Pediatric Enteral Nutrition

A Comprehensive Review

Disclosure: Support for this educational activity was provided by Nestlé HealthCare Nutrition, Inc.
Objectives

• To understand the history, indications, delivery modes, components, monitoring, and safety related to EN for pediatric patients

• To understand the role and implementation of EN in specialized pediatric populations including preterm infant, IBD, SBS, CF, CP, critically ill, and FTT patients
Program Outline

**History**

**Indications**

Premature Infant

Inflammatory Bowel Disease

**Short Bowel Syndrome**

Cystic Fibrosis

Cerebral Palsy

Failure to Thrive

**Delivery Modes/Tubes**

**Principles of Designing/Monitoring Pediatric EN Support**

Age/Medical Condition

Monitoring of Tolerance

Safety

**EN Support in Special Populations**

**Case-Based Module**

Short Bowel Syndrome

Malnutrition/Failure to Thrive
Program Faculty

Chair:

Ann O Scheimann, MD, MBA
Associate Professor of Pediatrics,
Gastroenterology & Nutrition Division of Gastroenterology, Hepatology and Nutrition
Johns Hopkins School of Medicine
Baltimore, MD USA

Faculty:

Sabina M Ali, MD
Gastroenterology and Nutrition
Children's Hospital Oakland
Oakland, CA USA

Mark R Corkins, MD, CNSP, SPR, FAAP
Associate Professor of Clinical Pediatrics
Indiana University School of Medicine
Co-director, Nutritional Support Team
Riley Hospital for Children
Indianapolis, IN USA

Conrad R Cole MD, MPH, MSc
Associate Professor
Division of Gastroenterology, Hepatology and Nutrition
Associate Medical Director,
Intestinal Rehabilitation Program
Cincinnati Children's Hospital Medical Center
Cincinnati, OH USA

Ilana M Fortgang, MD
Assistant Professor of Clinical Pediatrics
Tulane University School of Medicine
Section Chief of Pediatric Gastroenterology,
Hepatology and Nutrition
New Orleans, LA USA
Program Faculty (continued)

Faculty:

Praveen S Goday, MD, MBBS, CNSC
Associate Professor of Pediatrics,
Medical College of Wisconsin
Milwaukee, WI USA

Beth Goldberg, NP
Nurse Practitioner
Children's Hospital of Philadelphia
Philadelphia, PA USA

Maria Mascarenhas, MBBS
Section Chief, Nutrition Division of Gastroenterology,
Hepatology & Nutrition
Associate Professor of Pediatrics
University of Pennsylvania School of Medicine
Philadelphia, PA USA

Sarah Phillips, MS, RD, LD
Clinical Instructor, Manager Nutrition Support
Baylor College of Medicine
Texas Children's Hospital
Houston, TX USA

David Suskind, MD
Attending Physician
Seattle Children's Hospital
Associate Professor of Pediatrics
University of Washington School of Medicine
Seattle, WA USA

Justine Turner, MBBS, PhD
Associate Professor
Department of Pediatric Gastroenterology & Nutrition
University of Alberta
Edmonton, Alberta CANADA
Program Content and CME Reviewers

Content Reviewer

Jeff Critch, MD
Assistant Professor of Pediatrics
Memorial University
St. John’s, NL  CANADA

CME Content Reviewers

Ed Hoffenberg, MD
Professor of Pediatrics
University of Colorado School of Medicine
Aurora, CO  USA

Judith Kelsen, MD
Attending Physician
Assistant Professor of Pediatrics,
Perelman School of Medicine
University of Pennsylvania
Philadelphia, PA  USA

Program Development and Facilitation

Paul Sinclair, MSc.
INSINC Consulting Inc.
Guelph, ON CANADA
Faculty Disclosures

- Ann O Scheimann, MD, MBA, has nothing to disclose
- Sabina M Ali, MD, has nothing to disclose
- Mark R Corkins, MD, CNSP, SPR, FAAP consultant for Nestlé
- Conrad R Cole, MD, MPH, MSc., is a consultant for Abbott Nutrition and Nutricia
- Ilana M Fortgang, MD, has nothing to disclose
- Praveen S Goday, MD, MBBS, CNSC, has nothing to disclose
- Beth Goldberg, NP, has nothing to disclose
- Maria Mascarenhas, MBBS, has nothing to disclose
- Sarah Phillips, MS, RD, LD, has nothing to disclose
- David Suskind, MD, has nothing to disclose
- Justine Turner, MBBS, PhD, has a research Grant and is Principal Investigator for Fresenius Kabi
- Jeff Critch, MD, has nothing to disclose
- Ed Hoffenberg, MD, has nothing to disclose
- Judith Kelsen, MD, has nothing to disclose
- Paul Sinclair, MSc., has nothing to disclose
Disclosures

• Educational Support for the NASPGHAN FOUNDATION & NASPGHAN Pediatric Enteral Nutrition: A Comprehensive Review Slide Set was provided by Nestlé HealthCare Nutrition, Inc.

• NASPGHAN FOUNDATION & NASPGHAN do not endorse any commercial product. Any products named in this slide set are presented as part of the scientific evidence being cited and are used only to illustrate teaching points. The opinions expressed in the educational activity are those of the faculty. Please refer to the official prescribing information for each product for discussion of approved indications, contraindications, and warnings. Audience members are required to critically evaluate any product that they will use in clinical care.

• Speaker Disclosure here
List of Abbreviations

AA - amino acid
Ca – calcium
CARS - compensatory anti-inflammatory response syndrome
CHO - carbohydrate
CF - cystic fibrosis
CP - cerebral palsy
DXA - dual x-ray absorptiometry
EGF - epidermal growth factor
ELBW - extra low birth weight
ENT - Otolaryngologist
EPO - erythropoietin
EN - enteral nutrition
FFA - free fatty acid
FTT - failure to thrive
GI – Gastrointestinal
G-J - gastro-jejunal
GRV - gastric residual volume
GT – gastrostomy tube
HMF - Human milk fortifier
IBD - Inflammatory Bowel Disease
ICU - Intensive Care Unit
K - potassium
LBW - low birth weight
MCT - medium chain triglycerides
Mg - magnesium
Na - sodium
NEC – necrotizing enterocolitis
NG - nasogastric tube
NNH - number needed to harm
NNT - number needed to treat
PEG - percutaneous endoscopic gastrostomy
PICU - pediatric intensive care unit
Phos - phosphorus
PN - parenteral nutrition
QoL - quality of life
RFS - re-feeding syndrome
RTF - ready to feed
SBS - short bowel syndrome
Se - selenium
SIRS - systemic inflammation syndrome
SLP - Speech Language Pathologist
TEF - transpyloric enteral feeding
Zn - zinc
VLBW – very low birth weight

© 2012 NASPGHAN & NASPGHAN FOUNDATION
Ancient EN

• Egyptians and Greeks described 3,500 years ago
  – Given by enema
  – Wine, milk, whey, wheat/barley broths
  – Later added eggs and brandy

• Capivacceus in 1598
  – Hollow tube with bladder attached inserted into esophagus

History of EN

18TH Century
- John Hunter designed orogastric probe
- Whalebone encased in eel skin
- Jellies, eggs with milk, water with sugar beaten in

1930s:
- Protein hydrolysate formulations fed to surgical patients

1940s:
- First infant formula created: protein hydrolysate, corn oil, dextrimaltose, vitamins and minerals

1950s:
- Plastic tubing and pumps invented
- Formulations of blended infant foods

1960s:
- Advanced understanding of nutrient needs and design of liquid formulas
Indications
Indications for Nutrition Intervention

• There is no Grade A level evidence that indicate that EN will shorten stay or improve outcomes
  – Logically nutrition is needed for healing and metabolic processes
  – Adult studies indicate that the malnourished benefit from nutritional intervention \(^1\)
  – Can be used as exclusive or partial support

Pediatric Enteral Nutrition

- Enteral nutrition is the provision of nutrients via the gastrointestinal tract.

- Enteral nutrition maintains the integrity of the GI tract and is associated with fewer infections than parenteral nutrition\(^1\)

- Children who require EN support are those that
  - Eat less than 80% of needs by mouth
  - Require an extended period of time to eat

Progressive Intervention

• Attempt oral feeding first. If the gut works, use it
  – There are no trials comparing enteral versus parenteral nutrition
  – EN is physiologic, has reduced, or less severe, incidence infection as compared to parenteral EN, and is cost effective ¹

• If the patient cannot take enough nutrition orally or has intolerance, then begin NG feedings
  – Bolus usually first
  – Drip next

• If intolerant of NG feedings then transpyloric
  – Must be continuous feedings

Appetite Regulation

Adapted from Sanger GJ. Nature Reviews. 2008;241-54.
Causes of Decreased Appetite

• Disease itself may decrease, e.g. uremia, poor perfusion
• Drugs used for therapy may decrease, e.g. chemotherapy
• Electrolyte limitations or micronutrient deficiencies may decrease palatability, e.g. hyponatremia, Zn deficiency
• Diminished gastrointestinal motility, e.g. poor perfusion, biochemical changes
EN Considerations

• Fluid
  – Cardiac and renal patients often have fluid volume limits
  – Requires adjustment of nutrition plan

• Electrolytes
  – K most common problem

• Protein
  – Used to worry more in renal patients
  – Restrictions have eased in recent years
Delivery Modes/Tubes
Nasogastric (NG), Nasoduodenal (ND) and Nasojejunal (NJ) Tubes

NG tubes are temporary feeding tubes placed manually via the nose and esophagus into the stomach.

