factors Impacting Preterm Infant Growth

Table 1
Contributors to altered infant growth

Prenatal	Social determinants
	Maternal health (medical conditions, such as lupus, anemia, clotting problems, hypertension, diabetes, medications, smoking, alcohol, drugs)
	Infant genetic potential/inherited size
	Genetic disorders
	Multiple pregnancy
	TORCH infection (toxoplasmosis, rubella, cytomegalovirus, human immunodeficiency virus, syphilis)
	Maternal weight/weight gain
Neonatal/ postnatal	Social determinants of health
	Infant genetic potential/inherited size
	Morbidities: brain injury (which includes intraventricular hemorrhage and periventricular leukomalacia), patent ductus arteriosus, bronchopulmonary dysplasia, necrotizing enterocolitis, sepsis
	Neonatal stress
	Nutrition (inadequate nutrient intake, limited oral feeding ability)

From: Fenton T, et al. *Clin Perinatol*, 2022.

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Biochemical Assessment

- Considerations:
  - Blood volume of neonate vs. blood volume of tests
  - Method of lab draw (venous vs. heel stick)
  - Age specific reference ranges
  - Cost and turn around time

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Suggested Laboratory Monitoring for Neonates

Patients on parenteral nutrition

- Check BMP, Mg, Phos and TG daily until stable on goal solutions, then 1-2x/week

Patients on prolonged (> 2 weeks) parenteral nutrition

- Direct bilirubin every 2 weeks or more frequently if abnormal
- Liver function tests if DBili rising
- Trace elements (ferritin, ceruloplasmin, manganese, selenium, zinc) after 4-8 weeks of exclusive PN
- Essential fatty acid panel if concern for essential fatty acid deficiency (Omegaven)

Preterm patients on enteral nutrition

- Na, Cl, Ca, Phos and Alk Phos every 2 weeks until > 34 weeks GA and stable
- May check Vitamin D or Zinc if concern for deficiency

Tip: You can easily order PN or EN labs using the "NICU Nutrition Labs Panel" in Epic

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Clinical Assessment

- Nutrition Focused Physical Findings
- Vital Signs
- Urine & Stool Output
- Feeding Tolerance

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Infant Skin Assessment

OBSERVATION	POSSIBLE CLINICAL SIGNIFICANCE
COLOR	
Pallor (washed out, whitish)	Anemia (iron or vitamin deficiency or both), birth asphyxia, shock, patent ductus arteriosus
Plethora (deep, rosy red)	Polycythemia, over oxygenation, overheated
Jaundice	Yellowish: indirect hyperbilirubinemia Greenish: direct hyperbilirubinemia
Central Cyanosis (bluish skin, tongue, lips)	Low oxygen saturations (may be due to lung disease or congenital heart disease), Concern for gut perfusion
Acrocyanosis (bluish hand and feet only)	Cold stress, hypovolemia
Mottling (lacy red pattern)	Cold stress, hypovolemia, sepsis Can be normal variant
Petechiae (small hemorrhagic papillae)	Vitamin C or K deficiency, thrombocytopenia, birth trauma

Adapted from: AND Pocket Guide to Neonatal Nutrition, 3rd ed.

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Infant Skin Assessment

OBSERVATION	POSSIBLE CLINICAL SIGNIFICANCE
FLUID STATUS	
Periorbital or generalized edema, bulging fontanel	Overhydration, protein deficiency
Dry mucous membranes, sunken fontanel, poor skin turgor, lack of tears	Dehydration
INTEGRITY	
Dermatitis	Essential fatty acid, B vitamin or Zinc deficiency
Flaky paint dermatitis	Protein deficiency
Poor wound healing	Zinc, Vitamin C, calorie or protein deficiency
TEXTURE	
Scaly, dry	Essential fatty acid, Vitamin A or zinc deficiency
Excessive initial peeling	Post term: normal variant

Adapted from: AND Pocket Guide to Neonatal Nutrition, 3rd ed.

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Vital Signs

Temperature	Respiratory Rate (RR)	Heart Rate (HR)
• Normal Range: 36.5-37.5 °C • Hypo/Hyperthermia may increase metabolic rate, impact weight gain	• Normal Range: 30-60 breaths/min • Tachypnea (RR > 60 breaths/min) contraindication to oral feeding, may increase metabolic rate • Apnea (pause in breathing > 20 second) common in preterm infants, must resolve prior to d/c	• Normal Range: 100-180 beats/min • Tachycardia (> 180 beats/min) increases metabolic rate • Bradycardia (< 100 beats/min), often associated w/ apnea, if frequent/severe feed w/ caution

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Urine & Stool Output

- Urine
  - Normal Range: 1-3 ml/kg/hr, during diuresis: 5-7 ml/kg/hr
  - Oliguria:< 1 ml/kg/hr
  - Anuria: no urine output
- Stool
  - Frequency: variable (with every diaper change to every 3 days)
  - Meconium: first stool, dark, tarry, sticky, usually within 24-48 hours of birth, later in preterm infants
  - Breastfed: yellow, seedy, soft
  - Formula Fed: thicker, brownish
  - Black-, Red- or clay-colored stools stools should prompt further investigation

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Feeding Tolerance

- Reflux and spit up common in preterm infants
- Routine measurement of gastric residuals is NOT recommended
- RED FLAGS
  - Bilious emesis
  - Increase in ABDs w/ feeds, temperature instability
  - Changes in abdominal exam
    - Significant increase in girth
    - Visible loops of bowel
    - Discoloration of skin on or around abdomen
    - Hypoactive bowel sounds
    - Guarding with palpation

http://web.squ.edu.om/med-Lib/med/net/E-TALC9/html/clients/who/hcfc_images/necrotising%20enterocolitis%201.jpg

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Dietary Intake Assessment

- Diet "History"
  - Family's feeding plans
  - H/o allergies/intolerances in other children
  - Religious/cultural dietary preferences
- Review of current intake
  - IV fluids
  - Parenteral nutrition
  - Enteral intake (human milk/formula, fortifiers or modulars)
  - Vitamin/mineral supplements
- Comparison of intake to estimated nutritional needs

