Neonatal and Pediatric Parenteral Nutrition

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Neonatal/Pediatric Clinical Pharmacist
November 2, 2010
Learning Objectives

- Describe the nutritional needs specific to different age groups in the pediatric population
- Discuss the role of early initiation of amino acids in extremely-low-birth-weight infants
- List the requirements for macronutrients and electrolytes specific to different age groups in the pediatric population
- Identify the indications and monitoring parameters for an infant/child receiving parenteral nutrition
- Discuss the role of a pharmacist in the development of a patient-specific parenteral nutrition formulation based on patient disease states and laboratory parameters
Challenges of Parenteral Nutrition in Pediatric Patients

- Wide range of patient population
- Age and maturity-related changes of metabolism and fluid
- Variation in nutrient requirements
- Clinical conditions of infants/children
- Indications for parenteral nutrition
Indications for Parenteral Nutrition

- Premature neonates who cannot be fed or adequately fed by enteral nutrition
- Patients with congenital anomalies (i.e., meconium ileus, gastroschisis, etc)
- Patients with inflammatory bowel disease, necrotizing enterocolitis, short-bowel syndrome
- Hypercatabolic ICU patients
- Healthy infants and child who are NPO
  - < 1 year: > 3-5 days
  - 1-18 years: > 5-7 days
- Malnourished or high risk for malnutrition who are NPO
  - < 1 year: > 1 day
  - 1-5 years: > 2 days
  - 5-18 year: > 3 days
Nutrition Goals

- Fluids
- Vitamins & Minerals
- Electrolytes
- Calories
- Protein
- Fat
Nutrition Goals

- Goal is to achieve in utero body composition
  - Rather than weight gain

- Body compartments that change with nutrition
  - Fat mass
  - Protein mass—measure of true growth
Importance of Early Neonatal Nutrition

- Delay in nutrition leads to poor growth
- Very low birth weight (VLBW) infants are born at a time of otherwise very rapid intrauterine brain and body growth
  - VLBW: BW <1500g
  - ELBW: BW < 1000g
- Malnutrition may lead to irreversible deficits in brain growth due to decreased cell division and myelination
At 70% of gestation, there is little fetal lipid uptake.

Glucose is delivered at low fetal insulin concentrations.

Amino acid uptake greatly exceeds protein accretion requirements.

Lipids used as significant energy source.

Glucose administration exceeds in utero administration rate.

Amino acids are delivered at low rate.
Types of Parenteral Nutrition

**Peripheral Line**
- Short-term maintenance
- Partial or total nutrition for up to 2 weeks
  - Patients who cannot ingest or absorb enteral nutrients
  - Central vein parenteral nutrition not feasible

**Central Line**
- Long-term maintenance/home parenteral nutrition
- Impaired gastrointestinal function (> 7 days)
- > 2 weeks of parenteral nutritional support
- Greater calories intake required
- Fluid restriction required
Administration Concerns of Peripheral Parenteral Nutrition

- Limited by concentration of solutions
  - Maximum dextrose concentration 10-12.5%
    - 1% of dextrose = 50 mOsm/L
  - Maximum amino acids concentration 2.5-3%
    - 1% of amino acids = 90-100 mOsm/L
- Requires large fluid volumes to provide adequate energy needs
- Maximum osmolarity = 800-900 mOsm/L
- Calcium conc ≤ 10 mEq/L
- Potassium conc ≤ 40 mEq/L
Questions to Ask When Writing PN

- **Step 1: Determine IV access**
  - Peripheral lines
  - Central lines
    - UVC, UAC, PCVC or PICC, broviac, femoral

- **Step 2: Determine weight of infant**
  - Always use birth weight (BW) until gains BW
  - Expect 10-15% weight loss in preterm neonates

- **Step 3: Other continuous IV drips/fluids**
  - UAC line, pressors, etc

- **Step 4: Feedings or NPO**

- **Step 5: Determine fluid requirements**
## Changes in Total Body Water and Body Compartments

<table>
<thead>
<tr>
<th>Age</th>
<th>TBW (% BW)</th>
<th>ECF (% BW)</th>
<th>ICF (% BW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature</td>
<td>80-90</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Newborn</td>
<td>70-75</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td>1-year-old</td>
<td>60</td>
<td>27</td>
<td>40-45</td>
</tr>
<tr>
<td>Adolescence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>60</td>
<td>20</td>
<td>40-45</td>
</tr>
<tr>
<td>Females</td>
<td>55</td>
<td>18</td>
<td>40</td>
</tr>
</tbody>
</table>
Fluid Requirements