When feedings are not tolerated in the stomach, the tube may be placed into the duodenum (ND) or jejunum (NJ).

www.cincinnatichildrens.org/health/n/nasojejunal-kangaroo
## EN Feeding Methods: Gastric vs. Post-pyloric

<table>
<thead>
<tr>
<th>Site</th>
<th>Delivery Route</th>
<th>Indications</th>
<th>Potential Complications</th>
</tr>
</thead>
</table>
| Stomach      | Orogastric (infants) | - Short-term nutrition support (6-8 wks)  
- Inadequate oral intake  
- Refusal to eat  
- Nocturnal feeds  
- Inability to suck or swallow | - Aspiration  
- Nasal mucosal ulceration  
- Tube occlusion  
- Pneumothorax  
- Bleeding/Epistaxis  
- Sinusitis/otitis |
|              | NG             |                                                                              |                                               |
|              | GT             | - Long term tube feeding  
- Congenital anomalies, such as tracheo-esophageal fistula, esophageal atresia  
- Esophageal injury/obstruction  
- Failure to thrive | - Dislodgement  
- Aspiration  
- Tube deterioration  
- Bleeding  
- Tube occlusion  
- Pneumoperitoneum  
- Wound infection  
- Stoma leakage |
| Transpyloric | ND             | - Congenital upper GI anomalies  
- Inadequate gastric motility  
- High aspiration risk  
- Severe GER  
- Functioning intestinal tract with proximal obstruction | - Pneumatosis intestinalis  
- Bleeding  
- Dislodgement  
- Tube deterioration  
- Tube occlusion  
- Bowel obstruction  
- Stomal leakage  
- Wound infection |
| Postpyloric  | NJ             |                                                                              |                                               |
|              | G-J            |                                                                              |                                               |
|              | Jejunostomy    |                                                                              |                                               |

*Texas Children’s Hospital. Texas Children’s Hospital Pediatric Nutrition Reference Guide. 9th ed. 2011.*
What is a G Tube?

• A G tube is a tube placed into the stomach through an opening called a stoma

http://www.adamimages.com
Gastrojejunostomy Tube (G-J Tube)

A G-J tube is a tube that is placed via the opening into the stomach (stoma) and passes through the pylorus into the mid section of the small intestine (the jejunum). It has a G port which can be used for gastric decompression with jejunal feeds, gastric med delivery or bolus feeds. The j port can be used for continuous feeds.
Why Use a G or J Tube?

• A G tube allows need to EN to be met by feeding into the stomach

• A J tube can be used when needs for EN may not be met by feeding into the stomach, allowing EN feeding to occur past the stomach, i.e. in the jejunum
  – Cannot use bolus feeding technique beyond the pylorus due to dumping syndrome
Replacement Gastrostomy Tubes

These tubes have a balloon at the end that goes into the stomach. Replacement tubes are used after the initial tract has healed.
Replacement Gastrostomy Tubes

This is a low profile G tube that is held in place by a mushroom shaped dome inside of the stomach. There is no balloon port.

Mushroom Dome

Obturator-used for placing tube
Balloon G-J Tubes

**G-J tube**
- Goes in through stomach and has 3 ports: one ends in stomach; one ends in jejunum and one is the balloon port. Can be low profile or long version
- Medications given through G tube have a risk for clogging of the J tube limb
Basic Care of Tubes I

- Daily washing of site with soap and water as needed. Dry skin well. Do not use hydrogen peroxide. Do not apply occlusive dressings.
- Inspect site for infection, leakage or skin irritation/breakdown. If leakage present, always protect the peristomal skin with a skin barrier.
- Check water in balloon if having leakage from stoma or tube appears too tight or too loose.
- Every patient with G tube should have access to a replacement tube (via their homecare company).
Basic Care of Tubes II

• Consider measuring Low Profile G tubes for proper fit at least once a year or at any time the tube appears too tight or loose or with significant weight fluctuation.

• Rotate the gastrostomy hub position to minimize pressure

• Prevent clogged tubes by flushing the tube with sterile water before and after each medication and feedings. Post pyloric tubes (G-J, ND, NJ or surgical jejunostomies) clog easily and often require more frequent flushing. Avoid clogging J tubes by using liquid medications when possible, diluting viscous meds with sterile water, and not mixing meds directly into formula.
Bolus vs. Continuous Feedings

Bolus

- Can mimic or supplement meals
- More physiologic
- May not require a pump
- Freedom of movement between feedings
- Only GT feeding
- Can promote osmotic diarrhea

Continuous

- Slow infusion may improve tolerance and absorption
- Can be given overnight to avoid disruption of daytime schedule and oral intake
- Encourages intestinal adaption by constant mucosal stimulation
- Reduces need for parenteral calories

Review of EN Components

Protein
Infant Formulas: Protein Content

• Divided into 4 classes of formulas:
  – Cow’s milk–based formulas
    • Preterm and follow-up preterm formulas as well
    • Partially hydrolyzed whey; not considered hypoallergenic but less allergic diseases
  – Soy formulas
  – Casein hydrolysate formulas
  – Amino acid–based formulas

## Comparison of Formulas

<table>
<thead>
<tr>
<th>Cow’s Milk-Based Formulas</th>
<th>Soy Formulas</th>
<th>Casein Hydrolysate Formulas</th>
<th>Amino Acid-Based Formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Widely available</td>
<td>For vegans</td>
<td>Hydrolysate first line for formula protein allergy</td>
<td>Amino acid–based formula if hydrolysate not tolerated</td>
</tr>
<tr>
<td>Cheap starting material</td>
<td>Galactosemia and hereditary lactase deficiency (rare)</td>
<td>Reflux guidelines recommended 2-week trial</td>
<td></td>
</tr>
<tr>
<td>Constantly tweaked to attempt to simulate breast milk</td>
<td>No proven benefit in infantile colic or fussiness.</td>
<td>Data about prevention of atopic disease</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Review of EN Components

Carbohydrates
Infant Formulas – CHO

• Main types of carbohydrates in formulas\(^1\)
  – Lactose
  – Sucrose
  – Glucose polymers

• Galactosemia: soy formulas, because they do not contain lactose\(^2\)
  – Isomil\(^\circledR\)

• Which formulas contain sucrose?\(^1\)
  – Alimentum\(^\circledR\) and soy formulas, except Prosobee\(^\circledR\)

---

Perlstein D. *Infant Formulas*. MedicineNet.com
Review of EN Components

Fat
Infant Formulas – Fat Content

• Main types of fats in formulas
  – Long-chain triglycerides
  – MCTs

• When are MCTs beneficial?
  – Impaired fat absorption or lymphatic abnormalities
  – Cystic fibrosis, short gut syndrome, cholestasis, and protracted diarrhea

• Which formulas contain MCTs?
  – Alimentum® (33%), Pregestimil® (55%)
  – Enfacare® (20%)
  – Enfaport® (84%)
  – Elecare Infant® (33%), Neocate Infant® (33%)
  – Premie formulas (50%)
  – 3232A (85%)

DHA and ARA

- Docosahexaenoic acid (DHA) and arachidonic acid (ARA), both long-chain polyunsaturated fatty acids
- Present in breast milk; were not in formulas
- Animal models showed increased visual acuity and neurologic development; some infant studies agree
- No harmful effects found
- Now in most infant formulas
- A recent meta-analysis found no effect of DHA/ARA on cognitive development

Review of EN Components

Additives
Immune Input

- **Probiotics**
  - Evidence of decreased infectious illnesses, especially diarrheal illnesses
  - Now present in some infant formulas

- **Prebiotics**
  - Growth factors that foster the growth of “good bacteria” in the gut e.g., inulin, fructooligosaccharides (FOS)

Standard Cow Milk–Based

• Widely available
• Cheap
• Unflavored, which lowers osmolarity
• Lactose-free
  – Potential for lactose intolerance
• Fat mixture
  – Mixture of long and medium-chain fats
Metabolic Infant Formulas

• Specific formulas for specific diseases
  – Phenylketonuria, Maple syrup urine disease
• CHO-free formulas require the addition of a CHO
  – Ross Carbohydrate Free®
• Modified fat formulas
• Reduced mineral formulas
  – Renal disease
Di- and Tripeptide Formulas

• Not designed for allergy or malabsorption conditions

• Better gastric emptying $^{2,3}$

• Better tolerated
  – Fats contain a percentage of MCT

Elemental Pediatric Formulas

• AA–based

• Contain MCT

• Use for allergic?

• Short bowel
  – Better emptying
  – Absorption immediately

Enteral Feeding Questions

• Fiber? Helps with stooling issues
  – Soluble versus insoluble

• Transpyloric feeds - Elemental?
  – Tolerance okay
  – Animal studies; absorption better

• When are adult EN formulas suitable?
  – Adolescent? Ca and Phos needs to be higher
  – Do contain higher protein content
Immune Effects by Formulas

- No pediatric immunomodulating formulas
  - Modulen® IBD is not available in the USA but is available in the UK and Canada
  - Formulas containing ω-3 fats under study
- Specialty formulas for specific situations
  - Ketogenic diet
  - Fat transport defects

Blenderized Formula

• One commercially available
  – *Compleat® Pediatric*

• Parents perceive as better
  – Potential to be nutritionally incomplete without guidance
  – Resources available with carefully worked out recipes
  – Labor intensive for the family
Principles of Designing/Monitoring Pediatric EN Support

Age / Medical Condition
Administration

• The route of and duration (bolus vs. continuous) of enteral administration depends on:
  – Indication for EN, the duration of need
  – Anatomical integrity of the GI tract
  – Functional integrity of the GI tract
  – Risk of aspiration
## Enteral Feeding Methods
### Gastric Vs. Post-pyloric - I

<table>
<thead>
<tr>
<th>Site</th>
<th>Delivery Route</th>
<th>Indications</th>
<th>Potential Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>Orogastric (infants)</td>
<td>• Short-term nutrition support (6-8 wks)&lt;br&gt;• Inadequate oral intake due to increased needs or anorexia of chronic disease&lt;br&gt;• Refusal to eat&lt;br&gt;• Nocturnal feeds&lt;br&gt;• Inability to suck or swallow</td>
<td>• Aspiration&lt;br&gt;• Nasal mucosal ulceration&lt;br&gt;• Tube occlusion&lt;br&gt;• Pneumothorax&lt;br&gt;• Bleeding&lt;br&gt;• Epistaxis&lt;br&gt;• Sinusitis&lt;br&gt;• Otitis Media</td>
</tr>
<tr>
<td></td>
<td>Nasogastric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastrostomy</td>
<td></td>
<td>• Long term tube feeding&lt;br&gt;• Congenital anomalies, such as tracheoesophageal fistula, esophageal atresia&lt;br&gt;• Esophageal injury/obstruction&lt;br&gt;• Failure to thrive</td>
<td>• Dislodgement&lt;br&gt;• Aspiration&lt;br&gt;• Tube deterioration&lt;br&gt;• Bleeding&lt;br&gt;• Tube occlusion&lt;br&gt;• Pneumoperitoneum&lt;br&gt;• Wound infection&lt;br&gt;• Stoma leakage</td>
</tr>
</tbody>
</table>
# Enteral Feeding Methods
## Gastric Vs. Post-pyloric - II