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Estimated Nutritional Needs

	Parenteral		Enteral	
	Preterm	Term	Preterm	Term
Energy (kcal/kg)	90-120	85-110	110-140	105-120
Protein (g/kg)	3-3.5	2-3	3.5-4.5	1.5
Carbohydrate	14-17 g/kg	12-14 g/kg	11-13 g/kg	60 g/d
Fat	3 g/kg	2.5-3 g/kg	4.6-8.1 g/kg	31 g/d
Calcium	1.6-2 mmol/kg	0.8-1.5 mmol/kg	120-220 mg/kg	200 mg/d
Phosphorus	1.6-2 mmol/kg	0.7-1.3 mmol/kg	70-120 mg/kg	100 mg/d
Vitamin D (IU/d)	400-1000	400	400-1000	400
Iron	200-250 mcg/kg/d*	50-100 mcg/kg/d*	2-3 mg/kg/d	0.27 mg/d

*Routine addition of iron to parental nutrition not recommended

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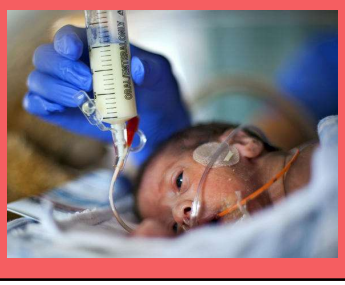
Nutrition Interventions in Preterm Infants

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Parenteral Nutrition

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Neonatal Parenteral Nutrition

- Indications
  - Prematurity (< 32 weeks or < 1500 grams)
  - Congenital GI anomalies
  - Impaired GI perfusion
  - Compromised GI tract function
  - Malabsorption

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Neonatal PN Access

	Peripheral	Central
Duration	Short term (ideally < 3 days)	Long term
Osmolarity	< 1000-1250 mOsm/L	n/a
Dextrose	< 12.5%	< 25-30%
Electrolytes	Limits to K and Ca concentrations	Dependent on solubility
Heparin	n/a	Recommended (0.5-1 unit/ml)
Types	Peripheral IV	Umbilical Venous Catheter (UVC) Peripherally Inserted Central Catheter (PICC) Central Venous Catheter (CVC)

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Premix PN for Preterm Infants

- Often called “starter” or “vanilla” PN
- Initiated as soon as access is established
- Intended to maintain blood glucose and prevent catabolism until custom PN can be ordered
- Intended for short term use
- May need to piggyback additional IV fluid to bring total fluids to goal

UMass Starter PN Solution

Contents	At 60 ml/kg/d provides:
10% dextrose	GIR: 4.2 mg/kg/min
5% amino acid	3 g/kg protein
Heparin (1 unit/ml)	

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Fluid Needs

Baseline Fluid Needs:
- <1 kg: 80-120 ml/kg/d
- 1-1.5 kg: 70-90 ml/kg/d
- > 1.5 kg: 60-80 ml/kg/d

Gradual fluid liberalization
- Advance by 20 ml/kg/d

Goal volume to support hydration and growth
- 140-160 ml/kg/d

- Clinical Monitoring:
  - Overhydration: early weight gain, edema, hyponatremia
  - Underhydration: excessive postnatal weight loss, hypernatremia, elevated BUN, sunken fontanel

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Talking About Fluids in the NICU

- **Total Fluids** – Fluid from IV drips, PN, Lipids, and enteral feedings. Reported in ml/kg/d.
- Calculated using birth weight until the infant has surpassed birth weight, then use daily weight (or dry weight if edema present)

- **EXAMPLE:** Calculate the total fluids for a 25 0/7 wk, 800 gram baby getting the following:
  - PN: 2 ml/hr x 24 hrs — 48 ml/d ÷ 0.8 kg = 60 ml/kg/d
  - SMOF (1 g/kg): 0.17 ml/hr x 24 hrs — 4 ml/d ÷ 0.8 kg = 5 ml/kg/d
  - 0.45% NaAce: 0.5 ml/hr x 24 hrs — 12 ml/d ÷ 0.8 kg = 15 ml/kg/d
  - MBM: 2 ml q 3 hrs — 16 ml/d ÷ 0.8 kg = 20 ml/kg/d

  TOTAL FLUIDS = 100 ml/kg/d

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Components of a PN solution

- Parenteral Nutrition (PN)
  - Dextrose and Amino Acid
  - Electrolytes
  - Vitamins and Minerals
  - Trace Elements
  - Other additives: Heparin, cysteine
- Lipids (SMOF)
  - 4 oil blend (Soy, MCT, Olive, Fish)
  - Provided as a separate infusion over 24 hours
  - Each gram of fat = 5 ml of SMOF

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Initiation and Advancement of Neonatal TPN

Nutrient	Initiate	Goal/Maintenance	Additional Notes
Dextrose	4-6 mg/kg/min	10-12 mg/kg/min	Advance by 1-2 mg/kg/min daily if blood glucose 80-120 mg/dL
Protein	3 g/kg/d	Preterm Infants: 3-3.5 g/kg/d Term Infants: 2.5-3 g/kg/d	Advance cautiously in infants with IUGR/refeeding syndrome
Fat (SMOF)	Start with custom PN Infants < 1 kg or SGA: 1 g/kg/d Infants > 1 kg and AGA: 2 g/kg/d	3 g/kg/d	Advance by 1 g/kg daily if TG < 250 mg/dL
Sodium	0-2 mEq/kg/d	3-5 mEq/kg/d	Extremely preterm infants may require > 5 mEq/kg/d
Potassium	0-2 mEq/kg/d	2-4 mEq/kg/d	Usually given as KPhos in balance with Calcium
Calcium	0-450 mg/kg/d	Preterm Infants: 600-1000 mg/kg/d Term Infants: 400-800 mg/kg/d	Standard ratio 450 mg Ca Gluc:1 mmol Phos
Phosphorus	0-1 mmol/kg/d	Preterm Infants: 1.3-2.2 mmol/kg/d Term Infants: 0.9-1.8 mmol/kg/d	If Phos < 4 mg/dL, use 350 mg CaGluc:1 mmol Phos
Chloride/Acetate	Adjust based on acid/base status. Preterm infants tend to be acidotic.		