- Fluid requirements are the SAME for enteral or parenteral nutrition
- Decrease fluid requirements
  - Congenital heart disease, PDA
- Increase fluid requirements
  - Fever increases insensible water loss via respiration and skin
    - Each degree of temp > 39°C, insensible water loss is increased by 5 mL/kg/day
Fluid Requirements - Neonates

- Total fluid intake (TFI) varies depending on gestational age as well as postnatal age
- Initiate at 80-100 mL/kg/day; increase by 10-20 mL/kg/day
- Maintenance of 130-160 mL/kg/day
- TFI includes all continuous IV drips, TPN, Intralipid and oral feeds
- Always use BW until they gain BW
Fluid Requirements - Infants & Children

- For > 20 kg: 20 mL/kg
- For 11-20 kg: 50 mL/kg
- For 1-10 kg: 100 mL/kg

15-kg infant:

$1000 \text{ mL} + 50 \text{ ml/kg} \times 5 \text{ kg} = 1250 \text{ mL/d} = 52 \text{ ml/hr}$
Caloric Requirements

- Caloric requirements are age-related and influenced by illness and therapy
- More calories required for enteral versus parenteral
- Lower energy needs in girls because of lower activity states
## Estimated Caloric Requirements

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Caloric Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm Neonate</td>
<td>110-120 Kcal/kg/day</td>
</tr>
<tr>
<td>Term Infant – 1 yr</td>
<td>90-100 Kcal/kg/day</td>
</tr>
<tr>
<td>1-7 years</td>
<td>75-90 Kcal/kg/day</td>
</tr>
<tr>
<td>8-12 years</td>
<td>60-75 Kcal/kg/day</td>
</tr>
<tr>
<td>13-18 years</td>
<td>30-60 Kcal/kg/day</td>
</tr>
</tbody>
</table>

Calories should be provided as carbohydrate and fat to assure optimal growth and development.
Caloric Distribution

- Fat = 9 Kcal/gm  (30%)
- Protein = 4 Kcal/gm  (10%)
- Carbohydrate = 60%
- Dextrose = 3.4 Kcal/gm
Glucose

- Primary energy source for neonate
- Provided as 50-60% of non-protein caloric intake
- Because of large proportion of metabolically active organs, large and continuous source of glucose is needed for energy metabolism
- Glucose administration to support protein deposition
  - 2-3 mg/kg/min per gram of protein intake
- Maximal glucose infusion rate (GIR) ~ 12-13 mg/kg/min
### Estimates of Glucose Consumption by Brain

<table>
<thead>
<tr>
<th>Age</th>
<th>mg/kg/min</th>
<th>gm/kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>8</td>
<td>11.5</td>
</tr>
<tr>
<td>1 year old</td>
<td>7</td>
<td>10.1</td>
</tr>
<tr>
<td>5 years old</td>
<td>4.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Adolescents</td>
<td>1.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Adults</td>
<td>1</td>
<td>1.4</td>
</tr>
</tbody>
</table>

*Kalhan et al. Europ J Clin Nutr 1999;53:S94-S100*
Carbohydrate Requirements
Rate of Glucose Administration

**Preterm Infants**
- Initiate at 4-6 mg/kg/min
- Increase by 1-2 mg/kg/min
- Maximum 12-14 mg/kg/min

**Term infants***
- Initiate at 6-8 mg/kg/min
- Increase by 1-2 mg/kg/min
- Maximum 12-13 mg/kg/min

**Infants/Children**
- Initiate at 6-8 mg/kg/min
- Increase by 2-4 mg/kg/min
- Max 12-13 mg/kg/min (Infant)
- Max 6-9 mg/kg/min (Child)

*Includes preterm infants restarting on parenteral nutrition

***Critically ill burned patients: maximum GIR = 5 mg/kg/min***
Glucose Infusion Rate

- To calculate GIR → Dextrose %

\[
\% \text{ Dextrose} = \frac{\text{GIR} \times 6 \times \text{wt (kg)}}{\text{rate (mL/hr)}}
\]

- To calculate Dextrose % → GIR

\[
\text{GIR (mg/kg/min)} = \frac{\% \text{ Dextrose} \times \text{rate (mL/hr)}}{6 \times \text{wt (kg)}}
\]
Overfeeding