<table>
<thead>
<tr>
<th>Site</th>
<th>Delivery Route</th>
<th>Indications</th>
<th>Potential Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transpyloric</td>
<td>• Nasoduodenal</td>
<td>• Congenital upper GI anomalies</td>
<td>• Pneumatosis intestinalis</td>
</tr>
<tr>
<td>Postpyloric</td>
<td>• Nasojejunal</td>
<td>• Inadequate gastric motility</td>
<td>• Bleeding</td>
</tr>
<tr>
<td></td>
<td>• Gastrojejunal</td>
<td>• High aspiration risk</td>
<td>• Dislodgement</td>
</tr>
<tr>
<td></td>
<td>• Jejunostomy</td>
<td>• Severe GER</td>
<td>• Tube deterioration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Functioning intestinal tract with obstruction above it</td>
<td>• Tube occlusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Bowel obstruction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Stomal leakage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Wound infection</td>
</tr>
</tbody>
</table>
Bolus vs. Continuous Feeds

- Enteral feeds may be given as bolus (intermittent), continuous, or a combination

**Bolus Feedings**

<table>
<thead>
<tr>
<th>Age</th>
<th>Initiation</th>
<th>Advance</th>
<th>Suggested Tolerance Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 12 months</td>
<td>10 – 15 mL/kg every 2 to 3 hours</td>
<td>10 to 30 mL per feed</td>
<td>20 to 30 mL/kg every 4 to 5 hours</td>
</tr>
<tr>
<td>1 - 6 years</td>
<td>5 – 10 mL/kg every 2 to 3 hours</td>
<td>30 to 45 mL per feed</td>
<td>15 to 20 mL/kg every 4 to 5 hours</td>
</tr>
<tr>
<td>&gt; 7 years</td>
<td>90 to 120 mL every 3 to 4 hours</td>
<td>60 to 90 mL per feed</td>
<td>330 to 480 mL every 4 to 5 hours</td>
</tr>
</tbody>
</table>

**Continuous Feedings**

<table>
<thead>
<tr>
<th>Age</th>
<th>Initiation</th>
<th>Advance</th>
<th>Suggested Tolerance Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 12 months</td>
<td>1 to 2 mL/kg/hour</td>
<td>1 to 2 mL/kg every 2 to 8 hours</td>
<td>6 mL/kg/hour</td>
</tr>
<tr>
<td>1 - 6 years</td>
<td>1 mL/kg/hour</td>
<td>1 mL/kg every 2 to 8 hours</td>
<td>1 to 5 mL/kg/hour</td>
</tr>
<tr>
<td>&gt; 7 years</td>
<td>25 mL/hour</td>
<td>25 mL every 2 to 8 hours</td>
<td>100 to 150 mL/hour</td>
</tr>
</tbody>
</table>
## Monitoring /Evaluation

<table>
<thead>
<tr>
<th>Category</th>
<th>Initial</th>
<th>Hospital</th>
<th>Outpatient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthropometrics</strong></td>
<td>Weight, Height</td>
<td>Daily Baseline</td>
<td>Weekly - monthly Monthly Monthly or at clinic</td>
</tr>
<tr>
<td></td>
<td>Height</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intake</strong></td>
<td>Calories, protein, fluid</td>
<td>Daily</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Monthly</td>
</tr>
<tr>
<td><strong>GI Tolerance</strong></td>
<td>Abdominal girth, residuals, emesis</td>
<td>As ordered, reported</td>
<td>As reported</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stool/Ostomy</strong></td>
<td>Volume, frequency, consistency</td>
<td>Daily</td>
<td>Report changes in stool pattern</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tube Placement</strong></td>
<td>Prior to each feeding</td>
<td>Prior to each feeding</td>
<td>Prior to each feeding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tube Site</strong></td>
<td>Daily</td>
<td>Daily</td>
<td>Daily</td>
</tr>
<tr>
<td>Problem</td>
<td>Prevention/Intervention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrhea/ Abdominal Cramping</td>
<td>• Decrease delivery rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Recognize or avoid drugs that result in diarrhea</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Consider fiber containing products</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Consider osmolarity and addition of modular additives</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Semi-elemental or elemental formula if indicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vomiting/ Nausea</td>
<td>• Ensure formula is always at room temperature prior to tube feedings</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Elevate head of bed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Consider postpyloric or continuous feeding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyperglycemia</td>
<td>• Reduce flow rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Use formulas with minimal simple sugars</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Consider insulin if clinically indicated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Monitoring/ Evaluation - II

<table>
<thead>
<tr>
<th>Problem</th>
<th>Prevention/Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constipation</strong></td>
<td>• Ensure optimal fluid intake</td>
</tr>
<tr>
<td></td>
<td>• Increase free water intake</td>
</tr>
<tr>
<td></td>
<td>• Change to a product containing fiber</td>
</tr>
<tr>
<td><strong>Gastric Retention of Formula</strong></td>
<td>• Monitor for correct tube placement</td>
</tr>
<tr>
<td></td>
<td>• If residuals are high (&gt;2 hour volume of feeds), hold feeds; recheck residuals in 1 hour</td>
</tr>
<tr>
<td></td>
<td>• Consider continuous or postpyloric feeding</td>
</tr>
<tr>
<td></td>
<td>• Position patient on right side</td>
</tr>
<tr>
<td><strong>Clogged Feeding Tube</strong></td>
<td>• Ensure tube is flushed after checking residuals, boluses and every 4 – 8 hours with continuous feeds</td>
</tr>
<tr>
<td></td>
<td>• Check tubing size for appropriateness for some formulas</td>
</tr>
<tr>
<td></td>
<td>• Infuse formula past pylorus</td>
</tr>
<tr>
<td></td>
<td>• Consider continuous infusion</td>
</tr>
</tbody>
</table>
Selecting the Right Formula

• Select formula based on gut function and volume tolerance
  
  – Normal function
    • Able to tolerate intact protein and long chain fats

  – Abnormal function
    • Unable to tolerate intact protein related to allergy or malabsorption
    • Unable to tolerate long chain fats related to liver function, pancreatic function or malabsorption

  – Volume tolerance
    • Fluid restricted
# Formula - I

<table>
<thead>
<tr>
<th></th>
<th>Protein</th>
<th>Fat</th>
<th>CHO</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>Oral Tube</td>
<td>Whole protein</td>
<td>Long-chain fats</td>
<td>Lactose-free</td>
</tr>
<tr>
<td>- Normal bowel function</td>
<td></td>
<td></td>
<td></td>
<td>• Nutren® Junior (1-10 yr)</td>
</tr>
<tr>
<td>- Normal fluids</td>
<td></td>
<td></td>
<td></td>
<td>• Pediasure® (1-10 yr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Ensure® (11yr-adult), Nutren® 1.0</td>
</tr>
<tr>
<td></td>
<td>Tube</td>
<td>Whole protein</td>
<td>long-chain fats</td>
<td>Lactose-free</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Compleat® Pediatric (1-10 yr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Jevity® 1 cal (11yr-adult)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Osmolite® (11yr-adult)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Jevity® (fiber) (11yr-adult)</td>
</tr>
<tr>
<td><strong>Volume Intolerance</strong></td>
<td>Concentrated</td>
<td>Whole protein</td>
<td>Varies</td>
<td>Lactose-free</td>
</tr>
<tr>
<td>- Normal/ Abnormal bowel function</td>
<td></td>
<td></td>
<td></td>
<td>• Pediasure® 1.5, Nutren® 1.5</td>
</tr>
<tr>
<td>- Increased calorie and protein needs</td>
<td></td>
<td></td>
<td></td>
<td>• Nutren® 2.0</td>
</tr>
<tr>
<td>- Fluid restricted</td>
<td></td>
<td></td>
<td></td>
<td>• Twocal® HN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Ensure® Plus</td>
</tr>
<tr>
<td><strong>Impaired Digestion/ Allergy</strong></td>
<td>Peptide Based</td>
<td>Hydrolyzed whey-protein 3-5 peptide chains</td>
<td>Mix of MCT and LCT fat</td>
<td>Varies: corn syrup solids</td>
</tr>
<tr>
<td>- Abnormal bowel function</td>
<td></td>
<td></td>
<td></td>
<td>• Peptamen® Junior</td>
</tr>
<tr>
<td>- Unable to digest fully intact protein, carbohydrate or fat.</td>
<td></td>
<td></td>
<td></td>
<td>• Pediasure® Peptide (1-13 yr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Nutramigen®, Pregestimil®</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Peptamen® 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Vital® HN</td>
</tr>
</tbody>
</table>
# Formula - II

<table>
<thead>
<tr>
<th>Abnormal bowel function - Related to allergy, malabsorption, short gut</th>
<th>Protein</th>
<th>Fat</th>
<th>CHO</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino acid Based</td>
<td>Free amino acids</td>
<td>Mix of MCT and LCT fat</td>
<td>Corn syrup solids</td>
<td>• Elecare® infant, Elecare® Jr, Neocate®, Neocate® Jr, Nutramigen® AA, Tolerex® (Free amino acids)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fat malabsorption - Related to chylothorax Pancreatitis</th>
<th>Protein</th>
<th>Fat</th>
<th>CHO</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat Mal-absorption</td>
<td>Intact whole protein / casein</td>
<td>Contain 55% or greater MCT oil, DHA, ARA</td>
<td>Corn syrup solids</td>
<td>• Portagen®, Enfaport®, Pregestimil®, Tolerex® (Free amino acids), Vital® HN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disease Specific</th>
<th>Protein</th>
<th>Fat</th>
<th>CHO</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varies</td>
<td></td>
<td></td>
<td></td>
<td>• Nutren Glytol (diabetic), Optisource® (bariatric surgery), Pulmocare®, Suplena® (renal)</td>
</tr>
</tbody>
</table>
Outline of Products

