Pediatric Nutrition Support

MAKING BABIES

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Park City, Utah

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Human Broth  (Julia’s Child Recipe)

- **Water**
- **Proteins:** Essential Amino Acids (8 + histidine, cysteine; +/- arginine, glutamine, taurine, tyrosine)
- **Fat:** essential fatty acids: linoleic (n-6), linolenic(n-3)
- **Salts:** NaCl, K₂PO₄, CaPO₄, MgSO₄
- **Metals:** Fe, Zn, Cu, Mn, Se, Cr, Mb, Sn, I
- **Vitamins:** A, Bs, C, (D), E, (K), biotin, inositol, pyridoxine
- **Sugars:** (Glucose)
- **Spices/Extras:** (choline, carnitine), fiber, microbes

*Mix water, protein, and fat to emulsify well; Blend in metals and vitamins; Add sugars and salts to taste; Sprinkle with fiber and microbes and simmer at 37° C

*Knead gently and Serve warm.*
The Nutrient Prescription

• Volume
• Determine a reference or metabolic weight
• Energy:
  – Total kcals needed
  – Composition of energy: Lipid + Carbohydrate
• Protein:
  – % total kcals
  – Non-protein kcal to Nitrogen ratio
• Electrolytes and Minerals
• Micronutrients
Volume Needs : Energy Needs

• Insensible losses: 40 cc/100 kcal
• Urinary losses: 60 cc/100 kcal
• Total losses: 100 cc/100 kcal
  – (Add 5 cc/kg for each degree > 38 C)
  – Caloric Needs:
    • 120 kcal/kg ----- 0-3 kg
    • 100 kcal/kg ----- 3-10 kg
    • 1000 + 50 kcal/kg------ each kg from 11-20
    • 1500 + 20 kcal/kg------ each kg > 20
Energy Expenditure

• Resting Metabolic Rate
• Total Daily Energy Expenditure
• Thermic Effect of Food
• Metabolic Mass: Lean Body Mass
  – Brain, Liver, Heart, Kidney
  – Muscle
  – Adipose/Fat Mass: metabolically inert
• Disease Effects
Body Composition: Fat vs. Lean

Composition of Metabolic Demand

TDEE = 1.6 x BMR
%BMR / 1.6 = %TDEE
60% BMR = 40% TDEE
40% BMR = 25% TDEE

Under 20 kg, the brain uses 25 - 40% of total calories!
Changing Proportions

The brain-head size is relatively huge for infants!
Determination of % weight for height age:

Length: 83 cm

Height age: 20 months

Actual Wt: 10 kg

Expected Wt: 11.4 kg

$\frac{10}{11.4} = 0.88$

or 88% of expected wt for length
Body Mass Index:
weight/(height)^2 = (kg/m^2)

Weight: 10 kg
Length: 83 cm = 0.83 m
BMI = 10 / 0.83 / 0.83 = 14.5 (5th %ile)
Weight for mean BMI

\[(\text{kg/m}^2) \times m^2 = \text{kg}\]

Weight: 10 kg
Length: 83 cm = 0.83 m
Age = 2 years
Mean BMI for 2 yrs = 16.5

\[16.5 \times 0.83 \times 0.83 = 11.4 \text{ kg}\]
Caloric Requirements

• Use median ("ideal") weight for height as Reference Weight
  – Fat is metabolically inert
  – Brain > Visceral Organs > Muscle consume metabolic energy
  – Consider using weight for cranial(OFC) age if head relatively large compared to length
• Multiply x RDA kcal/kg for wt-age or ht-age
• Example:
  – Average Infants are > 20%fat
  – Wasted 8 kg infant is 80% weight for height age
  – 10 kg is median weight for height age (adding the fat back)
  – Caloric needs are based on normally composed infant:
    • 100 kcal/kg x 10 kg = 1000 kcal/day
  – Kcal/kg actual weight: 1000 kcal/8kg = 125 kcal/kg
Estimated Energy Needs (RDA)

Age (years):
• 0-1
• 1-7
• 7-12
• 12-18
• >18

Kcal/kg body weight:
• 90-120
• 75-90
• 60-75
• 30-60
• 25-30

• Parenteral (IV) Requirement = 0.7-0.8 x Enteral
  • 70-80 kcal/kg TPN = 100 kcal/kg EN
Composition of Energy

• Carbohydrate $\rightarrow$ glucose
  – 3.4 kcal/gram (IV glucose)
  – 3.7 kcal/gram (PO glucose)
  – 40-50% of energy