- Definition: providing calories in excess of amount required for normal weight gain
- Varying effects of glucose intakes greater than maximal oxidation rate
  - Critically ill patients: non-oxidative production of fat
  - Premature infants: promote fat deposition
- Complications of overfeeding
  - Higher energy expenditure and increased CO₂ production
  - Fatty liver/hepatic steatosis, liver failure
  - Infections
- Malnourished patients are least affected; hypermetabolic patients are most susceptible
Amino Acids

• Neonatal period characterized by high rates of protein:
  o Turnover
  o Synthesis
  o Catabolism
  o Deposition

• Without exogenous protein intake, protein synthesis remains high, but breakdown increases

• Example: If IV glucose was given alone-
  o Lose ~ 0.5-1 g/kg/day or 1% body protein
  o 10% loss of protein stores = protein malnutrition
Current Practice

- Many NICUs supply glucose alone for several days and limit protein intake
- Theories:
  - Protein intolerance
  - Increased BUN/azotemia
  - Metabolic acidosis
  - Note: may be a sign of production of byproduct rather than intolerance
Role of Early Initiation of Amino Acids in Preterm Infants

- Prevents catabolism
- Promotes anabolism
- Decrease hyperglycemia & hyperkalemia
- Stimulates growth

Early Initiation of Amino Acids
Figure. Metabolic consequences of delaying initiation of amino acid administration to extremely-low-birthweight infants. Courtesy of David H. Adamkin, MD.
Protein Accretion

- Protein gain is the best indicator of "real" growth
- If no superimposed catabolic influences, protein gain increases linearly with protein intake
  - Range 0.5-4 g/kg/day
- 1.5-2 g/kg/day is sufficient to prevent catabolism
- If administered with 30 kcal/kg/day of energy, minimum intake of 1-1.5 g/kg/day is sufficient in the ELBW
<table>
<thead>
<tr>
<th>DAY</th>
<th>REGIMEN 1</th>
<th>REGIMEN 2</th>
<th>REGIMEN 3</th>
<th>REGIMEN 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GLUCOSE INTAKE (g/dL)</td>
<td>FLUID INTAKE (mL/kg/d)</td>
<td>PROTEIN INTAKE (g/kg/d)</td>
<td>LIPID INTAKE (g/kg/d)</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>80</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>120</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>140</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>150</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>REGIMEN 2</td>
<td>REGIMEN 3</td>
<td>REGIMEN 4</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>80</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>120</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>140</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>150</td>
<td>2.5</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>REGIMEN 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>80</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>100</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>120</td>
<td>2.5</td>
<td>1.5</td>
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<tr>
<td>4</td>
<td>10</td>
<td>140</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>150</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

*Cumulative protein and energy balances are determined by summing the net balance on a specific day and the net balances on all preceding days of the regimen.
Magnitude of Early Protein Loss in Extremely Premature Neonates

Change in body protein over first week of life in 1000 gm 26 wks GA

Denne et al. Sem Perinatol 2007;31:56-60
# Protein Requirements (gm/kg/day)

<table>
<thead>
<tr>
<th>Age</th>
<th>Starting Dose</th>
<th>Increase by</th>
<th>Maintenance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm infants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-25 weeks</td>
<td>2-2.5</td>
<td>0.5-1</td>
<td>3.75 -4</td>
</tr>
<tr>
<td>27-28 weeks</td>
<td>2-2.5</td>
<td>0.5-1</td>
<td></td>
</tr>
<tr>
<td>32 weeks</td>
<td>2-2.5</td>
<td>0.5-1</td>
<td></td>
</tr>
<tr>
<td>Term infants</td>
<td>1.5-2</td>
<td>0.5-1</td>
<td>2-3</td>
</tr>
<tr>
<td>1-7 yrs</td>
<td>1-1.5</td>
<td>0.5-1</td>
<td>1.5-2.5</td>
</tr>
<tr>
<td>8-12 yrs</td>
<td>1-1.5</td>
<td>0.5-1</td>
<td>1.5-2*</td>
</tr>
<tr>
<td>13-18 yrs</td>
<td>0.5-1</td>
<td>0.5-1</td>
<td>1.5*</td>
</tr>
</tbody>
</table>