• Infant Formulas
  – 0 to 1 year of age

• Pediatric Formulas
  – 1 to 13 years of age

• Specialized formulas/supplements

• Modular Additives
Infant Formulas

Standard and Premie

– Goal
  • simulate human milk (20 kcal/oz), Premie (22 kcal/oz or greater)

– Composed of intact protein, CHO, and fat

– Indications
  • functional gastrointestinal tract

– Intended for less than 1 year old
**Standard Infant Formulas**

<table>
<thead>
<tr>
<th>Protein</th>
<th>Low Birth Weight 20 kcal/oz – 24 kcal/oz</th>
<th>Infant Formulas 20 kcal/oz</th>
<th>Soy based Infant Formula 20 kcal/oz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whey:Casein ratio 60:40</td>
<td>Intact milk protein</td>
<td>Soy protein isolate</td>
<td></td>
</tr>
<tr>
<td>Lactose, Corn Syrup solids</td>
<td>Lactose, corn maltodextrins, sucrose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mix of MCT, soy, DHA, ARA</td>
<td>Mix of high oleic safflower or soy, DHA, ARA</td>
<td>Mix of high oleic safflower or soy, DHA, ARA</td>
<td></td>
</tr>
<tr>
<td>250 - 300</td>
<td>170 - 310</td>
<td>170 - 200</td>
<td></td>
</tr>
<tr>
<td>Formula designed for premature infants post discharge.</td>
<td>Available as powder, ready to feed and concentrate</td>
<td>Available as powder, ready to feed and concentrate</td>
<td></td>
</tr>
</tbody>
</table>
Specialty Infant Formulas

- Protein allergy/malabsorption
  - Cow milk allergy, multiple food allergies
  - Short bowel syndrome
- Fat malabsorption
  - Liver disease
  - Cystic fibrosis
  - Steatorrhea
  - Short bowel syndrome
  - Persistent diarrhea
## Specialty Infant Formulas

<table>
<thead>
<tr>
<th></th>
<th>Hydrolysate</th>
<th>Elemental</th>
<th>Elemental</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein</strong></td>
<td>Casein hydrolysate</td>
<td>100% free AA</td>
<td>100% free AA</td>
</tr>
<tr>
<td><strong>CHO</strong></td>
<td>Corn syrup solids, modified corn starch</td>
<td>Fructose, galactose, lactose, gluten, soy free</td>
<td>Sucrose, lactose, galactose free</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>Mix vegetable oil with DHA, ARA. May contain MCT oil</td>
<td>Vegetable oils</td>
<td>5% fat calories as MCT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33% fat calories as MCT DHA, ARA</td>
<td></td>
</tr>
<tr>
<td><strong>mOsm</strong></td>
<td>320</td>
<td>335</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>-Gluten, lactose, and galactose free</td>
<td>-Gluten, lactose, and galactose free</td>
<td>-Gluten, lactose, and galactose free</td>
</tr>
<tr>
<td></td>
<td>-Probiotic: <em>Lactobacillus rhamnosis</em> (LGG)</td>
<td>-Powder</td>
<td>-Powder</td>
</tr>
</tbody>
</table>
Standard Pediatric Formulas

Children 1-10 years, vitamins/minerals

- 30 kcal/oz (1kcal/ml)
- Milk based (whey, casein)
- With or without fiber
- Usually gluten-free, lactose free
# Pediatric Formulas

<table>
<thead>
<tr>
<th></th>
<th>Oral /Tube 30 kcal/oz</th>
<th>Oral /Tube 45 kcal/oz</th>
<th>Blenderized Tube 30 kcal/oz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein</strong></td>
<td>Sodium and calcium caseinates, whey protein concentrates</td>
<td>Sodium and calcium caseinates, whey protein concentrates</td>
<td>Chicken, casein, pea puree</td>
</tr>
<tr>
<td><strong>CHO</strong></td>
<td>Sucrose, maltodextrins</td>
<td>Sucrose, maltodextrins</td>
<td>Corn syrup solids, cranberry juice, fruits and vegetables</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>Vegetable oils, may contain MCT</td>
<td>Vegetable oils, may contain MCT</td>
<td>Vegetable, MCT, chicken fat</td>
</tr>
<tr>
<td><strong>mOsm</strong></td>
<td>335 - 350</td>
<td>370 - 390</td>
<td>380</td>
</tr>
<tr>
<td><strong>-May contain fiber</strong></td>
<td></td>
<td></td>
<td>-Contains fiber</td>
</tr>
<tr>
<td><strong>-Flavors vary</strong></td>
<td></td>
<td></td>
<td>-Gluten and Lactose free</td>
</tr>
<tr>
<td><strong>-Gluten and lactose free</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Semi Elemental

• Partially hydrolyzed protein (casein or whey)
• Indications:
  – Malabsorption/GI impairment
    • Short bowel syndrome, IBD
  – Protein allergy
    • Most children will outgrow their protein allergies
• Costly: $
## Semi-Elemental Formulas

<table>
<thead>
<tr>
<th></th>
<th>Peptide Based 30 kcal/oz (1kcal/ml)</th>
<th>Peptide Based 45 kcal/oz (1.5 kcal/ml)</th>
<th>Peptide Based 30 kcal/oz (1kcal/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>enzymatically hydrolyzed whey</td>
<td>hydrolyzed whey, sodium caseinate</td>
<td>non-dairy hydrolysates (meat &amp; soy), 44 % Free AA</td>
</tr>
<tr>
<td>CHO</td>
<td>maltodextrin, corn syrup solids</td>
<td>maltodextrin, corn syrup solids</td>
<td>corn syrup solids</td>
</tr>
<tr>
<td>MCT</td>
<td>60% fat calories</td>
<td>60% fat calories</td>
<td>35% fat calories</td>
</tr>
<tr>
<td>mOsm</td>
<td>260 - 400 (flavored)</td>
<td>450</td>
<td>430 - 440</td>
</tr>
<tr>
<td>Formulation</td>
<td>RTF: powder, lactose &amp; gluten free</td>
<td>RTF: lactose &amp; gluten free</td>
<td>RTF: powder, lactose &amp; gluten free</td>
</tr>
<tr>
<td>Flavors</td>
<td>chocolate, strawberry, vanilla, or un-flavored</td>
<td>strawberry, vanilla</td>
<td>banana, un-flavored</td>
</tr>
</tbody>
</table>
Specialty Pediatric Formulas

Elemental

- Broken down even more = Free AA
- Decreased palatability
- Indications:
  - Severe multiple food protein allergy/intolerance
  - Eosinophilic esophagitis
  - Gastrointestinal tract impairment/malabsorption
  - Severe GERD
- Costly: $$$
### Elemental Formulas

<table>
<thead>
<tr>
<th></th>
<th>Elecare Junior</th>
<th>Neocate Junior</th>
<th>Vivonex Pediatric</th>
<th>EO 28</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein</strong></td>
<td>Free L-amino acids</td>
<td>Free amino acids</td>
<td>Free amino acids</td>
<td>Protein: free amino acids</td>
</tr>
<tr>
<td><strong>CHO</strong></td>
<td>Corn syrup solids</td>
<td>Corn syrup solids</td>
<td>Maltodextrin, sucrose</td>
<td>Maltodextrin, sucrose</td>
</tr>
<tr>
<td><strong>MCT</strong></td>
<td>35% calories</td>
<td>35% calories</td>
<td>68% calories</td>
<td>35% calories</td>
</tr>
<tr>
<td><strong>mOsm</strong></td>
<td>560</td>
<td>590 - 700</td>
<td>360</td>
<td>820</td>
</tr>
<tr>
<td><strong>Formulation</strong></td>
<td>Powder</td>
<td>Powder</td>
<td>Powder</td>
<td>RTF: juice Box</td>
</tr>
<tr>
<td><strong>Flavors</strong></td>
<td>Vanilla, unflavored</td>
<td>Chocolate, tropical fruit, unflavored</td>
<td>Unflavored</td>
<td>Tropical fruit, orange/pineapple, and grape</td>
</tr>
</tbody>
</table>
Modular Additives - Protein

• Modular additives are used to increase kcals and/or protein

• Protein
  – Beneprotein®
    • Whey and soy protein isolates
    • NOT for milk protein allergy!!
  – Amino acid module
Modular Additives - CHO

Carbohydrate

- **Polycose® powder**
  - Low osmolality, minimal sweetness

- **Cornstarch**
  - Slow release CHO – helpful to treat hypoglycemia/dumping
  - **NOT** for 24 hour batch/continuous feeds. Thickens over time
  - Add at time of feeding

- **Corn syrup, dextrose, fructose, sucrose**
  - Not used often
Modular Additives - Fat

• Corn oil (8.4 kcal/mL)
  - Over the counter, inexpensive
  - Oleic/linoleic unsaturated. Fatty acids
  - Boluses acceptable

• MCT Oil® (7.7 kcal/mL)
  - Absorbed directly into portal system (bile salts & lipase not needed)
  - Does not contain EFA
  - Expensive
  - Good for patients with cholestatic liver disease

• Microlipid® (4.5 kcal/mL)
  - Safflower oil
  - 50% fat emulsion – mixes well with formulas/foods

• MCT Procal
  - 97% MCT per 16g sachet – powder form
  - Contains milk protein and lactose
Modular Additives - Combination

DuoCal®

- Used mostly in outpatient clinic
- Dissolves in waters, liquids and moist foods
- No altered taste
- High kcal (cornstarch + refined vegetable oils + MCT)
- Protein free, lactose free, gluten free
## Clear Liquid Diet Supplements

