Post Discharge Nutrition

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Declaration of potential conflicts of interest

Regarding this presentation the following relationships could be perceived as potential conflicts of interest:

- No conflicts of interest
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Objectives

- Fetal Programming
- “Malnutrition” during hospitalization
- Strategies and current outcomes
- Effects of disease states
- Iron, DHA
- Human milk
- Summary
Introduction

• Increasing survival of premature and extremely premature infants
• Hospital discharge at younger ages and weight
• Ongoing issues: nutrition, chronic lung disease, retinopathy, gastroesophageal reflux, apnea and immunizations
Introduction

- Adaptations in the immediate neonatal period may have long-term adverse outcomes
- Cardiovascular disease, hypertension, insulin resistance, diabetes mellitus, obesity
- Preterm infants experience both perinatal malnutrition and poor postnatal growth and malnutrition
- Increasingly unlikely that growth deficits can be made up by hospital discharge
Introduction

• Abundant evidence in the literature regarding critical windows where a stimulus or insult may have a lifelong consequence on structure or function

• Nutritional insults at a vulnerable period of brain development: permanent effects on brain size, cell number, behavior, learning memory [Dobbing, 1981]
Fetal Programming

• Low birth weight, small head circumference, or decreased length for age: associated increased risk for cardiovascular disease [Barker, 1989, 1993]

• Transgenerational: low maternal birthweight or HC: higher offspring blood pressure in adulthood [Fall et al., 1995]
Programming

• Most preterm infants are AGA
• Grow poorly in the postnatal period
• Resultant “SGA” status
• Catch up growth
Extremely Low Birth Weight Infants Grow Poorly

Average body weight compared to intrauterine growth

Ehrenkranz, Pediatrics, 1999
Reasons for poor postnatal growth

- Expected postnatal weight loss
- Undernutrition
  - delayed commencement of TPN
  - Intolerance to glucose and lipids
  - Feeding volumes and withholding
  - Unfortified human milk or term formulas
Best Practices for the current era

- Early aggressive parenteral nutrition
- Early enteral nutrition: either trophic or advance as tolerated but, at a slow rate
- Have guidelines for gastric residuals
- Human milk, fortified
- Age-specific formula for the premature infant
  - <1800g: 24 kcal, premature infant formula
  - 1801-2500: transitional formula
Nutritional Intake

• Example:
• Premature infants fed a standard term formula gain 13 g/kg/d and 1.2 mm HC/d
• When fed premature infant formulas, 16.6g/kg/d and 1.53 mm/d
• 110-130 kcal/kg/d should allow for adequate growth
Catch up growth

• Is it possible?
• Composition of weight gain
• Protein energy ratios of feedings compared to intrauterine predictions
Catch up Growth

![Graph showing catch up growth with bars for different categories: g/kg/d P, g/kg/d O, PROTEIN, Protein, Fat, FAT. The graph compares A, B, and C scenarios.]
Catch Up Growth

• Nearly impossible without excessive feeding or excessive fat gain
• Long-term consequences not known
Growth “In-Utero” and “Ex-Utero”, Bhatia et al., 1988
Skinfold thickness, 0 sec

![Bar chart showing skinfold thickness measurements in mm for Triceps, SubSc, and Abd in comparison between In-Utero (blue) and Ex-Utero (red) conditions.]
Late Enteral Nutrition

• Match or exceed intrauterine growth
• Current generation of formulas may not meet the nutrient needs, especially protein, of the smallest infants
• Human milk **MUST** be fortified: protein, Ca, Phosphorus, sodium, energy, zinc, iron
Protein Content of Preterm Human Milk

Lemons et al., Pediatr Res 1982

Protein, g/100mL

Day 7 | Day 14 | Day 21 | Day 28
## Protein Levels in Fortified Preterm Human Milk

<table>
<thead>
<tr>
<th></th>
<th>g/100 Calories</th>
<th>g/150 mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein in <em>unfortified</em> milk $^1$</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>1 packet powdered HMF + 25 mL PTHM</td>
<td>2.97</td>
<td>3.5</td>
</tr>
<tr>
<td>1 vial liquid HMF + 25 mL PTHM</td>
<td>4</td>
<td>4.8</td>
</tr>
<tr>
<td>PTHM + 30 calorie PTF [1:1]</td>
<td>2.64</td>
<td>3.3</td>
</tr>
</tbody>
</table>

## Assumed vs. Actual intakes

<table>
<thead>
<tr>
<th>Protein intake (g/kg/d)</th>
<th>Assumed</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Week 2</td>
<td>3.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Week 3</td>
<td>3.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Data of Arslanoglu, Moro & Ziegler, J Perinatology 2009; 29:489
Solutions to the problem of inadequate protein fortification of breast milk

In addition to commercial fortifier:

1. Add more fortifier
2. Add more protein
3. Targeted fortification
4. Add protein based on blood urea (BUN) ("adjustable fortification")
Approaches to Intervention

• Specially designed “post-discharge” formulas or preterm formulas
• Lucas et al. Randomized infants <1850g to either standard term formula or a post-discharge formula
• Higher bone mineral content, better weight, length and head circumference
Approaches to Intervention

- Lucas et al. Term or post-discharge formula for 9 months
- Weight was greater at 9 months but not at 18 months
- Length was greater at 9 and 18 months
- No differences in head circumference
- No differences in outcomes
- Growth benefits limited to males!
Growth with Preterm Formulas