*Critically ill child/adolescent*
Protein Requirements

- **Protein concentrations**
  - Limit to 2.5-3% for peripheral TPN
  - Osmolarity ~ 250-300 mOsm/L

- **Excessive protein intake > 6 gm/kg/day**
  - Aminoacidemia, azotemia, metabolic acidosis, increased BUN, hyperammonemia, lower IQ

- **Inadequate protein intake < 2.5 gm/kg/day**
  - Decreased nitrogen retention, low serum albumin/pre-albumin
  - Edema, slow growth

- **Net protein utilization most efficient with:**
  - 150-200 nonprotein Kcal per gram of nitrogen
  - 24 to 32 nonnitrogen Kcal per gram of protein
Starter Parenteral Nutrition

- **Indications**
  - BW < 1850 gm (including ELBW) and/or GA ≤ 34 weeks
  - Initial amino acids: 2-3 gm/kg/day

- **Solutions (dextrose and protein) to be initiated immediately after birth**

- **Intralipid 20% at 0.5-1 gm/kg/day may be initiated within 12-36 hours**

- **Results**
  - Better weight gain, length and head circumference
  - Positive nitrogen balance and increase protein accretion
  - No differences in metabolic acidosis or hyperammonemia
Examples of Starter PN Solutions

- **Stock solutions**
  - Dextrose 5% + Trophamine 2.5% or 4%
  - Dextrose 7.5% + Trophamine 2.5% or 4%
  - Dextrose 10% + Trophamine 2.5% or 4%

- Calcium and +/- heparin can be added to bag
### Starter Parenteral Nutrition Solutions

<table>
<thead>
<tr>
<th>Birth weight (gm)</th>
<th>500-750</th>
<th>751-1000</th>
<th>1001-1250</th>
<th>1251-1500</th>
<th>No UAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dextrose 5% (mg/kg/min)</td>
<td>2 - 2.2</td>
<td>2.2 – 2.4</td>
<td>2.4</td>
<td>2.4- 2.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Dextrose 7.5% (mg/kg/min)</td>
<td>2.9 – 3.3</td>
<td>3.3 – 3.5</td>
<td>3.5 – 3.7</td>
<td>3.7 – 3.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Dextrose 10% (mg/kg/min)</td>
<td>4 - 4.4</td>
<td>4.4 – 4.8</td>
<td>4.8</td>
<td>4.8 - 5</td>
<td>5.6</td>
</tr>
<tr>
<td>Amino Acid 2.5% (gm/kg/day – PIV)</td>
<td>1.4 - 1.6</td>
<td>1.6 – 1.7</td>
<td>1.7 – 1.8</td>
<td>1.8</td>
<td>2</td>
</tr>
<tr>
<td>Amino Acid 4% (gm/kg/day – CL)</td>
<td>2.2 – 2.6</td>
<td>2.6 – 2.7</td>
<td>2.7 – 2.8</td>
<td>2.8 – 2.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Calcium 10 mEq/L (mEq/kg/day – PIV)</td>
<td>0.5 – 0.64</td>
<td>0.64-0.68</td>
<td>0.68-0.7</td>
<td>0.7 – 0.72</td>
<td>0.8</td>
</tr>
<tr>
<td>Calcium 40 mEq/L (mEq/kg/day-CL)</td>
<td>2 – 2.56</td>
<td>2.56 - 2.7</td>
<td>2.7 – 2.8</td>
<td>2.8 – 2.9</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Amino Acid Composition

- Enzyme immaturity contributes to conditionally essential amino acids
- Adult formulations
  - Aminosyn®, FreAmine III, ® Travasol®
  - High concentrations of methionine, phenylalanine, glycine
  - Low concentrations of tyrosine, cysteine, taurine
- Pediatric formulations*
  - Aminosyn-PF®, Trophamine®, (Premasol®), Primene®, Neopham®
  - Low concentrations of methionine, phenylalanine, glycine
  - High concentrations of taurine, histidine, tyrosine, glutamate, arginine
  - L-cysteine HCl (40 mg/gm of amino acids) to be added at time of preparation
    - Decrease in pH of solution → increases solubility of Ca/Phos
    - Monitor for metabolic acidosis

*None of the above specifically designed for ELBW infant
Advantages of Pediatric Formulations

- Lower pH increases solubility of Ca & Phos
- Adequate weight gain even with below normal caloric intake
- Lower incidence of cholestasis in VLBW infants
- Positive nitrogen balance