<table>
<thead>
<tr>
<th></th>
<th>Enlive 31 kcal/oz</th>
<th>Resource Breeze 32 kcal/oz</th>
<th>Pediasure Clear 30 kcal/oz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein</strong></td>
<td>Whey protein isolate (3.7 grams/100 mL)</td>
<td>Whey protein isolate (3.8 grams/100 mL)</td>
<td>Whey protein isolate (3.1 grams/100 mL)</td>
</tr>
<tr>
<td><strong>CHO</strong></td>
<td>Maltodextrin, sucrose</td>
<td>Sugar, corn syrup solids</td>
<td>Corn syrup solids, sugar</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>mOsm</strong></td>
<td>796</td>
<td>750</td>
<td>430 - 440</td>
</tr>
<tr>
<td><strong>Formulation</strong></td>
<td>RTF: lactose &amp; gluten free</td>
<td>RTF: lactose &amp; gluten free</td>
<td>RTF: lactose &amp; gluten free</td>
</tr>
<tr>
<td><strong>Flavors</strong></td>
<td>Apple, mixed berry</td>
<td>Orange, wild berry, peach</td>
<td>Peach, berry pomegranate</td>
</tr>
</tbody>
</table>
Principles of Designing/Monitoring Pediatric EN Support

Monitoring of Tolerance
Monitoring Tube Position

• NG tube surveillance
  – Mark insertion point\(^1\)
  – Recheck X-ray if change in tube length

• NJ tube surveillance
  – As above
  – Recheck X-ray if change in tube length or change in feeding tolerance

Gastric Residual Volumes (GRV)

• No standard practices on how, when and what is a high value gastric residual volume (GRV)

• Difficult to withdraw well with small tube

• No studies that prove correlation of GRV with intolerance

• GRVs result in holding feedings despite no other signs of intolerance¹

Gastric Residual Volumes: Consensus

Consensus statement: Grade C evidence

In acutely ill pediatric patients receiving continuous drip feedings, the GRVs may be checked every 4 hours and held if the volume is greater than or equal to the hourly rate. If feedings are bolus, then the GRV may be checked before the next feeding and held if the residual volume is more than half of the previous feeding volume.

ICU and Aspiration Risk

• **Risks for Aspiration:** sedation, supine position, presence and size of NG tube, mechanical ventilation, vomiting, bolus feedings, high risk disease, poor oral health and nurse staffing level

• **NG tube feeds:** used primarily since easiest but do require functional stomach

• **G-J tube feeds:** ICU patients have received jejunal feeds due to aspiration risks; two adult meta-analysis did not support need for jejunal feedings

• **Recommendation:** start NG unless there is a heightened risk for intolerance

Intolerance Interventions

• Drip feedings-continuous

• Consider trial of promotility agents either to advance tube or enhance emptying/feeding tolerance
  – Several promotility agents have side effects

• Trans-pyloric feedings
  – Previous adult studies show it ends up delaying feeding initiation
  – Consider if aspiration risk or intolerance to gastric

Principles of Designing/Monitoring Pediatric EN Support

Safety
Refeeding Syndrome (RFS)

• RFS is a term used to describe the metabolic and clinical changes that can occur during nutritional support of a malnourished patient
  – Normally occurs within 3-4 days after initiating feeds
  – Signs/symptoms include weakness, muscle pain, ataxia, paresthesia, confusion, arrhythmia, seizures
  – Phos depletion is the hallmark and cause of the majority of symptoms

Risk Factors of RFS

• Severe malnutrition
• Anorexia nervosa
• Significant weight loss, including massive weight loss in obese patients
• Undernutrition due to prolonged intravenous (IV) therapy/fasting
• Most frequent identifier for a pediatric patient at risk for RFS was a calculated body weight less than 80% of ideal body weight.

Starvation/Malnutrition

- Glycogenolysis, gluconeogenesis, and protein catabolism
- Protein, fat, mineral, electrolyte, and vitamin depletion – salt and water intolerance
- Refeeding (switch to anabolism)
- Fluid, salt, nutrients (carbohydrate as a major energy source)

RFS

- ↑ Glucose uptake
- ↑ Thiamine utilization
- ↑ K⁺, Mg²⁺ and PO₄²⁻ uptake
- protein and glycogen synthesis

- ↑ Protein and glycogen synthesis
- Insulin secretion from the pancreas

Hypokalemia
Hypomagnesemia
Hypophosphatemia
Thiamine deficiency
Salt and water retention - edema

Serum abnormalities during refeeding and may include:

- Hypophosphatemia
- Hypokalemia
- Hypomagnesemia
- Glucose abnormalities
- Thiamine deficiency
- Derangements of sodium, nitrogen, and fluid balance

Phosphorus

• Important roles of Phos include adenosine triphosphate (ATP) and 2,3-diphosphoglycerate (2,3-DPG) generation

• During refeeding glucose intake leads to insulin surge, pulling Phos intracellularly, leading to deficits in both intra/extracellular Phos levels
  – Increased demand for and utilization of 2,3 DPG and ATP

• Baseline cardiac muscle atrophy due to malnutrition increases vulnerability of patient to the deleterious effects of Phos depletion
  – Potential of ventricular dysrhythmias and sudden death

Potassium and Magnesium

• K is driven intracellularly by insulin in response to glucose intake
  – K depletion can lead to cardiac arrhythmias (QTc prolongation and torsades de pointes) and cardiac arrest

• Hypo-magnesemia can result in cardiac and neuromuscular dysfunction

Glucose and Fluid Dysregulation

- After periods of starvation, glucose must be replaced at a slow and intentional rate
  - Replacement of large quantities of glucose quickly can result in hyperglycemia which leads to osmotic diuresis, dehydration, metabolic acidosis, and ketoacidosis

- CHO intake leads to a rapid decrease in renal excretion of sodium and water
  - Extra fluids are given to maintain “normal” urine output may lead to fluid overload and can result in cardiac failure

Mehanna et al. BMJ. 2008;336:1495-98.
Glucose and Fluid Dysregulation

- After periods of starvation, glucose must be replaced at a slow and intentional rate
  - Replacement of large quantities of glucose quickly can result in hyperglycemia which leads to osmotic diuresis, dehydration, metabolic acidosis, and ketoacidosis
- CHO intake leads to a rapid decrease in renal excretion of sodium and water
  - Extra fluids are given to maintain “normal” urine output may lead to fluid overload and can result in cardiac failure

Management Guidelines for RFS

• Identify patients at risk of RFS
  – Check electrolytes (including K, Ca, Phos, Mg, blood urea nitrogen, and creatinine) prior to start of feeding
  – Start refeeding at 50-75% of goal calories and increase to goal over 3-5 days

• Protein does not need to be restricted

• Rehydrate carefully, being careful not to fluid overload

• Monitor K, Ca, Phos, and Mg levels frequently during first four days and replace appropriately

Electrolyte/Micronutrient Replacements

Multivitamin and mineral supplementation

- Thiamine, Zn, and Se
- Fe usually not given during initial phase, as increased risk of infection and oxidative stress

<table>
<thead>
<tr>
<th></th>
<th>2-4 mmol/kg daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td></td>
</tr>
<tr>
<td>Phos</td>
<td>0.3-0.6 mmol/kg daily</td>
</tr>
<tr>
<td>Mg</td>
<td>0.2 mmol/kg daily IV or 0.4 mmol/kg daily orally</td>
</tr>
</tbody>
</table>

Summary: Principles of RFS

• Malnourished patients have altered metabolism

• Patients are severely intracellularly deficient in several electrolytes that are important in basic cell functions, including Phos, K, and Mg

• Initial management should focus on correction of the metabolic mechanisms and electrolyte repletion prior to initiating aggressive nutritional support

• Aggressive re-feeding in the initial phase and rehydration can prove deadly if deficiencies are not anticipated, corrected, and monitored carefully

  – Protein intake does not require restriction –
Overview of EN Support in Special Populations

Premature Infant
Enteral Nutrition - Preterm Infant

- Optimal nutrition is critical in the management of preterm infants
- Current recommendations
  - Provide approximate rate of growth of fetus
  - Prevent significant growth restriction

<table>
<thead>
<tr>
<th></th>
<th>&lt; 1000g</th>
<th>1000-1500g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluids (ml/kg)</td>
<td>160-220</td>
<td>135-190</td>
</tr>
<tr>
<td>Energy (Kcal/kg)</td>
<td>130-150</td>
<td>110-130</td>
</tr>
<tr>
<td>Protein (g/kg)</td>
<td>3.8-4.4</td>
<td>3.4-4.2</td>
</tr>
<tr>
<td>Carbohydrate (g/kg)</td>
<td>9-20</td>
<td>7-17</td>
</tr>
<tr>
<td>Fat (g/kg)</td>
<td>6.2-8.4</td>
<td>5.3-7.2</td>
</tr>
</tbody>
</table>

Trophic feeds (minimal enteral nutrition)

- Benefits
  - Shortens time to regain birth weight
  - Improves feeding tolerance
  - Enhances enzyme maturation
  - Improves gastrointestinal motility
  - Improves mineral absorption, mineralization
  - Lowers incidence of cholestasis

Trophic Feeds are Safe

- Trophic feeds are safe \(^1\)
- Early trophic feeds
  - Results in faster achievement in full feeds
  - Decreased length of hospital stay
  - No increased risk of NEC
  - Rates as low as 8ml/kg/day can increase intestinal enzyme activity (no effect when using diluted feeds) \(^2\)

Trophic Feeds

• When ready for trophic feeds
  – 10-20ml/kg/day
  – Contraindication to feed if
    • Hemodynamically unstable
      (requires reassessment of gut perfusion/status)
    • Intestinal perforation/necrotizing enterocolitis

• In ELBW or sick VLBW infants, keep at trophic feeds for 3 days prior to advancing

Feeding Advancement

• Cochrane review ¹
  – Combined studies include 496 total infants

• Slow advancement of feeds has not been shown to reduce NEC

• Advancement rates of up to 35ml/kg/day in LBW infants is safe

What Should We Feed?