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Neonatal PN Complications

ACUTE	CHRONIC
Metabolic Complications	**Systemic Complications**
Hypo/hyperglycemia Metabolic acidosis Refeeding Syndrome Hyperlipidemia	Exposure to parenteral contaminants Exposure to reactive oxygen species Parenteral Nutrition Associated Cholestasis Metabolic Bone Disease
Mechanical Complications	**Infectious Complications**
Extravasation and tissue necrosis Infiltration Thrombosis Pleural or pericardial infusion Cardiac arrythmia from catheter malposition	Bacterial infections Fungal infections

Adapted From: Patel P et al, *Semin Fetal Neonatal Med*, 2017

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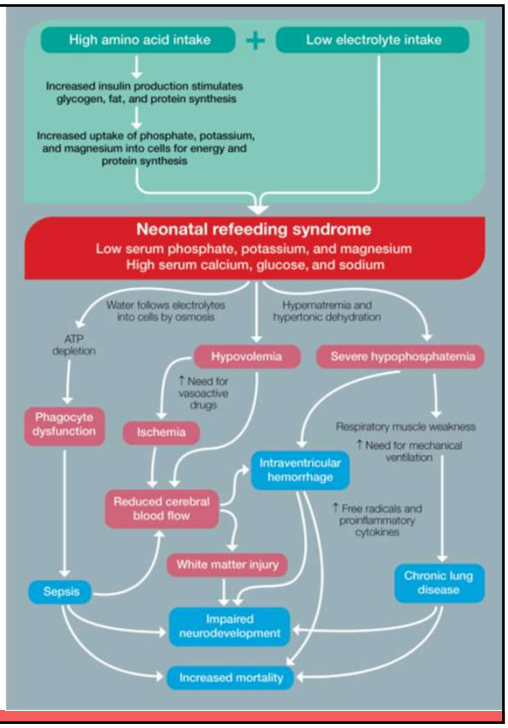
Neonatal Refeeding Syndrome

- Risk factors include: IUGR, SGA, extreme prematurity, placental insufficiency
- Incidence is not well characterized
- Associated with 3-fold greater mortality
- Prevention and management:
  - Provide early K and Phos
  - Conservative macronutrient advancement in at-risk infants
  - Close monitoring of K, Phos, Mg while PN advancing
  - Adjustment to Ca: Phos ratio to support phosphorus repletion
  - Case reports showing benefit of additional Thiamin, not routine practice yet



From: Cormack BE et al. *JPEN*, 2021.

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Parenteral Nutrition Associated Cholestasis (PNAC)

- Liver injury associated with prolonged PN
- Prevention
  - Use of lipids with lower phytosterol content (i.e. SMOF)
  - Minimize Aluminum exposure
  - Avoid overfeeding
- Treatment
  - Fish Oil Based Lipid Emulsion (Omegaven)
  - Limit Aluminum, reduce copper and withhold manganese
  - Minimal enteral nutrition if possible

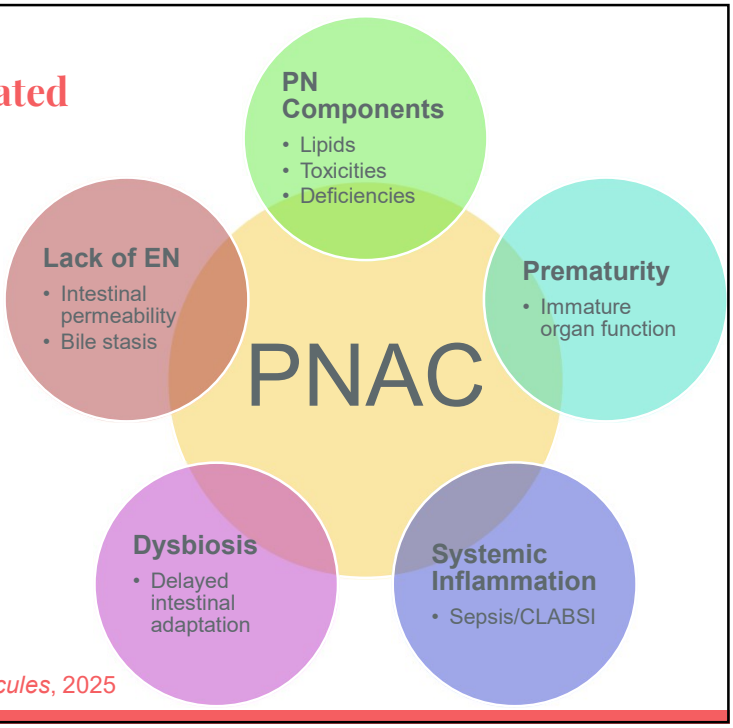

Figure adapted from: Mignini I, et al. *Biomolecules*, 2025

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NICU PN Workflow

- Mon-Fri: NICU RD will pend TPN orders in Epic, orders reviewed and signed in rounds
- Sat/Sun/Holidays: NNPs/PAs & Fellows will assist w/ PN orders
- **Nutrition notes on Fridays include recommendations for weekend PN orders**
- PN orders must be in by 11 am!
- New bags are hung at 5 pm