Pediatric Amino Acid Formulations
Roles of Lipid

- Provided at 30-40% of non-protein caloric intake
  - Serves as energy substrate (concentrated isotonic source of calories)
- Prevention of essential fatty acid deficiency (EFAD)
  - EFAD characterized by dermatitis, alopecia, thrombocytopenia, and increased susceptibility to infection
  - EFAD can develop within 72 hours of life
  - Minimum of 0.5 gm/kg **per day** (preterm/term/infants) or 1.5 gm/kg **twice a week** (older children/adolescents)
- Important for brain development and cell membrane integrity
- Prolongs the integrity of peripheral lines
<table>
<thead>
<tr>
<th>Age</th>
<th>Starting Dose</th>
<th>Increase by</th>
<th>Maintenance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm infants</td>
<td>0.5-1</td>
<td>0.5-1</td>
<td>3</td>
</tr>
<tr>
<td>Term infants</td>
<td>1</td>
<td>0.5-1</td>
<td>3-4</td>
</tr>
<tr>
<td>1-7 yrs</td>
<td>1-1.5</td>
<td>0.5-1</td>
<td>2-2.5</td>
</tr>
<tr>
<td>8-12 yrs</td>
<td>1-1.5</td>
<td>0.5-1</td>
<td>1.5-2</td>
</tr>
<tr>
<td>13-18 yrs</td>
<td>0.5-1</td>
<td>0.5-1</td>
<td>1.5-2</td>
</tr>
</tbody>
</table>

Preterm restarting on TPN: Initial dose: 2 gm/kg/day; maximum 3 gm/kg/day
Intralipid Composition

- Use 20% (2 Kcal/mL) over 10% (1.1 Kcal/mL) formulations
- Advantages
  - Better tolerated in premature neonates
  - Less phospholipid to triglyceride ratio
- Disadvantage
  - Less long chain polyunsaturated fatty acids (LC-PUFA)
  - LC-PUFA are “conditionally” essential for premature infants
Fat Metabolism

- Lipoprotein lipase (LPL) hydrolyzes triglycerides into free fatty acids (FFA) and glycerol
- Premature infants are at risk for decreased LPL activity
- Premature infants are carnitine deficient
  - Essential for transport of long-chain fatty acids via mitochondrial membrane for oxidation
  - Accretion occurs during last trimester of gestation
  - Meta-analysis showed no effect on metabolism of lipids, lipogenesis or weight
  - Recommended in those on exclusive PN > 4 weeks
    - Dose 2-5 mg/kg/day (up to 20 mg/kg/day)
Risk Factors for Hypertriglyceridemia

- Premature infants
  - Infuse over 24 hours or < 0.15 gm/kg/hr
- Malnourished patients due to slower rate of clearance
- Patients with sepsis or trauma
- Liver and/or renal disease
- Medications
  - Steroids
  - Propofol
  - Liposomal amphotericin
Monitoring/Complications

- **Essential fatty acid status**
  - Patients on long term PN or those with severe fat malabsorption

- **Indirect (unconjugated) hyperbilirubinemia**
  - FFA displaces bilirubin from albumin → increasing risk of kernicterus in neonates
  - Limit amount of fat 0.5 gm/Kg/day to prevent EFAD

- **PN-associated cholestasis/liver disease**
Electrolyte Requirements (mEq/kg/day)

**Sodium** (as acetate, chloride, or phosphate salts)
- Preterm/Term Neonates: 3-8
- Omit in first 1-2 days of life
- Infants/Children: 2-5
- Adolescents: 1-2

**Potassium** (as acetate, chloride, or phosphate salts)
- Neonates: 2-4
  - Omit in the first few days of life
- Infants/Children: 2-4
- Adolescents: 1-2
- PIV: ≤ 40 mEq/L

**Chloride** (as sodium or potassium)
- Neonates: 2-5
  - Omit in the first 5-7 days of life
- Infants/Children: 2-5
- Adolescents: 1-2
  - ~ 1/2 to 2/3 of total cations

ASPN. J Pediatr Enteral Nutr 2002;26:ISA-138SA
Electrolyte Requirements

- Greatest accretion of calcium occurs during last 6 wks of gestation
- In utero, ~ 120-150 mg/kg/day elemental Ca
- Calcium (as calcium gluconate; ~ 9% elemental Ca)
  - 1 gm = 4.6 mEq calcium gluconate

