NUTRIENT REQUIREMENTS OF PRETERM INFANTS

M. Luisa Malheiro
Serviço de Neonatologia, CHAA, Guimarães
“The chief variable in determining the weight curve of such infants is the feeding policy”

Goal of Nutrition in Term Infant

- Growth and development of the healthy breast-fed term infant

Daily nutrient requirements defined as the amount present in the average volume of human milk ingested daily

Food and Nutrition Board, Institute of Medicine 2002
Goal of Nutrition in Preterm Infant

- Achieving a post-natal growth that approximates the in utero growth of normal fetus at the same postconceptional age

American Academy of Pediatrics Committee on Nutrition, 1985

Sufficient? Desirable? Achievable?
Goal of Nutrition in Preterm Infant

- Intrauterine different from extrauterine environment
- Small stores
- Rapid growth
- Metabolic immaturity
- Gastro-intestinal immaturity
- Immature neuromuscular function
- Medical/surgical complications
- Inadequate nutritional intake

Embleton NE. Pediatrics 2001
Fetal nutrition vs “Classic” preterm nutrition

- **Amino acids** are pumped into the fetus at rates and concentrations that are higher than he can use
  - Excess amino acid load is oxidized for energy
  - **Glucose** is taken up and used to meet energy needs
  - Little fetal **lipid** uptake

- **Amino acids** are provided at rates that are less than needed for normal growth rates
  - **Glucose** is pumped into the infant at rates and concentrations that are higher than infant can use
  - The excess glucose load produces hyperglycemia and fat deposition
  - **Lipids** provided at high amounts as energy source

Hay WW. Neonatology 2008
Postnatal growth restriction

Ehrenkranz RA. Pediatrics 1999
Clin Perinatol 2000
Postnatal growth restriction

- Multifactorial origin; about 50% - nutritional deficits

Protein deficit - Main limiting factor of growth

- Adequate protein intake rarely achieved in practice

Discrepancy between daily recommended dietary intakes (RDI) and actual intakes in the first weeks of life

<table>
<thead>
<tr>
<th>Deficit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy deficit</td>
<td>$813 \pm 542$ kcal/kg</td>
</tr>
<tr>
<td>Protein deficit</td>
<td>$23 \pm 12$ g/kg</td>
</tr>
</tbody>
</table>

by 5th week of life

Carlson SJ, Ziegler EF. J Perinatol 1998
Kashyap S. Am J Clin Nutr 1990

Embleton NE. Pediatrics 2001
Postnatal growth restriction

Consequences:

- Increased short-term morbidity
- Growth failure / Impaired growth
- Impaired neurocognitive development
Postnatal growth restriction

- Increased short-term morbidity

> Vulnerability to infectious diseases
  Lafeber HN. J Nutr 2008

> Susceptibility to lung injury
  Bhatia J. Neonatology 2009

< Intestinal maturation
Postnatal growth restriction

- **Growth failure / Impaired growth**

  . 20% VLBW infants < 10<sup>th</sup> P at birth
  . 96% VLBW infants < 10<sup>th</sup> P at discharge

  Lemons JA. Pediatrics 2001

  . 34-45% VLBW < 10<sup>th</sup> P at 18 months corrected age

  Dusick A. Pediatr Research 2001

  . VLBW females catch-up growth by 20 years
  VLBW males remain significantly shorter and lighter than controls

  Hack M. Pediatrics 2003
Postnatal growth restriction

- Growth failure / Impaired growth

  . Impaired organ development

    - Pancreas
      - $\downarrow$ insulin secretion/ insulin resistance ...
      - $\downarrow$ capacity amino acids synthesis into protein

    - Kidneys
      - $\downarrow$ nephrons size and number ...