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Enteral Nutrition

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Human Milk

- Gold standard for infant feeding
- Mother's own milk
  - Rich in bioactive molecules
  - Evolves during lactation to meet baby's needs
  - Adapts (slightly) to preterm delivery
  - Associated with decreased complications of prematurity and improved developmental outcomes
- Donor human milk
  - Recommended for all VLBW infants when mother's milk unavailable
    - UMass Criteria: < 34 weeks, < 1800 g at birth or per NICU Team discretion
  - Donors are screened and milk is pasteurized to minimize infectious risks
  - Generally lower in nutrient density than mother's own milk
- Most infants < 1800 grams or < 34 weeks will require fortification of human milk to meet needs for protein, fat soluble vitamins, calcium, phosphorus and sodium

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Fortification of Human Milk

- Human milk fortifiers specifically designed to optimize human milk for preterm infants
- Sterile, Liquid Bovine-Based Products most widely used
  - Recommended for infants < 34 weeks OR < 1800 grams
  - Each packet adds 1 kcal/oz to 100 ml breast milk
    - Standard dose 4 kcal/oz from HMF
    - Can go to maximum 5 kcal/oz from HMF in cases of poor growth, increased protein needs, increased mineral needs
- Human Milk-Based Fortifiers also available (not used at UMass currently)

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Human Milk + Fortifier

	Needs for preterm VLBW	Human milk @ 160 ml/kg/d (20 kcal/oz)	HM + 4 kcal/oz HMF @ 160 ml/kg/d (24 kcal/oz)	HM + 5 kcal/oz HMF @ 160 ml/kg/d (25 kcal/oz)
Calories (kcal/kg)	110-140	107	128	131
Protein (g/kg)	3.5-4.5	1.9	4	4.5
Carbohydrate (g/kg)	11-13	12.8	13.6	14
Fat (g/kg)	4.6-8.1	5.6	6.3	6.3
Sodium (mg/kg)	69-115	30	64	70
Calcium (mg/kg)	120-220	37	197	227
Phosphorus (mg/kg)	70-120	21	110	127
Vitamin D (IU/d)	400-1000	3 IU/kg	190 IU/kg	227 IU/kg
Iron (mg/kg)	2-3	0.1	0.6	0.7
Zinc (mg/kg)	2-3	0.3	1.8	2.1

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Infant Formulas

	Premature	Premature Discharge	Standard Term	Low Lactose	Partially Hydrolyzed	Extensively Hydrolyzed	Elemental	Thickened
UMass Preferred Product	Special Care (Stand Protein or High Protein)	Neosure	Similac 360 Total Care / Similac Advance	Similac Sensitive	Similac Total Comfort	Alimentum	Elecare or Neocate	Enfamil AR
Standard Concentration(s)	20, 24, 30 kcal/oz	22 kcal/oz	20 kcal/oz	20 kcal/oz	20 kcal/oz	20 kcal/oz	20 kcal/oz	20 kcal/oz
Protein (g)/100 cal	3 (3.3)	2.8	2.1	2.1	2.3	2.8	2.8-3.1	2.5
Protein (whey:casein)	Intact (60:40)	Intact (50:50)	Intact (50:50)	Intact (20:80)	Partially Hydrolyzed (100:0)	Extensively Hydrolyzed (0:100)	Free Amino Acids	Intact
Ca (mg)/100 cal	180	105	78	84	105	105	116	78
Phos (mg)/100 cal	100	62	42	56	75	75	84	53
Format (ready to feed, powder)	RTF	RTF, P	RTF, P	RTF, P	RTF, P	RTF, P	P	P
Additional Notes	Use if < 34 wks Only available in hospital	Use if 34-37 wks			Best for general feeding intolerance (not preterm!)	For milk or soy protein allergy	For severe allergy or malabsorption	Thickened for reflux or dysphagia
Alternative Products:	Enfamil Premature	Enfacare	Enfamil Neuropro Good Start Gentle	Enfamil Sensitive Good Start SoothePro	Gentlease	Nutramigen, Gerber Extensive HA	PurAmino, Alfamino	none

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Supplements, Vitamins, and Minerals

MCT Oil

- Does not require bile salts for absorption
- Adds fat calories only (7.7 kcal/ml), 1 ml add 2 kcal/oz to 100 ml
- Typical dose: add 2-4 kcal/oz to feeds

Infant formula powder

- Can be used as a human milk fortifier if HMF not appropriate or available
- ½ tsp adds approx. 2 kcal/oz to 2 oz milk
- Typical dose: add 2-6 kcal/oz to feeds

Vitamin D

- Given to most preterm and term infants
- Cholecalciferol 400 IU/ml (400 IU/d)

Iron

- Supplementation recommended for preterm infants unless on full formula
- Ferrous Sulfate 15 mg/ml solution (2-3 mg/kg/d)

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Supplements, Vitamins, and Minerals Continued

Sodium	Zinc	Phosphorus	Calcium	Infant multivitamins
• Deficiency possible: ELBW, donor BM, diuretics • Sodium Chloride 2 mEq/ml solution (2-4 mEq/kg/d)	• Given when deficiency suspected (diuretics, ileostomy) • Zinc Sulfate 10 mg/ml solution (0.5-1 mg/kg/d)	• For infants with osteopenia • Potassium Phosphate 3 mmol/ml solution (0.5-1 mmol/kg/d) • Don't give at same time as oral calcium	• For infants with osteopenia • Calcium Gluconate 100 mg/ml solution (50-100 mg/kg/d) • Don't give at the same time as oral phosphorus	• Includes: A, C, D, E, Thiamin, Riboflavin, Niacin, B6, B12, +/- iron • Infants on limited fortification or if increased needs • Typical dose 1 ml/d

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Enteral Initiation and Advancement

- Guiding principles for enteral feeding in preterm infants
  - Oral care with human milk can begin as soon as possible after birth even if NPO
  - Enteral nutrition should begin as soon as infant is clinically stable (goal within 6-8 hrs of life)
    - Hemodynamically stable
    - Stable respiratory support
    - No severe electrolyte abnormalities
    - No gastrointestinal contraindications
  - Feeding beings as trophic feedings – small volume (10-30 ml/kg/d) enteral feeding, "gut priming", maintained for 1-3 days
  - Gradual volume advancement by 20-30 ml/kg/d
  - Fortification / Increased calories around 50% of goal volume
  - Continued advancement to 150-160 ml/kg/d
- Enteral feeding practice can vary among institutions
- Standardized feeding protocols associated with improved nutritional outcomes