<table>
<thead>
<tr>
<th>Age</th>
<th>Calcium Requirements (mEq/kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm Neonates</td>
<td>3-4</td>
</tr>
<tr>
<td>Term Neonates</td>
<td>2-3</td>
</tr>
<tr>
<td>Infants/Children</td>
<td>1-2 (10 mEq/day)</td>
</tr>
<tr>
<td>Adolescents</td>
<td>5-10 mEq/day</td>
</tr>
</tbody>
</table>

- Peripheral TPN: < 10 mEq/L

Electrolyte Requirements

- Greatest accretion of phosphorus occurs during last 6 wks of gestation
- In utero, ~ 70-85 mg/kg/day elemental phosphorus
- Phosphorus (as sodium or potassium salts)

<table>
<thead>
<tr>
<th>Age</th>
<th>Phosphate Requirements (mmol/kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm Neonates</td>
<td>1-2</td>
</tr>
<tr>
<td>Term Neonates</td>
<td>1-1.5</td>
</tr>
<tr>
<td>Infants/Children</td>
<td>0.5-1 (10 mmol/day)</td>
</tr>
<tr>
<td>Adolescents</td>
<td>5-10 mmol/day</td>
</tr>
</tbody>
</table>

- 1 mEq K+ salt = 0.68 mmol phosphate
- 1 mEq Na+ salt = 0.75 mmol phosphate

Electrolyte Requirements

- **Ideal Ca (mEq) to P (mmol) ratio is 1.7:1**
  - Promote highest retention of Ca and P
  - Simulate in utero bone mineral accretion rates

- **Magnesium (as sulfate)**
  - Neonates/Infants/Children: 0.25-0.5 mEq/kg/day
    - Omit in preterm neonates if exposed to maternal magnesium
      - Tocolytics
      - Pre-eclampsia
      - Neuroprophylaxis
  - Adolescents: 5-10 mEq/day

---

Factors Affecting Calcium & Phosphorus Solubility

- pH
  - Cysteine
  - Amino acid & dextrose
  - Lipid

- Temperature/light

- Calcium & Phos concentrations

- Calcium salt

- Order of adding Ca & Phos
Figure 1. Solubility curves for TPN solutions containing amino acid 2 g/dL with cysteine 40 mg/g, lipid emulsion buffer, and 10% dextrose at pH 4.8; see first paragraph of results for explanation (Aminosyn ; ; TrophAmine—-; relative calcium to phosphate ratio—-).
Consequences of Ca & P Precipitation

- Severity can range from mild to life threatening
- Visual tests may pick up ppt of 50-100 µm
- Smaller precipitates (5-50 µm) can obstruct pulmonary arterioles
- Potential symptoms due to Ca/Phos precipitates
  - Respiratory distress
  - Pulmonary emboli
  - Interstitial pneumonitis
Strategies to Decrease Ca/Phosphate Precipitation

- Calculate solubility based on soln volume at time of Ca & P addition
- Consider the P ions present in amino acids
- Use Ca gluconate over Ca chloride
- Avoid use of bicarbonate
- Avoid use of 3 in 1 PN
- Add phosphate first and Ca last
- Use 1.2 µm filter for lipid and 0.2 µm for PN
- Flush line after infusion of incompatible products
**Recommended Intravenous Trace Elements**

- Trace elements are essential micronutrients for support of human metabolic processes

<table>
<thead>
<tr>
<th>Element</th>
<th>Preterm Neonates (mcg/kg/day)</th>
<th>Term Neonates/Infants (mcg/kg/day)</th>
<th>Children (mcg/kg/day) [max mcg/day]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>400</td>
<td>250 &lt; 3 mo 100 &gt; 3 mo</td>
<td>50 [5000]</td>
</tr>
<tr>
<td>Copper</td>
<td>20</td>
<td>20</td>
<td>20 [300]</td>
</tr>
<tr>
<td>Manganese</td>
<td>1</td>
<td>1</td>
<td>1 [50]</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2 [5]</td>
</tr>
<tr>
<td>Selenium*</td>
<td>2</td>
<td>2</td>
<td>2 [30]</td>
</tr>
</tbody>
</table>

*Only if duration of PN > 2 weeks

Commercial combo trace elements (PedTrace®) per mL contains zinc 1 mg, copper 0.1 mg, manganese 25 mcg, chromium 1 mcg