  . Osteopenia, micronutrients deficits

- Diabetes
- HTA
Postnatal growth restriction

- **Altered body composition**
  
  Body composition at hospital discharge
  
  149 PT ≤ 34 w GA, ≤ 1750g BW

  - Reduced linear growth
  - >> Global and central fat mass
  - < Global fat free mass

  suggesting that dietary protein needs were not met before discharge

Concerns about the development of insulin resistance and metabolic syndrome x

Cooke RJ. Acta Paediatrica 2009
Postnatal growth restriction

• **Brain development**

  Last trimester of pregnancy, *in* or *ex-útero*  
  Neuronal differentiation  
  Synaptogenesis  
  Myelination  
  If undernutrition not prevented / corrected

  Permanent alterations in **brain** growth, structure and function

**Impaired neurocognitive development**
Impaired neurocognitive development

- Postnatal growth restriction associated with **impairment of neurocognitive development** in a dose dependent fashion
  
  Age of follow-up ranged from 1 to 19 years

Improvement of neurocognitive outcome

- Study linking neurodevelopmental outcome directly to nutrient intakes rather than to growth failure

Increase **first week** protein and energy intakes, in EBP infants

- Higher MDI scores and lower likelihood of length growth restriction at 18 months

  - Every 10 kcal/kg/day energy ➔ 4.6 point increase in MDI
  - Every 1g/kg/day protein ➔ 8.2 point increase in MDI

Higher protein intake ➔ Lower likelihood length < 10th percentile

Early origins of adult disease

- Risk factor of disease in adulthood

“Early rapid growth can lead to the development of adverse cardiovascular markers, such as lipid profile, arterial hypertension and insulin resistance in adolescence and adulthood”

Singhal A et al. Early origins of Cardiovascular Disease: Is There a Unifying Hypothesis? Lancet 2004
“The Neonatologist´s Dilemma”

• Adverse effect of postnatal growth restriction in short term prognosis and neurodevelopment

  Versus

• Adverse effect of rapid catch-up growth, after fetal or postnatal growth restriction, in long term health

“Catch-up growth or Beneficial Undernutrition?”

Thureen PJ. The Neonatologist´s Dilemma: Catch-up Growth or Beneficial Undernutrition in VLBW Infants- What Are The Optimal Growth Rates? JPGN 2007
If addressed properly, an adequate nutrition will at least partly prevent postnatal growth restriction and could prevent the necessity for a long and large catch-up growth curve.

Martin CR. Pediatrics 2009
“The Neonatologist's Dilemma”

“There can be no questions that the advantages associated with catch-up growth outweigh any possible disadvantages”

Ziegler EE. Nestlé Nutr Workshop ser Pediatr Program 2007
Nutrient requirements of preterm infants

• A good understanding of nutrient requirements is a prerequisite for efforts to ameliorate inadequate nutrition
Nutrient requirements of preterm infants

Factorial and Empirical Methods

- Factorial method

  - Based on chemical composition of human fetus, constructed the *reference fetus* (Ziegler EE, 1976)

  - Uses the fetal model to derive necessary intakes of **protein**, energy, and other nutrients