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UMass NICU Enteral Feeding Guidelines

Gestational Age	23 0/7 – 24 6/7 weeks	25 0/7 – 27 6/7 weeks	28 0/7 – 31 6/7 weeks	32 0/7 – 34 6/7 weeks
IV access and PN at birth	UVC at birth for PN	UVC at birth for PN	<1500 g: UVC at birth for PN ≥1500 g: UVC or PIV based on clinical status, should get PN	PN recommended for infants <1500 g or if prolonged NPO anticipated
Total fluid initiation, advancement and goal	100 ml/kg/d Advance 20 ml/kg daily to goal of 160 ml/kg/d	90 ml/kg/d Advance 20 ml/kg daily to goal of 160 ml/kg/d	80 ml/kg/d Advance 20 ml/kg daily to goal of 160 ml/kg/d	80 ml/kg/d Advance 20 ml/kg daily to goal of 160 ml/kg/d
What to feed	MBM or Donor Breast Milk	MBM or Donor Breast Milk	MBM or Donor Breast Milk	If ≤1800 g or < 34 0/7 weeks MBM or Donor Breast Milk If >1800 g and 34-37 weeks, MBM or Neosure formula
Start feedings on DOL#0 at	10 ml/kg/d	10 ml/kg/d	20 ml/kg/d	20-30 ml/kg/d [c]
Feeding advance timing, volume and goal	10 ml/kg BID ordered on DOL#1 to goal of 160 ml/kg/d	10 ml/kg BID ordered on DOL#1 to goal of 160 ml/kg/d	10 ml/kg BID ordered when feeds initiated to goal of 160 ml/kg/d	15-20 ml/kg [c] BID ordered when feeds initiated to goal of 160 ml/kg/d
Volume or DOL to increase calories	Increase to 24 kcal/oz at 80 ml/kg/d and continue feeding advances as ordered [d]	Increase to 24 kcal/oz at 80 ml/kg/d and continue feeding advances as ordered [d]	Increase to 24 kcal/oz at 80 ml/kg/d and continue feeding advances as ordered [d]	Increase to 24 kcal/oz on DOL#3 if indicated [e] and continue feeding advances as ordered If <34 weeks, use HMF If ≥34 weeks, use Neosure powder
Enteral volume to discontinue PN/IV fluids	120 ml/kg	120 ml/kg	120 ml/kg	100-120 ml/kg [g]
Vitamin D initiation and dose	48 hours after reaching full feedings, 400 IU/d (dose divided q 12 hr)	48 hours after reaching full feedings, 400 IU/d (dose divided q 12 hr)	48 hours after reaching full feedings, 400 IU/d (divided q 12 hrs if < 1500 g)	48 hours after reaching full feedings, 400 IU/d (divided q 12 hrs if < 1500)
Ferinsol initiation and dosing	3 mg/kg/d (dose divided q 12 hrs) at 2 weeks of age	3 mg/kg/d (dose divided q 12 hrs) at 2 weeks of age	3 mg/kg/d (dose divided q 12 hrs) at 2 weeks of age	3 mg/kg/d if on exclusive human milk, 2 mg/kg/d if mixed HM/formula No supplementation if full formula Start at 2 weeks of age
Nutrition laboratory monitoring	Na, Cl, Ca, Phos, Alk Phos, Hct q 2 weeks (include Retic after 1 month of age)	Na, Cl, Ca, Phos, Alk Phos, Hct q 2 weeks (include Retic after 1 month of age)	Na, Cl, Ca, Phos, Alk Phos, Hct q 2 weeks (include Retic after 1 month of age)	If <34 weeks, Na, Cl, Ca, Phos, Alk Phos, Hct q 2 weeks (include Retic after 1 month of age)
Growth Failure QI protocol	Initiate once corrected to 31 0/7 weeks, increase goal to 170 ml/kg/d, maintain until 34 0/7 weeks	Initiate once corrected to 31 0/7 weeks, increase goal to 170 ml/kg/d, maintain until 34 0/7 weeks	Initiate once corrected to 31 0/7 weeks AND tolerating feedings of 160 ml/kg/d x 48 hours, increase goal to 170 ml/kg/d, maintain until 34 0/7 weeks	For babies = 32 0/7 weeks at birth, initiate once tolerating feedings of 160 ml/kg/d x 48 hours, increase goal to 170 ml/kg/d, maintain until 34 0/7 weeks

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Enteral Feeding Methodologies

Gastric, Bolus (NG or OG)

- Preferred feeding method, the most "physiologic"
- Every 3 hours
- Usually pump delivered if > 10 ml volume
- Ideally over 30 minutes
- May require slow infusion for tolerance or hypoglycemia

Gastric, Continuous (NG or OG)

- Gentle, limits gastric distention
- Increased nutrient losses (fat, Ca and Phos) from adherence to tubing

Post pyloric, continuous (ND/J or OD/J)

- May be use for severe GE reflux to minimize aspiration risk
- Requires trained provider for tube placement
- Increased nutrient losses (fat, Ca and Phos) from adherence to tubing

Gastrostomy tube

- Long term tube feeding (i.e. > 2 months post discharge)
- Less risk for accidental displacement
- Less feeding aversion than long term NG/OG

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Oral Feeding

- Suck, Swallow, Breathe (SSB) coordination develops around 32-34 weeks corrected GA
- Infant-Driven Feeding® (IDF™) is an evidence-based, systematic model intended to support oral feeding success
- Assessment of oral feeding readiness begins at 33 weeks in medically stable infants
- Oral feeding can begin when the infant demonstrates IDF™ Readiness Scores of 1 or 2 > 50% in 24 hours
  - Readiness scores of 1 or 2: may attempt oral feeding
  - Readiness scores of 3-5: gavage feed
- Caregivers use standardized scoring and language to describe the quality of the feeding and caregiver interventions utilized
- Primary goal is safe, pleasurable feeding experiences
- Feeding tube typically discontinued when able to take ~80% of feedings PO