- Preterm infants
  - 0.2 mL/Kg/day PLUS additional zinc 0.2 mg/Kg/day

- Term infants ≥ 2.5 Kg or ≤ 3 mos
  - 0.2 mL/Kg/day PLUS additional zinc 0.05 mg/Kg/day

- Infants > 3 mos & Children
  - 0.2 mL/Kg/day

- > 20 Kg: use adult trace element (1 mL/day)
Trace Elements

- Cholestatic liver disease/impaired biliary excretion
  - Decrease copper and manganese
- Renal failure
  - Decrease chromium and selenium
- Significant ostomy drainage or persistent diarrhea
  - Give extra zinc of ~ 200 mcg/kg/day
- Exterior biliary drainage due to jejunostomies
  - Give additional copper of 10-15 mcg/kg/day
Multivitamins

- Commercially available products approved for use
  - M.V.I Pediatric™ (US) or Infuvite Pediatric™ (Canada)

- Pediatric dosing guidelines
  - < 1 Kg: 1.5 mL
  - 1-3 Kg: 3.25 mL
  - 3-40 Kg: 5 mL
  - > 40 Kg (or 11 yrs): use adult MVI (10 mL/day)

- Neonatal dosing guidelines
  - < 2.5 Kg: 2 mL/kg/day
  - ≥ 2.5 Kg: 5 mL/day
Other Supplementations

- **Heparin**
  - Reduces formation of fibrin sheath around catheter \(\rightarrow\) reduced phlebitis
  - Stimulates release lipoprotein lipase \(\rightarrow\) improve lipid clearance
  - Recommended dose: 0.25 – 1 units/mL

- **Intravenous iron**
  - Considered only among long-term PN-dependent infants/children who are NOT receiving frequent blood transfusions
  - Term infants: 100 mcg/kg/day (delay until 3 mos of age)
  - Preterm infants: 200 mcg/kg/day (delay up to 2 mos of age)
  - Lack of compatibility data among IV iron products
Nutritional Assessment
Growth Measurements

- **Weight gain (daily)**
  - Term infants: at least 20-30 gm/day
  - Preterm infants: at least 10 gm/kg/day
  - Infants/Children
    - 3-12 months of age: 10-25 gm/day
    - 12-24 months of age: 5-10 gm/day

- **Height/length (weekly)**

- **Head circumference (weekly)**
  - Neonates and young infants
Nutritional Assessment
Visceral Protein Measurements

- **Serum albumin**
  - Long half-life of 14-20 days
  - Poor indicator of acute nutritional assessment
  - May be affected by albumin infusion, dehydration, sepsis, trauma, liver disease

- **Prealbumin**
  - Short half-life of 1-2 days
  - Good indicator of acute nutritional assessment
  - Good marker for visceral protein pool
  - May be decreased in liver disease and falsely elevated in renal failure

- **Blood urea nitrogen (BUN)**
  - Low BUN < 5 mg/dL: inadequate amino acid intake
  - High BUN > 20 mg/dL: too much amino acid intake
<table>
<thead>
<tr>
<th>Labs</th>
<th>Baseline</th>
<th>Daily for several days</th>
<th>Twice a week</th>
<th>Q 1-2 weeks</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolytes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Serum glucose (Accuchecks Q8hrs) | ✓        | ✓                      | ✓            |             | - Increase GIR if glucose < 120 mg/dL  
- Decrease GIR if glucose > 150 mg/dL                                      |
| Liver function tests        | ✓        |                        | ✓            | ✓           | DB > 2 mg/dL (early signs of cholestasis)                                  |
| Triglycerides               | ✓        |                        | ✓            |             | - Increase FAT if TG < 150 mg/dL  
- Decrease FAT if TG > 250 mg/dL (infants) or > 400 mg/dL (children)       |
| Trace elements (Zinc, Cu, Mn) |         |                        | ✓            | ✓           | May be considered in those with cholestasis or have ileostomies            |
Transition from Parenteral to Enteral Nutrition

- Depends on duration of PN, individual circumstances and age and size of infant or child
- Decrease amount of all parenteral nutrients while increasing enteral feeds as tolerated
- Do not dilute or concentrate formulas or breast milk
- Discontinue parenteral nutrition when
  - 3/4 or 75% enteral intake in neonates/infants
  - 2/3 or 67% enteral intake in children
What You Need to Know When Writing or Checking Parenteral Nutrition Order