  - Permit estimation of the extra nutrients needed for catch-up growth

Ziegler EE. Ann Nutr Metab 2011
Requirements Determined by the Factorial Method

Table 1. Protein and energy intakes needed to achieve fetal weight gain

<table>
<thead>
<tr>
<th></th>
<th>Body weight</th>
<th>500–700 g</th>
<th>700–900 g</th>
<th>900–1,200 g</th>
<th>1,200–1,500 g</th>
<th>1,500–1,800 g</th>
<th>1,800–2,200 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fetal weight gain, g/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fetal weight gain, g/kg/day</td>
<td></td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>Protein, g/kg/day</td>
<td></td>
<td>21</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Loss</td>
<td></td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Growth (accretion)</td>
<td></td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.4</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Required intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parenteral</td>
<td></td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.4</td>
<td>3.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Enteral</td>
<td></td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>3.9</td>
<td>3.6</td>
<td>3.4</td>
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<tr>
<td>Energy, kcal/kg/day</td>
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<td>Loss</td>
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<td>60</td>
<td>65</td>
<td>70</td>
<td>70</td>
<td>70</td>
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<tr>
<td>Resting expenditure</td>
<td></td>
<td>45</td>
<td>45</td>
<td>50</td>
<td>50</td>
<td>50</td>
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<td>Other expenditure</td>
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<td>15</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Growth (accretion)</td>
<td></td>
<td>29</td>
<td>32</td>
<td>36</td>
<td>38</td>
<td>39</td>
<td>41</td>
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<tr>
<td>Required intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parenteral</td>
<td></td>
<td>89</td>
<td>192</td>
<td>101</td>
<td>108</td>
<td>109</td>
<td>111</td>
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<tr>
<td>Enteral</td>
<td></td>
<td>105</td>
<td>118</td>
<td>119</td>
<td>127</td>
<td>128</td>
<td>131</td>
</tr>
<tr>
<td>Protein/energy, g/100 kcal</td>
<td></td>
<td>3.9</td>
<td>3.8</td>
<td>3.5</td>
<td>3.1</td>
<td>2.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Parenteral</td>
<td></td>
<td>3.8</td>
<td>3.7</td>
<td>3.4</td>
<td>3.1</td>
<td>2.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Enteral</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Nutrient requirements of preterm infants

• Empirical method

  . The intake of growth-limiting nutrients, energy and protein (in formulas or human milk) is manipulated, and uses the growth and/or nitrogen balance as outcome

  . Estimates of requirements for protein and energy needed to achieve a specific rate of growth

  . Can provide estimates of nutrient needs for catch-up growth and what degree it is possible.
**Table 3.** Protein requirements and recommended intakes

<table>
<thead>
<tr>
<th></th>
<th>Weight &lt;1,200 g</th>
<th></th>
<th>Weight &gt;1,200 g</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg/day</td>
<td>g/100 kcal</td>
<td>g/kg/day</td>
<td>g/100 kcal</td>
</tr>
<tr>
<td>Ziegler (table 1)</td>
<td>4.0</td>
<td>3.7</td>
<td>3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Kashyap and Heird [34]</td>
<td>–</td>
<td>–</td>
<td>3.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Rigo [35]</td>
<td>3.8–4.2</td>
<td>3.3</td>
<td>3.4–3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>LSRO [37]</td>
<td>3.4–4.3</td>
<td>2.5–3.6</td>
<td>3.4–4.3</td>
<td>2.5–3.6</td>
</tr>
<tr>
<td>ESPGHAN 2010 [38]</td>
<td>4.0–4.5</td>
<td>3.6–4.1</td>
<td>3.5–4.0</td>
<td>3.2–3.6</td>
</tr>
</tbody>
</table>

**LSRO** = Life Sciences Research Office; **ESPGHAN** = European Society for Pediatric Gastroenterology, Hepatology and Nutrition.

LSRO e ESPGHAN 2010- carga calórica máxima de 135 Kcal/kg/dia
VII- Recommended Intakes
Official recommendations

1. Guidelines on Paediatric Parenteral Nutrition of the European Society of Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) and the European Society for Clinical Nutrition and Metabolism (ESPEN), Supported by the European Society of Paediatric Research (ESPR)


*Dr. von Hauner Children’s Hospital, Ludwig-Maximilians-University of Munich, Germany; †Hopital Necker-Enfants Malades, Paris, France, ‡Meyer Children’s Hospital, Haifa, Israel
## 1. Parenteral Nutrition

### Energy

- Resting metabolic rate: 40 kcal/kg/d
- Protein accretion: 10 kcal/g protein intake (above 1g)
- Minimum energy requirement: 50 kcal/kg/g at amino acid 2g/kg/d
- Maximum: 60 kcal/kg/d 
  
- Goal: 90-100 kcal/kg/d
- Maximum: 110 kcal/kg/d
1. Parenteral Nutrition

Amino Acids
Without protein intake EBW infant loses 1.5% total body protein/day, so amino acids supply should start on the first postnatal day

• A minimum amino acid intake of 1.5 g/kg/d is necessary to prevent a negative nitrogen balance. Higher intakes are needed to achieve physiological protein deposition

• Protein of 2-4 g/kg/d with caloric intake of 100 kcal/kg may maximize protein accretion

• A maximum amino acid intake of 4g/kg/d is recommended
1. Parenteral Nutrition

Lipids

- In order to prevent EFA deficiency a minimum linoleic acid intake of $0.25\text{g/kg/d}$ should be given to preterm infants.