• Breast milk is preferred – should consider donor milk if BM unavailable
  – Improves feeding tolerance
  – Contains important
    • antibodies (IgA)
    • antibacterial peptides (lysozyme)
    • oligosaccharides (improves colonization of helpful intestinal bacteria)
    • hormones (EPO/EGF)
    • anti-inflammatory cytokines (IL-10)
  – Reduces NEC
    • Even when donor milk is used (NNH 33)
    • When used as base for HMF (NNT12.5)

Human Milk Fortifier (HMF)

• Components of HMF

• HMF should be offered if:
  – Less than 1800g or less than 34 weeks at birth

• Benefits
  – Increases delivery of calories without increasing volume
  – Better bone mineralization
  – Better nutrient balance

What If Breast Milk Is Unavailable?

• Preterm formula should be offered if:
  – Less than 1800g or less than 34 weeks at birth

• Advantages of Preterm formula
  – Higher intake of Ca and Phos to provide net mineral retention and improve bone mineralization
  – Appropriate protein required to promote anabolism and prevent negative nitrogen balance
  – Optimize fat absorption

Optimizing Management

Recommend advancing caloric density when feeds at 100ml/kg/day (prior to advancing volume)

- This will allow optimization of calorie and protein intake
- Reduces deficit by 41kcal/kg and 4.3g/kg protein
When Do We Stop Preterm Formula or HMF

- Needs premature formula until all oral feedings, or greater than 1,800g, or near discharge \(^1\)

- Premature infants benefit from transitional formulas (Enfacare\(^\circledR\), Neosure\(^\circledR\)) at discharge \(^2,3\)

- Continue HMF until 2.4 - 2.7 kg \(^1\)

# Screening for Nutrition Risk in Preterm Infants

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| Birth to 1 week | 1. Birth weight $< 1000g$  
|              | 2. $> 15\%$ weight loss from birth weight                                |
| 1-2 weeks   | 1. Continued weight loss  
|              | 2. Intake $< 60$ kcal/kg/day                                             |
| > 2 weeks   | 1. Growth $< 10g/kg/day$  
|              | 2. Enteral Intake $< 80$ kcal/kg/day or combined PN + EN $< 70$ or TPN $< 60$ kcal/kg/day  
|              | 3. Lab values: serum conjugated bilirubin $> 2$ mg/dL; serum phos $< 4$ mg/dL; serum alk phos $> 1000$ U/L; serum albumin $< 2.5$ g/dl |
| > 2 months  | 1. Any of the above criteria  
|              | 2. Patient still on PN                                                   |

**Diagnoses**

Increased needs including surgery, chronic lung, heart, metabolic, neurologic problems

Overview of EN Support in Special Populations
The Working GI Tract

**The Functional GI Tract**
- Stimulated by appetite
- 3 jobs
  - digest
  - absorb
  - eliminate
- 4 anatomic areas
- Depends on what area of the intestine is afflicted
- Impaired intake, digestion and absorption can cause malnutrition and increase diarrhea

**Consequent Deficiencies**
- Macronutrients
  - Carbohydrates
  - Fats
  - Protein
- Micronutrients
  - Vitamins: water and fat soluble
  - Minerals
- Free water

History of EEN

1970s

- Observation that CD pts on TPN (bowel rest) improved \(^1,^2\)
- Case reports (Europe) \(^3,^4\)

1980s:

- Elemental diet \(^5,^6\)

2004:

- Polymeric diet \(^7\)

2006:

- First-line induction in Europe and Japan \(^8,^9\)

EN: Effective Induction Therapy for Crohn’s Disease

• Formula feeds $^{1,2}$
  – Exclusive enteral nutrition (EEN) and partial enteral nutrition (PEN)
  – Elemental, semi-elemental or polymeric

• Routes
  – PO
  – NG
  – G/J tube

• Duration $^3$
  – 8-12 weeks
  – Role of PEN in maintenance

Data

- 85% achieve remission \(^1,2\)
- Complete nutritional rehabilitation \(^3\)
- Complete mucosal healing \(^4,5\)
- Resumption of growth \(^6,7\)
- Control flares \(^8\)

EN Utilization: Discrepancy

Use of EN in Europe and United States

• Prescribed by 62% European pediatric gastroenterologists \(^1,^2\)
• Prescribed by 4% American pediatric gastroenterologists \(^1,^2\)

Use of EN in Japan

• Total enteral nutrition in the form of an elemental formula is indicated as primary therapy for children with Crohn’s disease at onset as well as the active stage. \(^3\)

Proposed Mechanisms of Action

• Reformation of gut microflora

• Complete nutritional repletion; provision of micronutrients

• Correction of intestinal permeability

• Restriction of dietary antigen

• Decreased intestinal synthesis of inflammatory mediators

Concerns

- Palatability/adherence
- Cost
- Refeeding syndrome
Other Diets for IBD

<table>
<thead>
<tr>
<th>Low fiber/low residue</th>
<th>Popular diets</th>
</tr>
</thead>
<tbody>
<tr>
<td>• UC</td>
<td>• Specific Carbohydrate Diet</td>
</tr>
<tr>
<td>• Strictureing disease</td>
<td>• Gluten free</td>
</tr>
<tr>
<td>• Typically use low residue with active colitis and move to higher fiber with mucosal healing</td>
<td>• Lactose free</td>
</tr>
</tbody>
</table>
Other Enteral Supplements

• Fish oil
  – Anti-inflammatory
    • Inconclusive
    • More mouse studies than human \(^{1,2}\)

• Probiotics
  – Restoration of gut microflora \(^{3-5}\)

Summary

• Nutritional derangement common in IBD
• EN is effective and underutilized
• Elemental, semi-elemental and polymeric formulas have equivalent efficacy
• Current theory is that EN alters gut microbiota favourably
• Other diets not proven to improve disease but may ameliorate symptoms
• Nutritional supplements are unusual diets are common however beware of potential toxicity
Overview of EN Support in Special Populations

Short Bowel Syndrome/
Intestinal Failure
Short Bowel Syndrome (SBS)/Intestinal Failure

• Functional definition (not dependent on length alone)
  – Malabsorptive state occurring as a result of the loss of a significant portion of the intestine
  – Characterized by the inability to maintain protein-energy, fluid, electrolyte or micronutrient balances when on a conventionally accepted, normal diet.

• Results from surgical resection, congenital defect or disease-associated loss of absorption
  – Most frequent cause is surgical resection due to NEC
  – Other causes of include intestinal atresia, gastroschisis, midgut volvulus, or later in childhood from trauma or Crohn's disease

Proposed New Definition

- Loss of bowel or enterocyte mass
- Short Bowel
- Surgical Resection
- Congenital Defect
- Disease-Associated Loss of absorption
- Obstruction Dysmotility
- Chronic Obstruction

SBS
Associated Intestinal Failure

Factors Affecting Patient Outcomes

• PN has dramatically improved the historically dismal prognosis of SBS.
  – Prior to PN, severe SBS was invariably fatal from dehydration, electrolyte deficiencies and malnutrition.

• Today, factors associated with the prognosis of SBS-associated intestinal failure are:
  – Underlying disease and age of patient
  – Length of residual small intestine and functional bowel
  – Presence/absence of the colon and of the ileocecal valve
  – Status of enteral dependence or independence.

Principles of Nutritional Care of SBS

- EN key to intestinal adaptation and reduction of dependence on PN
- Goals in nutrition management
  - Keep the infant/child well nourished and growing
  - Keep fluid and electrolyte status stable
  - Maximize the process of bowel adaptation
- Successful transition to EN feeding depends upon
  - Length of remaining bowel & percentage of daily energy intake enterally
  - Remaining segments of small bowel and intestinal continuity
  - Presence of the colon and an intact ileocecal valve
  - Intestinal adaptation

Sites Of Absorption

- Carbohydrates
- Fats
- Proteins
- Calcium
- Magnesium
- Trace elements
- Vitamins
- Vitamin B12 and bile salts
- Short chain Fatty acids
- IRON AND FOLATE
- Water and Electrolytes

Short chain Fatty acids
## Nutritional Consideration with Bowel Loss

<table>
<thead>
<tr>
<th>Jejunum</th>
<th>Ileum</th>
<th>Ileocecal Value</th>
<th>Colon</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Primary site for digestion and absorption of most nutrients</td>
<td>- Ileal loss can predispose to malnutrition, excessive fluid losses and electrolyte deficiencies because the jejunum is more porous and has limited capacity to enhance absorption</td>
<td>- Slows down transit time</td>
<td>- Loss of “colonic brake”</td>
</tr>
<tr>
<td>- Loss does not result in severe malabsorption because ileum has a large capacity to compensate for increased absorption</td>
<td></td>
<td>- Prevents reflux of colonic contents into Small Bowel</td>
<td>- Loss of water and electrolyte resorptive capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Reduce absorption of vitamin B 12</td>
<td>- Loss of ability to salvage calories from malabsorbed carbohydrates.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Deconjugate bile salts</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Reduce bile salt absorption</td>
<td></td>
</tr>
</tbody>
</table>
Nutrition Therapy

• TPN – ensure adequate nutrition and hydration

• Enteral feeding
  – Formula type
  – Route: oral, NG, GT
  – Bolus vs. continuous
  – Progression to solids

Total Parenteral Nutrition

• Essential for survival in SBS, but may contribute to the mortality of this condition

• Allows adequate macro and micronutrient intake in individuals with intestinal failure

• Clinical Disadvantages
  – Does not promote intestinal adaptation
  – PN-associated cholestasis (PNALD) / Intestinal failure-associated liver disease (IFALD)
  – Metabolic complexity
  – Requires central line – nidus for infection and clot formation

Benefit of Feeding Type in SBS

• Breast-milk
  – Immune benefits, contains growth factors, encourages healthy microbiome

• Standard Formula
  – Increased possibility of malabsorption with intact protein, CHO (lactose) and fat source, allergic reaction to cow or soy protein common

• Protein Hydrolysate Formula
  – Lower antigenicity, contains medium chain triglycerides (does not require bile acids or micelles for absorption)

• Amino Acid Formula
  – Shorter duration of TPN
  – Reduced intestinal allergy
  – Higher content of long chain triglycerides which can be trophic to the intestines