• Fat:
  – 10 kcal/gram (IV lipids): lipid emulsions: 20 % = 20 g/100ml
  – 9 kcal/gram (PO fat)
  – > 30 - 40% of calories for < 2 years
  – < 30% of calories for > 2 years
  – Essential Fatty Acids
    • Omega 6: linoleic acid $\rightarrow$ ARA $\rightarrow$ PG
    • Omega 3: linolenic acid $\rightarrow$ EPA/DHA $\rightarrow$ cytokines
Substrate Tolerance

- Fluid Volume
- Electrolytes and Minerals
- Glucose
- Lipids
- Amino Acids
- Alterations in Disease States:
  - Cardiac, Pulmonary, Renal, Hepatic
  - Inflammatory: infection, immunologic
  - Endocrine: insulin, corticosteroid
  - GI: short gut, maldigestion, malabsorption
  - Liver: cholestasis, fatty liver disease
Respiratory Quotient:

\[ RQ = \frac{\text{vCO}_2}{\text{vO}_2} \]

- **CHO oxidation:** \( RQ = 1.0 \)
  - \( \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \implies 6\text{CO}_2 + 6\text{H}_2\text{O} \)
  - Maximum rate: 8 mg/kg/min

- **FAT oxidation:** \( RQ = 0.7 \)
  - \( \text{C}_{16}\text{H}_{32}\text{O}_2 + 23\text{O}_2 \implies 16\text{CO}_2 + 16\text{H}_2\text{O} \)

- **CHO ----> FAT synthesis:** \( RQ = 8.7 \)
  - \( 13.5\text{C}_6\text{H}_{12}\text{O}_6 + 3\text{O}_2 \implies \text{C}_{55}\text{H}_{104}\text{O}_6 + 26\text{CO}_2 + 29\text{H}_2\text{O} \)
  - For glucose infusion > 8 mg/kg/min

*Overfeeding carbs/calories makes extra CO\textsubscript{2} to blow off*
Balance Fat and Carbs

• Too much glucose: > 8-15 mg/kg/min
  – Hyperinsulinemia
  – High RQ: increased CO2 per kilocalorie in fat synthesis
  – Fatty liver disease: fatty acid toxicity

• Too little glucose:
  – Gluconeogenesis: protein catabolism
  – Ketogenesis if inadequate glucose

• Too much fat: > 3.5 g/kg/d or 0.15 g/kg/hr
  – Lipemia: atherogenic; dCO, PA viscosity, platelet/PMN

• Too little fat: < 3-6% of total energy(calories)
  – Essential fatty acid deficiency
  – Increased general glucose consumption
Energy: Protein Interrelationship

- **Obligatory glucose requirement:**
  - Brain: glucose or ketones
  - Gluconeogenesis:
    - Glycogen
    - Protein: catabolism of branched chain amino acids in caloric insufficiency
  - Lipolysis /Ketogenesis as protein-sparing
  - Transition to ketone metabolism (> 24 hours)

- **Energy → Protein retention (+N-balance)**
Protein Requirements

- LBW infant
- Full-term infant
- 1-10 years
- Boys > 10
- Girls > 10
- Critically Ill child

- 3-4 g/kg/day
- 2-3
- 1-1.2
- 0.9
- 0.8
- 1.5
Protein-Energy Relationship

At any level of protein intake, increasing energy intake increases nitrogen retention (N-balance)
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Protein Requirements

• Protein : Energy relationship
• Protein is 16% Nitrogen:
  • Nitrogen Balance based on N in – N out
    – Increasing energy intake improves N-bal
    – Increasing protein intake improves N-bal
• Protein : 4 kcal/gm
• Ideal non-protein kcal to Nitrogen ratio:
  – 150 – 200 kcal/g N or 24 – 32 kcal/g Protein
  – 11 to 15 % of total calories

*Need to give enough energy to keep from burning protein!*
Electrolyte and Mineral Needs

- Na: 3 mEq/kg
- K: 2 mEq/kg
- Cl: 5 mEq/kg
- Ca:
  - 0-6 mos.: 210 mg
  - 6-12 mos.: 270 mg
  - 1-3 yrs.: 500 mg
  - 4-8 yrs.: 800 mg
  - 9-18 yrs.: 1300 mg
Micronutrients

- **Iron:** 1 mg/kg  
  \( (4 \text{ - } 12 \text{ mg/liter} \rightarrow 1 \text{ mg/100cc}) \)
- **Other metals:** Zn, Cu, Mn, Se, Cr, Mb
- **Vitamins**
  - **Fat Soluble:** A, D, E, K
  - **Water Soluble:** B-vitamins [thiamine, riboflavin, niacin, folate, pantothenate, B6, B12] , Biotin, Ascorbic(C)
- **Essential Fatty Acids (\( \sim 3\text{-}6\% \text{ of total calories})\):**
  - Omega 6 fatty acids \( \rightarrow \) ARA \( \rightarrow \) PGs
  - Omega 3 fatty acids \( \rightarrow \) EPA \( \rightarrow \) DHA \( \rightarrow \) leukotrienes
## Composition of formulas