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Breastfeeding

- Exclusive breastfeeding may not be possible for some preterm infants
- Breastfeeding can and should be included in infant feeding plans if family desires
- Supporting mom's milk production throughout NICU stay is crucial
  - IBCLC support
  - Early and frequent pumping (8x/day) with hospital grade pump
  - Encourage skin to skin time and non-nutritive breastfeeding
- Test weights can help evaluate milk intake
  - 1 g weight gain = 1 ml milk intake

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Nutrition Related Complications of Prematurity

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Necrotizing Enterocolitis (NEC)

- A disease of the intestinal tract characterized by bowel wall infection and inflammation
- Occurs primarily in preterm infants, affecting 3-10% of VLBW infants
- Clinical presentation:
  - Abdominal distention
  - Abdominal wall discoloration
  - Bloody stools
  - Bilious emesis
  - Lethargy, vital sign instability
- Radiographic Diagnosis:
  - Pneumatosis (air in the bowel wall), +/- portal venous gas on abdominal x-ray
  - Pneumoperitoneum (free air in the abdominal cavity) – requires surgical intervention

Image from: Children's Hospital of Los Angeles, chla.org

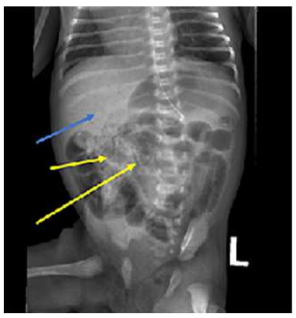

Image from: Nutritional Care of Preterm Infants: Scientific Basis and Practical Guidelines, 2nd ed.

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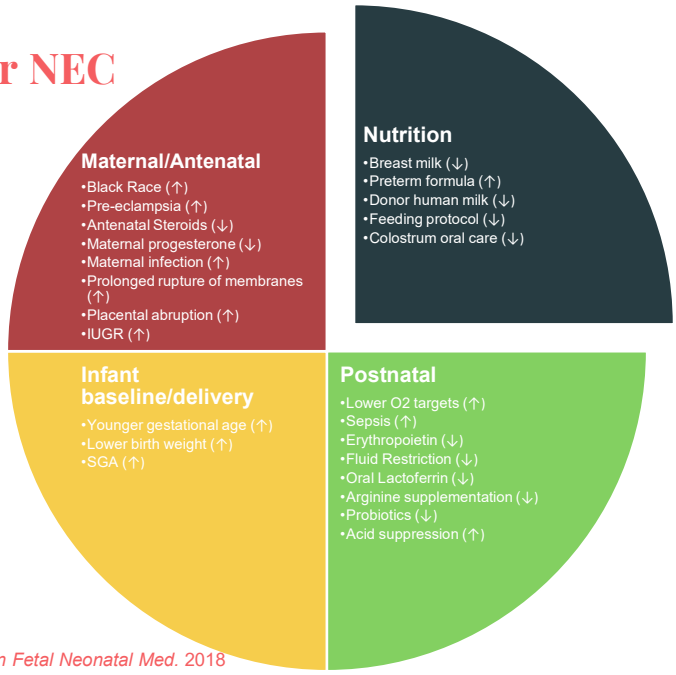
Risk Factors for NEC



Adapted From: Rose AT, Patel RM. *Semin Fetal Neonatal Med.* 2018

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Influence of Nutritional Factors on NEC

Nutrition Practice	Evidence
Mother's own milk	Dose dependent effect on risk of NEC, especially significant during the first 5-10 days of life (PMID: 18716628, 22922675, 25765818)
Donor human milk	Reduces risk of NEC by half in VLBW infants (as compared to preterm formula use) in meta analysis; 12 trials, 2,296 infants (PMID: 39239939)
Colostrum oral care	Associated with a 50% reduction in relative risk of NEC in 2022 meta analysis; 11 RCTs, 1137 infants (PMID: 35832583)
Early enteral feedings	Delayed enteral feeding **does not** reduce risk of NEC and increases risk of invasive infection (PMID: 35049036)
Rate of feeding advancement	Rapid advancement of feeding had been associated with NEC in observational studies (PMID: 17768154) Advancement of feedings up to 30-40 ml/kg/d **does not** increase risk of NEC in large meta analysis; 14 trials; 4026 infants (PMID: 34427330)
Fortification	Limited studies comparing human milk-based fortifier to bovine-based; 1 RCT (127 infants) showed no decrease in NEC (PMID:29878061) Limited studies comparing timing of fortification; small trials have shown safety as early as 20 ml/kg/d (PMID: 27112041)
Standardized feeding guidelines	Associated with an 80% reduction in relative risk of NEC when compared to non-standardized feeding guidelines; 15 trials, 18,160 infants (PMID: 28358382)

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Management of Infants with NEC

- Bowel rest (NPO), gastric decompression, and antibiotics for 7-14 days depending on severity
- May require surgical intervention if bowel perforation or necrosis occurs – potential for short bowel syndrome if significant resections
- Risk for strictures and adhesions which may require future surgery
- Parenteral nutrition support
- Gradual reintroduction of feedings – lack of consensus for best practice
  - Human milk is preferred
  - Eventual reintroduction of human milk fortifier is appropriate
  - Extensively hydrolyzed or amino acid-based formula may be required for short bowel syndrome

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Bronchopulmonary Dysplasia (BPD)

- Chronic lung disease affecting premature infants, ~50% of VLBW infants
- Combined effects of immature lungs and damage from prolonged mechanical ventilation and oxygen use
- Treatments include:
  - High dose steroids to decrease inflammation
  - Diuretics to minimize pulmonary edema
  - Bronchodilators to relax airway muscles
- May require long term respiratory support, even after discharge
- May impact ability to orally feed