Andorsky et al. J Pediatr. 2001;139(1);27–33.
# Frequency For Monitoring Growth Children With SBS

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Comment</th>
<th>Initial Period</th>
<th>Long-Term Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>Preterm infants</td>
<td>Daily</td>
<td>Every 2-4 weeks</td>
</tr>
<tr>
<td></td>
<td>Age &gt; 1 year</td>
<td>Twice a week</td>
<td>1-6 month</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>Birth to 3 year</td>
<td>Every 2 weeks</td>
<td>1-3 month</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>Birth to 3 year</td>
<td>Every 2-4 weeks</td>
<td>1-3 month</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>Age ≥ 2 year</td>
<td>Every 4 weeks</td>
<td>1-6 month</td>
</tr>
</tbody>
</table>
## Frequency For Monitoring Nutrient Status In Children With SBS - I

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Comment</th>
<th>Initial Period</th>
<th>Long-Term Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolytes, Ca, Phos, Mg</td>
<td>Patients on PN</td>
<td>Twice a week</td>
<td>Every 2-4 weeks</td>
</tr>
<tr>
<td>Transaminases, direct bilirubin, GGT</td>
<td>Patients on PN</td>
<td>Every 1-2 weeks</td>
<td>1-3 month</td>
</tr>
<tr>
<td>Total protein, prealbumin</td>
<td></td>
<td>Every 2-4 weeks</td>
<td>1-3 month</td>
</tr>
<tr>
<td>Complete blood count, reticulocyte count</td>
<td></td>
<td>Every 2-4 weeks</td>
<td>1-3 month</td>
</tr>
<tr>
<td>PT/PTT/INR, Iron studies, Vitamin/Trace elements</td>
<td>Baseline/as indicated</td>
<td></td>
<td>As indicated</td>
</tr>
</tbody>
</table>
# Frequency For Monitoring Nutrient Status In Children With SBS - II

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Comment</th>
<th>Initial Period*</th>
<th>Long-Term Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron studies (Fe, transferrin, % saturation, TIBC)</td>
<td></td>
<td>baseline</td>
<td>as indicated</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>baseline 3 months</td>
<td>baseline</td>
<td>3 months</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>(\alpha)-tocopherol:cholesterol ratio &lt; 2.47 mg/g consistent with deficiency</td>
<td>baseline</td>
<td>3 months</td>
</tr>
<tr>
<td>Vitamin D (25-hydroxyvitamin)</td>
<td>Also consider seasonal factors influencing risk of deficiency</td>
<td>baseline</td>
<td>3 months</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>(\downarrow) plasma B12 accompanied by (\uparrow) urine methylmalonic acid confirms deficiency</td>
<td>baseline</td>
<td>3-6 months</td>
</tr>
<tr>
<td>Trace Minerals (Cu, Zn, Se, Mn)</td>
<td>as indicated</td>
<td>as indicated</td>
<td>3-6 months</td>
</tr>
</tbody>
</table>
What’s New

• Omega-3 Fatty Acid-rich lipid emulsion
• Glucagon-like peptide 2 (GLP-2)
• Serial Transverse EnteroPlasty (STEP)
Omega 3 Fatty Acid Infusion

• Fish-oil based intravenous lipid solution

• n-3 (\(\Omega 3\)) v n-6 (\(\Omega 6\)) fatty acids

• Reduced production of proinflammatory cytokines, e.g. TNF\(\alpha\), IL-6 & 8

• Improves cholestasis of children with PNALD

SBS Conclusion

• Maintain proper nutrition and growth
• Enteral feeding is the most important stimulus for bowel adaptation
• Continuous enteral feeds results in more nutrient absorption
• Transition to enteral can be a slow and steady process
Overview of EN Support in Special Populations

Cystic Fibrosis
EN: Cystic Fibrosis

• Long term survival is linked to nutritional status
• Lung disease, airway inflammation & infection result in appetite suppression & increased energy expenditure
• Descriptive studies looking at correlation of nutritional status & pulmonary function
  – Improved survival associated with changes in dietary management
  – Declining FEV1 strongly associated with increased mortality
• International and US CF Foundation nutritional guidelines are available
• Goals
  - Normal growth and optimal nutritional status
  - Ages 0-2 year: weight for length ≥50th percentile
  - Ages 2-20 year: BMI percentile ≥ 50th percentile
  - BMI for males: 23, BMI for females: 22

FEV₁ and BMI Outcomes

The data show that pulmonary function and nutritional status are highly correlated. Some centers are achieving the goals established in the CF Foundation Nutrition Guidelines.²

FEV₁ Percent Predicted vs. BMI Percentile in Patients 6 to 20 Years

FEV₁ Percent predicted is positively correlated with BMI percentile for patients 6 to 20 years of age (p<0.0001).

Cystic Fibrosis Foundation: Registry: Annual Data Report to the Center Directors, Bethesda, MD.
Nutrient Requirements - I

• Optimal energy intake important for care; may be based on:
  • Pulmonary exacerbation/function
  • Maldigestion/malabsorption
  • Gender and pubertal status
  • Genetic mutation
  • Age
  • Liver disease
  • CFRD
  • Daily calorie requirements: 110-200% of recommended intakes for normal individuals
  • CFF nutrition consensus: any equation is a starting point and use gains in weight, height, height velocity and fat stores to assess adequacy

Nutrient Requirements - II

• Protein intake is based on age, malabsorption, losses, stress and healing; in general adequate caloric intake results in adequate protein intake.

• Micronutrient intake is very important especially:
  • Na intake
  • Zn status
  • Fat soluble vitamins: A, D, E, K
  • Essential fatty acids

Nutritional Management - I

- Different needs at different ages
- Greatest “at risk” period for malnutrition is the first two years of life, the first year after diagnosis and the peripubertal period
- Start when BMI is \( \leq 10^{th} \) percentile or when deviation from CFF goals
- Nutritional assessment at every visit (Q3 months; more frequent in infants) & review:
  - Weight, length/height, weight for length, BMI, head circumference in infants
  - Nutritional education & dietary counseling
  - Review pancreatic enzyme replacement therapy (PERT)
  - Review need for micronutrient supplementation: fat soluble vitamins (A, D, E, K), Ca, Fe, Zn, Na (salt), EFA
  - Pubertal status (yearly)

Nutritional Management - II

- High calorie balanced diet rather than a high calorie, high fat diet; preferable to use vegetable fats as fat source if possible

Tests:

- Annual studies which include CBC, CMP, GGT, fat soluble vitamin levels including PIVKA II level, Zn & U/A.
- Essential fatty acid level / Triene:Tetraene ratio if indicated, DXA, OGTT

Types of enteral nutrition support

- Oral: high calorie diet, oral supplements
- Tube feeds: NG, G-T, NJ, GJ, JT

Prevention of Nutritional Deficits: Anticipatory Guidance

- Infants: breast milk, formula, solids, Na
- Toddlers/preschool: calories, feeding behavior, whole milk
- School age: calories, snacks, autonomy, adherence, education
- Adolescence: high-risk period (Diabetes Mellitus, liver disease, infections, puberty, increased physical activity, adolescent behavior, eating disorders)

What to Do When Poor Growth is Identified

- See patients more frequently with RD
  - Infants every 2 - 4 weeks; children ≥2 years every 4 - 6 weeks
- Include
  - medical, behavioral, and nutritional assessment as well as education interventions
- Look for active pulmonary disease
  - Sinusitis, GER, CFRD, liver disease
- Evaluate PERT usage
- Diet analysis
  - Qualitative: where, when, who, which, how much, e.g. meal skipping
  - Quantitative: 24 hour diet recall or three day food records to assess kcal and nutrient intake
- May need consultation with gastroenterologist
- Aim
  - Achieve patients target weight for length or BMI percentile taking into account genetic height potential

Interventions for Nutritional Failure

- Increase oral caloric intake by increasing food intake and using oral supplements
- Behavioral evaluation: assess early, check for ineffective feeding behaviors & parenting strategies, look for eating disorders in adolescents, check for skipping enzymes (30%)
- Behavioral strategies: are effective
  - Increase calories one meal at a time
  - Teach parents alternative ways to respond to children who eat slowly or negotiate what he/she eats
  - Identify appropriate rewards for improved eating behavior
- If cannot increase oral intake: tube feeds

Tube Feeds – I

• Tube feeds are well tolerated, successful in improving BMI, and allow individualized regimens

• Give 30-50% of goal kcals overnight
  – night time feeds to allow normal day time eating patterns)

• Goals
  – Infants: 120-150 kcal/kg/day (catch-up, lung & long term growth)
  – Titrate calories based on weight gain, fat stores & growth

• Standard (complete protein, long-chain fat) formula well tolerated

Tube Feeds - II

- Very low fat elemental formulas
  - no need for PERT
  - useful in intubated patients given continuous feeds
- Calorically dense (1.5 - 2 kcal/cc) may be needed to provide adequate calories
- MCT containing formulas may be beneficial
- Use semi-elemental formulas in patients with excessive anorexia, bloating, nausea
- Check sugar 2-3 hours into feeds and at end of feeds on two separate nights
- Give insulin if blood sugar is > 180mg/dl. Repeat blood sugar if patient not gaining weight, is ill, or is on corticosteroids
- Monitor for bloating, reflux, and steatorrhea

PERT and Tube Feeds

• Neonates/infants
  – Start when formula intake is 60 cc Q3H: 3,000 lipase units PO in applesauce
  – With continuous feeds – use 3,000 lipase units Q4H
  – Watch for skin breakdown at ostomy & anus
  – Clean mouth after feeds to prevent oral ulcers

• Children & adolescents
  – Take usual dinner dose orally at start with all feeds except very low fat elemental formulas
  – May give additional doses midway or at end of feeds
CFF Nutrition Guidelines for Infants

• Use human milk or standard infant formula; hydrolyzed protein formulas are not needed

• Calorie dense feeds if weight loss/ inadequate weight gain

• Encourage positive feeding behaviors / use available educational resources

• When growth deficits are present, intensive treatment with behavioral intervention and nutrition counseling is required