Graph A: Weight (kg) vs. PMA (weeks)
- + 2SD
- Mean
- - 2SD
- BW, > 1250g
- BW, < 1250g

Graph B: Length (cm) vs. PMA (weeks)
- + 2SD
- Mean
- - 2SD
- BW, > 1250g
- BW, < 1250g
Approaches to Intervention

- Cooke et al. Randomized to preterm formula until 6 months post conception OR preterm until expected date of delivery and then term formula OR term formula for 6 months
- Down regulated intake to achieve similar energy intakes
- Higher protein, zinc, vitamin and mineral intakes
- Boys: weight, length, HC were greater in preterm formula group and persisted at 18 months
Approaches to Intervention

- Infants fed preterm formula had better growth compared to fortified human milk fed infants
- No differences in developmental outcome
- Breastfed after discharge: lower serum PO4, alkaline phosphatase, transferrin
- Lower bone mineral mass, poorer growth and higher fat mass in the first year
Therefore

• Preterm infant formulas
• Transitional formulas
• Fortified human milk
Post-Discharge Nutrition and Growth

Pediatrics 2008, JPGN 2009

- 39 LBW infants [2004-2005]
- Randomly assigned at discharge to fortified human milk or control
- Fed for 12 weeks, follow-up 1 year
- At 12 weeks significant improvement of length and head circumference, no change in weight
- At 1 year, increased length and bone mineral content, increased HC in <1250g
Incidence of Normal Body Weight* Among Very Low Birth Weight Infants

*Above the 10th percentile

Adapted from Lemons, Pediatrics, 2001
Post Discharge Growth 1982-85
Post Discharge Growth 1989-91
Infants < 1000g
Postnatal Malnutrition—Ernst et al., 2003

Figure 3. Comparison of infants <10th percentile for weight at birth, discharge, and follow-up showing extrauterine growth retardation during hospitalization with catch-up growth postdischarge.
Figure 4. Comparison of infants <10th percentile for HC at birth, discharge, and follow-up showing the same pattern as for weight.
Infants with Chronic Lung Disease

• After discharge, these infants do not always receive the intensive nutritional assessment and intervention

• 73% of infants in one study demonstrated weight decrease between discharge and 7 months

• Feeding enriched formula: improved length, lean mass, higher bone mineral content
Iron

• Growing fetus accumulates iron at a rate of 1.6-2.0 mg/kg/d
• Lower iron stores in growth restriction, diabetes, fetal losses
• Frequent blood sampling
• 6-10 mg/kg/d iron
• Standard formulas will provide 2 mg/kg/d when fed at 150 mL/kg/d
Osteopenia

• Calcium and phosphorus deficiency
• Fetus accumulates large quantities in third trimester
• Ca: 200 mg/kg/d, P 100 mg/kg/d
• Premature infants fed premature infant formulas until 6 months of age were longer than their term formula-fed counterparts
Bone Mineral Content

![Graph showing bone mineral content over postnatal age (weeks)].

- **Group HM**
- **Group F**

Bone Mineral Content (mg/cm)

**Postnatal Age (Wk)**

- Fortified Human Milk
- Human Milk or Term Formula
- Breastfeeding ± Mixed Diet

**Georgia Health Sciences University**
Growth in Preterm Infants
Innis et al 2002

- Preterm infants fed DHA, DHA and ARA or control and discharged on term formula without DHA
- Compared to breast-fed term infants
- Mean GA 29-30 weeks
- Mean BW 1230-1280g
Weight Innis et al., 2002

![Bar chart showing weight changes over time for different groups: Control, DHA, DHA+ARA, and BF. The chart compares weight at 40 weeks, 48 weeks, and 57 weeks.](chart.png)
Human Milk and IQ

- Exclusively breast-fed premature infants had an IQ score 10% higher than formula-fed counterparts
- ? Supplementing human milk could enhance growth while maintaining IQ advantage
- Fortification of human milk remains a challenge
- Increasing use of donor milk
- Inadequate protein intake remains reason for growth failure
Guidelines for feeding preterm infants

- < 1800g: 24 kcal/ounce preterm formula or fortified human milk
- Transition to 22 kcal/oz >1800g or fortified human milk, all growth parameters are 25% or above and gaining 15-40g/d
- Transition from 22 to 20 kcal/ounce term formulas or human milk at 4-6 months CGA, all growth parameters above 25%
Recommendations

• Growth assessment and recognition of failure to thrive
• Iron supplementation
• Attention to energy intakes and growth
• Achieve the best possible gain without adverse effects
Is slower growth beneficial?  
[Singhal et al., 2004]

• Accelerated neonatal growth increases the later incidence of cardiovascular disease
• Cohort of preterm infants who had been part of a longitudinal investigation studied [216 out of 926] at 13-16 years
• Brachial artery flow-mediated endothelium-dependent dilation [FMD]
• Resting and hyperemic blood flow velocities determined
FMD in Adolescence

![Graph showing Flow Mediated Dilation (FMD) across different weight change quartiles.](image)
Singhal et al., 2004, contd

- No statistically significant differences in FMD between children born preterm and fed different feedings.
- FMD in children with weight gain in the first two weeks of life greater than sample mean was lower than those with weight gain below the mean [p=0.0003]; also different from term controls.
- A greater rate of weight gain during the 2 week window was associated with endothelial dysfunction in adolescents.
Nutrition and the Preterm Infant

• Optimal growth and requirements remain to be defined
• At least for now, the guidelines provided should be followed
• Long term strategies for feeding required