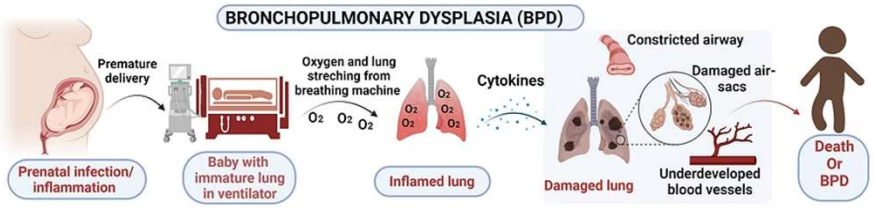

Figure from: Ayuvis.com

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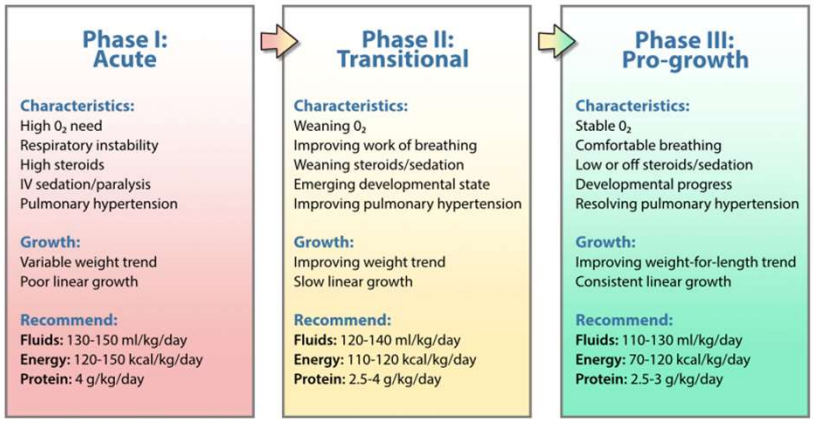
Nutritional Needs for Infants with BPD



From: Miller AN, et al. *Neoreviews*, 2024

Possible Nutrients Deficiencies requiring supplementation:

- Sodium
- Potassium
- Calcium
- Phosphorus
- Vitamin D
- Zinc

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Osteopenia of Prematurity / Metabolic Bone Disease

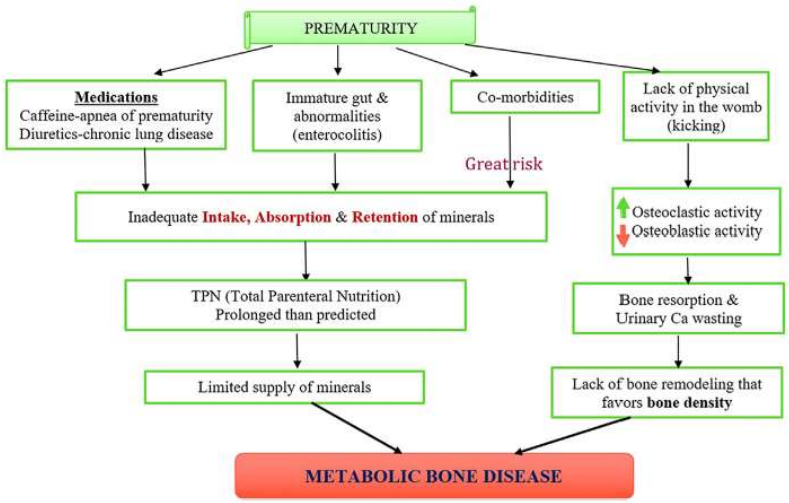

Fig. 4. Pathophysiology of metabolic bone disease of prematurity.

From: Kellar K, et al. *Clin Perinatol*, 2023

Screening/diagnosis

- Radiographic
- Biochemical
  - Alk Phos >900 mg/dL & Phos <5.6 mg/dL has 100% sensitivity and 70% specificity

Consequences of osteopenia

- Structural deformities
- Spontaneous fractures
- Long term growth stunting
- Osteoporosis risk in adulthood

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Prevention and Treatment of Osteopenia

- Concurrent Ca and Phos in PN, optimal ratio 1-1.3:1 molar
- Early enteral feeding
- Human milk fortification/preterm formula
- Ensure adequate Vitamin D stores
- Limit diuretics if possible (choose thiazide over furosemide)
- Assisted physical activity
- Additional Ca and Phos supplementation if evidence of osteopenia

Table 2. Recommended Mineral Intake for Prevention and Treatment of Metabolic Bone Disease of Prematurity

	Calcium (mg/kg/day)	Phosphorus (mg/kg/day)	Vitamin D (IU/day)
Enteral	150–220	75–140	200–1,000[a,b]
Parenteral	75–100	50–80	200–1,000[b]
Treatment	20–80	10–50	200–1,000[b]

[a]200 IU/day is recommended for infants weighing less than 1,500 g; infants weighing more than 1500 g should receive 400 IU/day. (30)
[b]The upper limit of 1,000 IU/day comes from the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition guidelines (33); there are few guidelines for required parenteral and treatment doses of vitamin D.

From: Lee B. et al, *NeoReviews*, 2022

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Questions?

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Feeding and Fluid Calculations

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Calculating Total Fluids

- **Example:** Calculate the total fluids for a 25 0/7 wk, 800 gram baby getting the following:

○ PN: 2 ml/hr x 24 hrs	48 ml/d ÷ 0.8 kg = 60 ml/kg/d
○ SMOF (1 g/kg): 0.17 ml/hr x 24 hrs	4 ml/d ÷ 0.8 kg = 5 ml/kg/d
○ 0.45% NaAce: 0.5 ml/hr x 24 hrs	12 ml/d ÷ 0.8 kg = 15 ml/kg/d
○ MBM: 2 ml q 3 hrs	16 ml/d ÷ 0.8 kg = 20 ml/kg/d
	TOTAL FLUIDS = 100 ml/kg/d

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Calculating Total Fluids

- **Example:** The baby from the previous example (25 0/7 wk, 800 grams) is doing well and the plan discussed in rounds is to d/c the fluid infusing through the second UVC port, start a feeding advance of 10 ml/kg BID, increase SMOFLipid to 2 g/kg/d (10 ml/kg) and increase total fluids to 120 ml/kg/d with tonight's TPN order. At what rate should you order the TPN?