- Parenteral lipid intake should be limited to a maximum of $3\text{ (4) g/kg/d}$ in infants, administered continuously over 24h.

- If lipid infusion is increased in increments of $0.5-1\text{g/kg/d}$, it may be possible to monitor for hypertriglyceridermia.

- Lipid intake should provide 40% of non protein PN calories in newborns.
1. Parenteral Nutrition

Glucose

• In preterm infants glucose infusion should be started with 4-8 mg/kg/min and should be increased to the highest rate that is tolerated while maintaining euglycemia.

• The rate of glucose administration that exceeds the maximal glucose oxidative capacity probably is above 11-13 mg/kg/min (≈18 g/kg/d).

• Glucose intake should usually cover 60-75% of non-protein calories.
1. Parenteral Nutrition

Table 1. Fluid and macronutrient guidelines for parenterally fed premature infants by ESPGHAN and ESPEN (European Society for Clinical Nutrition and Metabolism) in 2005 [2]

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Goal, per kg/day</th>
<th>When to start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid, ml</td>
<td>BW &lt;1.5 kg 160–180</td>
<td>immediately with 80–90 ml/kg per day</td>
</tr>
<tr>
<td></td>
<td>BW &gt;1.5 kg 140–160</td>
<td>immediately with 60–80 ml/kg per day</td>
</tr>
<tr>
<td>Energy, kcal</td>
<td>110–120</td>
<td></td>
</tr>
<tr>
<td>Protein, g</td>
<td>1.5–4.0</td>
<td>postnatal day 1</td>
</tr>
<tr>
<td>Lipids, g</td>
<td>up to 3–4</td>
<td>postnatal days 1–3</td>
</tr>
<tr>
<td>Carbohydrates, g</td>
<td>up to 11.5–18.0 (8.0–12.5 mg/kg per min)</td>
<td>immediately with 5.8–11.5 g/kg per day (4–8 mg/kg per min)</td>
</tr>
</tbody>
</table>
2. Enteral Nutrition

Enteral Nutrient Supply for Preterm Infants: Commentary From the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition Committee on Nutrition

*C. Agostoni, †G. Buonocore, ‡V.P. Carnielli, §M. De Curtis, ¶D. Darmaun, ⌂T. Decsi,  
#M. Domellöf, **N.D. Embleton, ††C. Fusch, †††O. Genzel-Boroviczeny, §§O. Goulet, ||||S. C. Kalhan,  
††S. Kolacek, †°B. Koletzko, ***A. Lapillonne, ††††W. Mihatsch, ††††L. Moreno, §§§J. Neu,  
||||||B. Poindexter, †††††J. Puntis, ††††G. Putet, ****1J. Rigo, †††††A. Riskin, †††††B. Salle, §§§§P. Sauer,  
||||||||R. Shamir, ††††††H. Szajewska, ††††††P. Thureen, *****D. Turck, †††††††J.B. van Goudoever,  
and ††††††††E.E. Ziegler, for the ESPGHAN Committee on Nutrition

JPEN 2010
Ranges of enteral intakes for stable growing preterm infants up to a weight of approx. 1800 g

The Committee advocates the use of human milk for preterm infants as standard practice, provided it is fortified with added nutrients where necessary to meet requirements. As an alternative to human milk, preterm formulas may be used.