<table>
<thead>
<tr>
<th>CHO</th>
<th>Human milk</th>
<th>Infant Formula</th>
<th>Cow Milk</th>
<th>Child Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>11g/100kcal</td>
<td>41% 11g/100kcal</td>
<td>26% 6.9g/100 kcal</td>
<td>53% 13.2 g/100</td>
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<tr>
<td>53%</td>
<td>13.2 g/100</td>
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<tr>
<td>6%</td>
<td>1.5 g/100</td>
<td>8.4% 2.1 g/100</td>
<td>20% 4.9 g/100 kcal</td>
<td>12% 3 g/kg/100</td>
</tr>
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<td>2.1 g/100</td>
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<tr>
<td>12%</td>
<td>3 g/kg/100</td>
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</tr>
<tr>
<td>51%</td>
<td>5.7g/100</td>
<td>48% 5.3 g/100</td>
<td>50% 5.6 g/100 kcal</td>
<td>35% 4 g/kg/100</td>
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<tr>
<td>51%</td>
<td>5.7g/100</td>
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</tr>
<tr>
<td>35%</td>
<td>4 g/kg/100</td>
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<tr>
<td>0.67 kcal/cc</td>
<td>0.67 kcal/cc</td>
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<td>0.67 kcal/cc</td>
<td>1 kcal/cc</td>
</tr>
</tbody>
</table>
Jejunum: longer villi, absorbs most nutrients, fluid excretion

Ileum: B12, bile acids, fat soluble vitamins, tight junctions, net absorption, more adaptable. Peyers patches immunity. Enterohepatic circulation

Colon: Absorbs water, electrolytes, short chain fatty acids, vitamin K
Algorithm for Administration

- Functional GI tract: Enteral
  - Oral:
    - Breast Milk; fortifier
    - concentrated formula, additives
  - Nasogastric
  - Nasojejunal
  - Gastrostomy
    - Percutaneous Endoscopic
    - Surgical + Anti-reflux surgery
  - Gastrojejunostomy
  - Jejunostomy
Algorithm for Administration

• Dysfunctional GI Tract: Parenteral
  – Peripheral IV:
    • risk infiltration, osmotic limits
  – Central Venous
    • Peripherally Inserted CV Catheter (PICC)
    • Tunneled CV Catheter (eg Broviac)
    • Sub-cutaneous access port (eg Portacath)
Parenteral Strategy

• Avoid excessive calories:
  – complement enteral intake, assuming 80% efficiency to approx. 80-90 kcal/kg equivalent TPN calorie total; dextrose < 15 mg/kg/min
  – Risk of hepatic steatosis

• Cycle TPN: 2-12 hours off as enteral increases

• Trophamine AA: has taurine, tyrosine

• Balanced nutrient composition:
  – 12-15% AA (up to 3.5 g/kg/day-LBW; 2.5- FT)
  – 30% lipids (up to 3 g/kg/day)
Accommodation / Refeeding Risks

• Chronically malnourished patient is adapted or *accommodated* to the undernourished steady state.
  – Reduced metabolic rate, cardiac demand
  – Depleted intracellular ions: K, P, Ca, Mg
  – Depleted fat and muscle stores, including myocardium

• Providing nutrients increases metabolic demand:
  – Increased cardiac demand/stress
    • Congestive heart failure, edema
  – Intracellular influx of P, K, Mg, Ca;
  – P bound in ATP, intermediary metabolism.
    • Risk of hypophosphatemia, hypoK, hypoMg, hypoCa
    • Risk of prolonged QTc and ventricular arrhythmia on ECG
Refeeding Syndrome

Starvation / Malnutrition

Glycogenolysis, gluconegenesis and protein catabolism

Protein, fat, mineral, electrolyte and vitamin depletion – salt and water intolerance

Refeeding (switch to anabolism)

Fluid, salt, nutrients (CHO major energy source)

↓ Insulin secretion

↑ Protein and glycogen synthesis

↑ Uptake of K⁺, Mg²⁺ & PO₄²⁻

↑ Utilization of thiamine

↑ Glucose uptake

Salt and water retention - oedema

Hypokalaemia
Hypomagnesaemia
Hypophosphataemia
Thiamine deficiency

Refeeding syndrome