	Total Fluid = 100 ml/kg/d	Total Fluid = 120 ml/kg/d
PN: 2 ml/hr	60 ml/kg/d	?
SMOF (1 g/kg/d): 0.17 ml/hr	5 ml/kg/d	10 ml/kg/d
0.45% NaAcetate: 0.5 ml/hr	15 ml/kg/d	0 ml/kg/d
MBM: 2 ml q 3 hrs	20 ml/kg/d	30 ml/kg/d

Fluid remaining for TPN = 80 ml/kg/d
80 ml/kg/d x 0.8 kg = 64 ml/d ÷ 24 hours = 2.666 ml/hr
Tonight's TPN order should be written for 2.7 ml/hr

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Feeding and Fluid Calculations

- Trophic feedings: Refer to guidelines for amount (10-20 ml/kg/d)
  - ml/kg/d x body weight in kg = ml per day of feeds
  - Divide by the # of times you are feedings each day (usually q 3 hours)
    - 8 times per day if feeding q 3 hours
    - 6 times per day if feeding q 4 hours
  - Round up or down to the nearest whole number
    - Can use 0.5 ml increments for smaller babies

Example: Calculate the trophic feeding order for a 25 0/7 wk baby (BW: 800 grams)
- 10 ml/kg/d x 0.8 kg = 8 ml per day
- 8 ml/d ÷ 8 feedings per day = 1 ml q 3 hours

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Feeding and Fluid Calculations

- Calculating feeding advances
  - Refer to guidelines for how quickly to advance
  - ml/kg x body weight in kg = ml per day advance
  - Divide by the # of times you are feeding each day
  - Round up or down to the nearest whole number

Example: Calculate the feeding advance for a for a 25 0/7 wk baby (BW: 800 grams)
- Enteral guidelines are for a 10 ml/kg BID advance
- 10 ml/kg x 0.8 kg = 8 ml
- 8 ml/d ÷ 8 feedings per day = 1 ml increase in feed volume
- Advance would be 1 ml BID (we generally write 1 ml q 12 hrs)

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Feeding and Fluid Calculations

- Then determine your max: use 160 ml/kg/d
  - 160 ml/kg/d x body weight in kg = ml per day of feeds
  - Divide by the # of times you are feeding each day
  - Round up or down to the nearest whole number

Example: Calculate the feeding max for a 25 0/7 wk baby (BW: 800 grams)
  - 160 ml/kg/d x 0.8 kg = 128 ml per day
  - 128 ml/d ÷ 8 feedings per day = 16 ml q 3 hours

Complete feeding advance order would be : "Advance feeds 1 ml q 12 hrs to a max of 16 ml q 3 hrs"

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Feeding and Fluid Calculations

- Calculating IV fluid/TPN rate decrease
  - ml/kg decrease x body weight in kg = total ml decrease
  - Divide by 24 to convert to an hourly rate to subtract from IV fluid
  - Round up or down to the nearest 10th

Example: Calculate the TPN decrease for a 25 0/7 wk baby (BW: 800 grams) to keep total fluids stable. Feeds are advancing 1 ml q 12 hours (10 ml/kg BID)
  - 10 ml/kg x 0.8 kg = 8 ml decrease
  - 8 ml ÷ 24 hrs = 0.333 ml/hr
  - Decrease TPN by 0.3 ml/hr with each feeding advance

*Tip: If you want Total Fluids to advance by 20 ml/kg daily and feedings are advancing by 20 ml/kg BID, you can decrease IV fluids by 10 ml/kg with each advance

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Feeding and Fluid Calculations

Example: Baby A is a 33 week, 2 kg infant. Calculate the admission feeding and IV fluid orders based on UMass NICU guidelines

Feedings

Initiation (20-30 ml/kg)

- 20 ml/kg/d x 2 kg = 40 ml per day
- 40 ml/d ÷ 8 feedings per day = 5 ml q 3 hrs

Advance (15-20 ml/kg BID)

- 20 ml/kg x 2 kg = 40 ml
- 40 ml ÷ 8 feedings per day = 5 ml increase in feed volume
- Advance would be 5 ml BID (we generally write 5 ml q 12 hrs)

Goal (160 ml/kg/d)

- 160 ml/kg/d x 2 kg = 320 ml
- 320 ml/d ÷ 8 feedings per day = 40 ml q 3 hrs

Feeding Order: MBM or DBM (must obtain parent consent). Start at 5 ml q 3 hrs, increase by 5 ml q 12 hrs to max of 40 ml q 3 hrs

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Feeding and Fluid Calculations

Example: Baby A is a 33 week, 2 kg infant. Calculate the admission feeding and IV fluid orders based on UMass NICU guidelines

IV fluids

Initiate

- Total Fluids DOL#0 = 80 ml/kg/d - 20 ml/kg/d from feedings = 60 ml/kg/d from IV fluid
- 60 ml/kg/d x 2 kg = 120 ml per day
- 120 ml/d ÷ 24 hrs = 5 ml/hr

IV fluid Decrease

- Feeds advancing by 20 ml/kg BID, but want total fluids to advance 20 ml/kg/d so can decrease IV fluids by 10 ml/kg with each advance
- 10 ml/kg x 2 kg = 20 ml decrease
- 20 ml ÷ 24 hrs = 0.83 ml/hr
- Decrease IV fluids by 0.8 ml/hr with each feeding advance

IV Fluids (usually D10): Order at 60 ml/kg/d
Administration Instructions: Decrease by 0.8 ml/hr with each feeding increase

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