Ranges of nutrient intake per 100 kcal will ensure that the infant receives intake of the minimum or maximum of each specific nutrient at an intake of 110 kcal/kg/d
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Min–max</th>
<th>Per kg(^{-1}) • day(^{-1})</th>
<th>Per 100 kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid, mL</td>
<td>135–200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy, kcal</td>
<td>110–135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein, g (&lt;1) kg body weight</td>
<td>4.0–4.5</td>
<td>3.6–4.1</td>
<td></td>
</tr>
<tr>
<td>Protein, g (1–1.8) kg body weight</td>
<td>3.5–4.0</td>
<td>3.2–3.6</td>
<td></td>
</tr>
<tr>
<td>Lipids, g (of which MCT &lt;40%)</td>
<td>4.8–6.6</td>
<td>4.4–6.0</td>
<td></td>
</tr>
<tr>
<td>Linolenic acid, mg(^{*})</td>
<td>385–1540</td>
<td>350–1400</td>
<td></td>
</tr>
<tr>
<td>(\alpha)-linolenic acid, mg</td>
<td>&gt;55 (0.9% of fatty acids)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DHA, mg</td>
<td>12–30</td>
<td>11–27</td>
<td></td>
</tr>
<tr>
<td>AA, mg(^{†})</td>
<td>18–42</td>
<td>16–39</td>
<td></td>
</tr>
<tr>
<td>Carbohydrate, g</td>
<td>11.6–13.2</td>
<td>10.5–12</td>
<td></td>
</tr>
<tr>
<td>Sodium, mg</td>
<td>69–115</td>
<td>63–105</td>
<td></td>
</tr>
<tr>
<td>Potassium, mg</td>
<td>66–132</td>
<td>60–120</td>
<td></td>
</tr>
<tr>
<td>Chloride, mg</td>
<td>105–177</td>
<td>95–161</td>
<td></td>
</tr>
<tr>
<td>Calcium salt, mg</td>
<td>120–140</td>
<td>110–130</td>
<td></td>
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<tr>
<td>Phosphate, mg</td>
<td>60–90</td>
<td>55–80</td>
<td></td>
</tr>
<tr>
<td>Magnesium, mg</td>
<td>8–15</td>
<td>7.5–13.6</td>
<td></td>
</tr>
<tr>
<td>Iron, mg</td>
<td>2–3</td>
<td>1.8–2.7</td>
<td></td>
</tr>
<tr>
<td>Zinc, mg(^{†})</td>
<td>1.1–2.0</td>
<td>1.0–1.8</td>
<td></td>
</tr>
<tr>
<td>Copper, (\mu)g</td>
<td>100–132</td>
<td>90–120</td>
<td></td>
</tr>
<tr>
<td>Selenium, (\mu)g</td>
<td>5–10</td>
<td>4.5–9</td>
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<td>Manganese, (\mu)g</td>
<td>(\leq)27.5</td>
<td>6.3–25</td>
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<td>Fluoride, (\mu)g</td>
<td>1.5–60</td>
<td>1.4–55</td>
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<tr>
<td>Iodine, (\mu)g</td>
<td>11–55</td>
<td>10–50</td>
<td></td>
</tr>
<tr>
<td>Chromium, mg(^{†})</td>
<td>30–1230</td>
<td>27–1120</td>
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<tr>
<td>Molybdenum, (\mu)g</td>
<td>0.3–5</td>
<td>0.27–4.5</td>
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<tr>
<td>Thiamin, (\mu)g</td>
<td>140–300</td>
<td>125–275</td>
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<tr>
<td>Riboflavin, (\mu)g</td>
<td>200–400</td>
<td>180–365</td>
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<tr>
<td>Niacin, (\mu)g</td>
<td>380–5500</td>
<td>345–5000</td>
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</tr>
<tr>
<td>Pantothenic acid, mg</td>
<td>0.33–2.1</td>
<td>0.3–1.9</td>
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</tr>
<tr>
<td>Pyridoxine, (\mu)g</td>
<td>45–300</td>
<td>41–273</td>
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<tr>
<td>Cobalamin, (\mu)g</td>
<td>0.1–0.77</td>
<td>0.08–0.7</td>
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<tr>
<td>Folic acid, (\mu)g</td>
<td>35–100</td>
<td>32–90</td>
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<tr>
<td>l-ascorbic acid, mg</td>
<td>11–46</td>
<td>10–42</td>
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<tr>
<td>Biotin, (\mu)g</td>
<td>1.7–16.5</td>
<td>1.5–15</td>
<td></td>
</tr>
<tr>
<td>Vitamin A, (\mu)g RE, 1 (\mu)g ~ 3.33 IU</td>
<td>400–1000</td>
<td>360–740</td>
<td></td>
</tr>
<tr>
<td>Vitamin D, IU/day</td>
<td>800–1000</td>
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<td></td>
</tr>
<tr>
<td>Vitamin E, mg</td>
<td>2.2–11</td>
<td>2–10</td>
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</tr>
<tr>
<td>((\alpha)-tocopherol equivalents)</td>
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<td></td>
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</tr>
<tr>
<td>Vitamin K(_1), (\mu)g</td>
<td>4.4–28</td>
<td>4–25</td>
<td></td>
</tr>
<tr>
<td>Nucleotides, mg</td>
<td>(&lt;5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choline, mg</td>
<td>8–55</td>
<td>7–50</td>
<td></td>
</tr>
<tr>
<td>Inositol, mg</td>
<td>4.4–53</td>
<td>4–48</td>
<td></td>
</tr>
</tbody>
</table>
Fluid