- **Weight of patient**
  - Use birth weight until gains birth weight
- **Infusion site**
  - Peripheral or central (UVC, PCVC, broviac, fem)
- **Total fluid intake**
- **Other IV fluids given as continuous infusions**
- **Enteral feedings**
- **Laboratory values**
- **Medical conditions**
  - Renal and/or liver failure
How to Check a TPN Order

- **For peripheral TPN**
  - Limit dextrose 10-12.5%
  - Limit protein 2.5-3%
  - Calcium conc $\leq 10 \text{ mEq/L}$
  - Potassium conc $\leq 40 \text{ mEq/L}$

- **Check each component for**
  - Adequate dose adjusted based on renal/liver failure
  - Decimal point errors
  - Large increase or decrease in rate or nutrients from previous day
  - Omission of electrolytes and micronutrients

- **Calcium and phosphate solubility**
Calculations for Checking Calcium/Phosphate Solubility

- Protein % = $\frac{\text{gm/kg/day} \times Wt \ (kg) \times 100}{\text{TPN volume (mL)}}$

- Calcium (mEq/L) = $\frac{\text{Calcium (mEq/kg/day)} \times Wt \ (kg)}{\text{TPN volume (L)}}$

- Phosphate (mMol/L) = $\frac{\text{Phosphate (mMol/kg/day)} \times Wt \ (kg)}{\text{TPN volume (L)}}$
Calculations of Caloric Intake

- **CHO (dextrose):** GIR x 4.9 = kcal/kg/day
- **Intralipid (20%):** 2 Kcal/ml
- **Formulas**
  - 20 cal/oz = 0.67 cal/mL
  - 22 cal/oz = 0.73 cal/mL
  - 24 cal/oz = 0.8 cal/mL
  - 27 cal/oz = 0.9 cal/mL
  - 30 cal/oz = 1 cal/mL
- **Breast milk:** ~20 cal/oz = 0.67 cal/mL
Calculate GIR and Calories

- Need to calculate GIR of TPN
- Need to calculate GIR of each IV fluid
  - If the fluids contain the same dextrose amount, can calculate GIR together
- Need to calculate caloric intake from fat
- Need to calculate caloric intake from feedings
- All caloric intake (CHO + fat only) must be calculated in Kcal/kg/day
Examples

- Patient on enteral feeds plus PN. Patient becomes NPO overnight and the physician would like to increase the current PN rate to make up the enteral feeds. Do you agree?
Examples

- 800-gm, 28 weeks preterm infant developed acute renal failure and the physician would like to decrease her fluid intake from 140 mL/Kg/day (4.7 mL/hr) to 60 mL/Kg/day. (2 mL/hr). He gives a verbal order to the nurse to decrease the current PN solution to 2 mL/hr. Do you agree?
Examples

- Patient developed acute renal failure and the physician would like to eliminate amino acid intake in the PN. Do you agree?
- The PN solution contains dextrose 12%, amino acids 3 gm/kg/day, and the following electrolytes.

<table>
<thead>
<tr>
<th>mEq/kg/day</th>
<th>mEq/kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium: 5</td>
<td>Calcium gluconate: 3</td>
</tr>
<tr>
<td>Potassium: 3</td>
<td>Phosphate: 1.5</td>
</tr>
<tr>
<td>Chloride: 3</td>
<td>Magnesium: 0.25</td>
</tr>
<tr>
<td>Acetate: to balance</td>
<td></td>
</tr>
</tbody>
</table>
Patient (1.2 kg) with TPN solution infusing at a rate of 5 mL/hr via a central line but overnight, the line was dislodged and the RN wants to hang the current TPN bag via a peripheral vein since this is the only line the patient has. Do you agree with the RN’s recommendation?

The current PN contains dextrose 11%, protein 3.5 gm/kg/day and the following electrolytes:

<table>
<thead>
<tr>
<th>mEq/kg/day</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Sodium: 3</td>
<td>Calcium gluconate: 4</td>
</tr>
<tr>
<td>Potassium: 1.5</td>
<td>Phosphate: 2</td>
</tr>
<tr>
<td>Chloride: 0</td>
<td>Magnesium: 0.25</td>
</tr>
<tr>
<td>Acetate: to balance</td>
<td></td>
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</tbody>
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