- 135-200 ml/kg/d
- 150-180 ml/kg/d, for routine feeding

Energy

- If protein to energy ratios adequate (> 3-3.6g/100 kcal) energy intake > 100 kcal/kg/d is appropriate

Healthy growing preterm infant

110-135 kcal/kg/d
Enteral Nutrient Supply for Preterm Infants
ESPGHAN 2010

Protein
• Protein accretion 1,7-2,5 g/kg/d
  Protein loss ≈ 1,0 g/kg/d
• Protein intake 3 g/kg/d = weight gain ≈ in utero
• Compensation for accumulated protein deficit, protein supply up to 4,5 g/kg/d

BW ≤ 1000g  4,0-4,5 g/kg/d  3,6-4,1g/100 kcal
BW 1000g-1800g  3,5-4,0 g/kg/d  3,2-3,6g/100 kcal

! Current preterm formula  3,0g/100kcal
Enteral Nutrient Supply for Preterm Infants
ESPGHAN 2010

Lipids

- Intra-uterine fat deposition: 3g/kg/d
- Lipid loss from fat malabsorption: 10-40%
- From unavoidable oxidation: 15%

<table>
<thead>
<tr>
<th>Lipids (MCT&lt;40%)</th>
<th>4.8-6.6 g/kg/d</th>
<th>4.4-6.0 g/100 kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linoleic acid</td>
<td>385-1540 mg/kg/d</td>
<td>350-1400 mg/100 kcal</td>
</tr>
<tr>
<td>α-linolenic acid</td>
<td>&lt;55 mg (0.9% FA)</td>
<td>&lt;50 mg/100 kcal</td>
</tr>
<tr>
<td>DHA</td>
<td>12-30 mg</td>
<td>11-27 mg/100 kcal</td>
</tr>
<tr>
<td>AA</td>
<td>18-42 mg</td>
<td>16-39 mg/100 kcal</td>
</tr>
</tbody>
</table>

Beneficial effects: visual, cognitive and immune development
Carbohydrates

- Major source of energy

**Glucose** or nutritionally equivalent di, oligo and polysaccharides 11.6-13.2g/kg/d 10.5-12 g/100 kcal
Calcium/ Phosphorus

Calcium absorption depends on calcium and vitamin D intakes
Calcium retention is related do absorbed phosphorus

• Calcium/ phosphorus ratio ≈ 2/1

<table>
<thead>
<tr>
<th>Calcium</th>
<th>120-140 mg/kg/d</th>
<th>110-130 mg/100 kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>60-90 mg/kg/d</td>
<td>55-80 mg/100 kcal</td>
</tr>
</tbody>
</table>
Enteral Nutrient Supply for Preterm Infants
ESPGHAN 2010

**Vitamin D**  800-1000 IU/D during the first months of life

- Formula should provide the basic needs to which a supplement must be given, **100-350 IU/100 kcal**

**Iron**  2-3 mg/kg/d  1.8-2.7g/100 kcal

- Prophylactic enteral iron supplementation (separate iron supplement) should be started at 2-6 weeks of age (2-4 weeks in ELBW)
- Iron supplementation should be delayed in infants with multiple blood transfusions or > serum ferritin, and should continue at least until 6-12 months of age
### 2. Enteral Nutrition

**Table 2. Fluid and macronutrient guidelines for enterally fed premature infants by ESPGHAN in 2010 [1]**

<table>
<thead>
<tr>
<th></th>
<th>Goal (per kg/day)</th>
<th>Goal (per 100 kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid, ml</td>
<td>135–200</td>
<td>not applicable</td>
</tr>
<tr>
<td>Energy, kcal</td>
<td>110–135</td>
<td>not applicable</td>
</tr>
<tr>
<td>Protein, g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW &lt;1 kg</td>
<td>4.0–4.5</td>
<td>3.6–4.1</td>
</tr>
<tr>
<td>BW &gt;1 kg</td>
<td>3.5–4.0</td>
<td>3.2–3.6</td>
</tr>
<tr>
<td>Lipids, g</td>
<td>4.8–6.6</td>
<td>4.4–6.0</td>
</tr>
<tr>
<td>Carbohydrates, g</td>
<td>11.6–13.2</td>
<td>10.5–12.0</td>
</tr>
</tbody>
</table>
Preterm birth- Nutritional emergency

Hospital staff

Fortified HM + protein/Preterm formula

Infrastructure/ Monitoring

Early initiation MEN

Early initiation PN

Cooke R. Ann Nutr Metab 2011
Preterm birth - Nutritional emergency

Early PN with amino acids

- Prevention of protein catabolism
- Prevention of a decrease in growth regulating factors, such as insulin, and downregulation of glucose transporters
- Prevention of hyperglycemia and hyperkalemia

- Several studies demonstrated the **efficacy** and **safety** of early administration of amino acids, without recognizable metabolic derangements (hyperammonemia, metabolic acidosis, or abnormal aminograms). Increase of **blood urea nitrogen** is not a sign of toxicity.
Parenteral nutrition should start at birth and continue until enteral feeding provide > 90% required intakes

- **Aminoacids** should be started right at birth (≤ 2h) and should begin ≥ 2g/kg/d (3 g/kg/d), and increased within 2-4 days to 3.5-4 g/kg/d
- **Lipids** should start within 1-2 days of birth at a dose of 1 g/kg/d and increased to 3g/kg/d
- **Glucose** should be provided at the highest rate that is tolerated while maintaining euglycemia (≤ 13 mg/kg/min ≈ 18g/kg/d)
- **Energy** intakes need to be 90-110 kcal/kg/d for optimal growth
Preterm birth- Nutritional emergency

Early enteral nutrition, within 1-2 days of birth

- "Trophic feedings"; preferred feeding, human milk
- Standardized feeding schedules- Shorten the time to full feeds and reduce the risk of NEC

- Parenteral nutrition phased out as enteral feedings advance. Discontinued when full feeds reached

Late enteral nutrition

- Mother’s milk + HM fortifier + additional protein
- Formulas for premature infants
Take home messages

• The first few days or weeks of life provide a critical window which might well be the most decisive period in a premature infant life.

• Inadequate nutrition during this period has directly been linked to growth failure, disease and suboptimal long-term outcome, even into adulthood.

• Providing the right amount and quality of nutrients, at the right time, could prove pivotal for normal growth and development of those vulnerable infants.
THANK YOU!