• Start appropriate multivitamins shortly after diagnosis. Check fat soluble vitamin levels 2 months later and annually; increase frequency if values are abnormal

• Trial of elemental Zn 1 mg/kg/day for 6 months, if not growing well despite adequate caloric intake and PERT

• Salt: 1/8 tsp, diagnosis - 6 mo; 1/4 tsp after

• 0.5 - 2 year: if water has < 0.3 ppm, give fluoride 0.25 mg/dl
Summary

• Nutrition plays an important role in the care of the patient with CF

• Growth assessment should be done at every visit. Goal is BMI \( \geq 50^{th} \) percentile for children aged 2-20 years or weight for length \( \geq 50^{th} \) percentile for children 0-2 years

• Annual monitoring should be part of management

• PERT should be reviewed at every visit (total daily dose) and when the patient is not growing optimally

• The CF center dietitian should evaluate the patient quarterly or more often if there is growth failure
Overview of EN Support in Special Populations

Cerebral Palsy
Nutrition & Cerebral Palsy

• Under-nutrition, growth failure & overweight may be present

• Micronutrient deficiencies include:
  – Vitamins: C, D & E
  – Trace elements: Se, Zn
  – Essential fatty acids
  – Minerals: Fe, Ca, Phos

• Osteopenia: more prevalent in non ambulatory children and may be related to anti-convulsant therapy & reduced physical activity

• Nutritional monitoring is very important including consultation with RD

Goals & Benefits

• Goals of nutritional therapy
  – Consistent and adequate weight gain
  – Linear growth commensurate with underlying neurological disorder since neurological disease may adversely affect linear growth even in the absence of under-nutrition
  – Optimize functional status and quality of life

• Benefits of nutrition
  – Restore linear growth & normalize weight
  – Improve health and QoL
  – Reduce hospitalization rate and missed fewer days of social activity
  – Decrease irritability and spasticity
  – Increase alertness and enhance development
  – Improve wound healing and peripheral circulation
  – Ameliorate GER

Factors Resulting in Nutritional Deficits

• Nutritional factors
  – Inappropriate dietary intake
  – Oral motor dysfunction, dependency on caretaker, longer mealtimes
  – Increased nutrition losses (spillage, reflux, emesis from gastroparesis)
  – Abnormal energy expenditure

• Non- nutritional factors
  – Type & severity of neurological disability
  – Mechanical forces and ambulatory status: scoliosis, contractures
  – Cognitive ability
  – Genetic factors
  – Endocrine dysfunction: GH
  – Environment: home vs. chronic care facility

Nutrition Assessment - I

• History
  – Medical, nutritional assessment, growth, and social (caretakers)

• Anthropometry
  – Weight, length/height, head circumference, mid arm measurements
  – Alternative measurements of linear growth
  – Always need to use the same method for monitoring
  – Appropriate measuring equipment needed: wheel chair scales, bed scale, anthropometer

Nutrition Assessment - II

• Growth charts
  - *Normal* or *Traditional* growth charts may not always be appropriate
  - Many CP specific are available which may be descriptive rather than prescriptive
  - New growth charts stratified for gender and gross motor function classification system level may be useful in prognosis and determining level of intervention
  - If using the CDC or WHO charts, look for trends rather than the absolute percentile, see if the patient is tracking parallel to the 3\textsuperscript{rd} percentile. Remember that not everyone belongs on the 50\textsuperscript{th} percentile.

Nutrition Assessment - III

• Physical examination
  – Evaluate for under-nutrition, stunting, overweight
  – Micronutrient deficiencies
    • pallor, skin rash, smooth tongue, gum bleeds, petechiae, bony deformities, edema
  – Other
    • muscle tone, activity, athetosis, contractures, scoliosis, signs of aspiration, abdominal distension, decubitus ulcers

• Meal observation
  – Important to observe
    • portion size offered, spillage, parent child interactions, eating efficiency, oral motor function

Nutrition Assessment -IV

• Laboratory testing
  – CBC, Fe studies, serum electrolytes, Ca, Phos, 25OH vitamin D, albumin and pre-albumin, Zn, Se, vitamin E, linoleic acid and triene:tetraene ratio

• Other testing
  – DXA (lumbar, distal femur, forearm)
  – REE measurements
  – Additional gastrointestinal evaluation as warranted (radiology, ultrasound, endoscopy)

Determining the Nutritional Plan - I

- Individualized plan based on nutritional status, feeding abilities, and medical condition
- Determine a target weight/target skinfold thickness (weight at which the TSF is between the 10-15\textsuperscript{th} percentile)
- Annual nutritional assessments at a minimum and increased frequency in younger children
- EN is preferred vs. PN
- Oral diets are preferable. May need to use thickened fluids in patients with dysphagia and aspiration.
- Positioning of the patient is important for oral feeding along with the use of an oromotor therapist.
- Behavior modification and feeding therapy will help with food acceptance

Determining the Nutritional Plan - II

- Tube feeds if patients cannot orally meet nutritional needs
- Formula is preferable to blenderized diets due to risks of infection, inappropriate composition, and clogging of tubes
- Ethical considerations
  - Tube placement is sensitive issues for some families
  - Thoughtful discussions and consideration of parental wishes is key
- Energy intake
  - WHO equation is easy requiring only weight, age, and activity/stress factor but may overestimate calories.
  - In general would use lower number, response to therapy, and subsequent weight measurements to adjust caloric intake
- Fluid
  - Often patients do not receive maintenance fluids

Determining the Nutritional Plan - III

- All regiments need to be assessed to provide enough protein, vitamins, and minerals
- Protein
  - Insufficient data; but often low intake documented
- Micronutrients
  - Deficiencies exist; supplementation may be required
- Route of administration of feeds
  - Short-term (NG, NJ tubes); long-term (G, G-J, J tubes)
- Method of administration or tube feeds:
  - Bolus feeds are more physiological, flexible, and convenient in ambulatory children
  - Continuous feeds (day or night) used with feeding intolerance or with JT

Picking a Formula

- No one formula meets needs of all children with CP
- Often need to manipulate formula to provide adequate protein in the face of low calories and use modular formulas, vitamins and electrolyte solutions, or combine two formulas
- Calorie needs may be very low; monitor for sufficiency of intake of Na, Phos, K, Ca, Fe, vitamin D, and protein
- Can use standard age appropriate formulas
- Adult formulas may provide more protein but may not meet Fe, vitamin D, Ca, and Phos needs
- Whey based may be better tolerated to enhance gastric emptying
- Fiber can be helpful but may cause bloating if advanced too fast
- If use 1.5 or 2 cal/mL formulas but warrants monitoring of fluid, protein, and micronutrient intake

Feeding Intolerance

• Symptoms
  – Vomiting, reflux, bloating, constipation or diarrhea and nausea

• Treatment
  – Exclude progression of neurological disease, infection, intestinal obstruction
  – Consider
    • change from bolus to continuous feeds
    • decrease rate of infusion
    • concentrate formula to decrease volume
    • alternative formula: whey based formulas are associated with improved gastric emptying
    • treat reflux, gastroparesis, constipation

Summary

• Nutrition plays an important role in the care of patients with CP

• Nutritional status affects prognosis and QoL

• Growth assessment and monitoring is important

• Nutritional regimens need to be individualized and monitored for fluid, calorie, protein and micronutrient adequacy
Overview of EN Support in Special Populations

Critically Ill
With few exceptions a functional gut should be used for EN, including in critical illness

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce gut atrophy</td>
<td>More likely to <em>underfeed</em></td>
</tr>
<tr>
<td>Improve gut motility</td>
<td><em>Contraindications</em>: nonfunctional gut: anatomical disruption, obstruction, ischemia, peritonitis; Severe shock states</td>
</tr>
<tr>
<td>Reduced infections (enhanced gut immune function and avoidance of translocation)</td>
<td>Frequent interruptions for fasting for diagnostic and other procedures limit efficacy, especially in malnourished patients</td>
</tr>
<tr>
<td>Cost effective</td>
<td>Risk of aspiration</td>
</tr>
<tr>
<td>Less likely to <em>overfeed</em></td>
<td></td>
</tr>
</tbody>
</table>
Benefits of EN in an ICU Setting

• Reduce gut atrophy
• Improve gut motility
• Reduced infections
  – Enhance gut immune function
  – Avoid translocation
  – Avoid PN (with direct immune suppressing effects)
• Less likely to overfeed
• Cost effective
Limitations of EN

• Absolute Contraindications nonfunctional gut
  – Anatomical disruption/obstruction
  – Peritonitis
  – Ischemia & severe shock

• Limitations
  – Tolerance
  – Risk of underfeeding
  – Risk of aspiration
  – Risk of ischemia
When to Start EN

• Timing of nutrition may be as or more important than route
  – Meta-analysis in adult patients; early PN reduced mortality (but increased infections) when compared to delayed enteral \(^1\)

• Pediatric Guidelines
  – If EN is not possible PN should start 1-3 days infants, 4-5 days for older children \(^2\)
  – Meta-analysis identified one trial in pediatric burns patients and concluded *no difference* with enteral nutrition < 24 hours compared to ≥ 48hrs; but data is inconclusive \(^3\)

\(^1\) Joffe et al. Cochrane Database of Systematic Reviews. 2009(2)CD005114.
\(^3\) ASPEN Guideline Task Force JPEN J Parenter Enteral Nutr. 2002;26:1SA-138SA.
Starting EN: Lessons Learned from Gastrointestinal Surgery

• Early initiation of EN post major gastrointestinal surgery reduces complications 1,2

• NPO status post surgery waiting for bowel sounds or gas increases malnutrition and worsens outcomes after (adult) surgery 3

• Pediatric studies need to be done, across developmental stages

EN vs. PN

- Pediatric data limited
- Meta-analysis of adult trials suggests PN associated with greater infectious complications, but not with greater mortality 1-5
- Considering the above, if poorly tolerant to EN a combination approach may be more optimal (versus inadequate nutrition support) 6,7

The Systemic Inflammatory Response Syndrome:

Critical Insult
Sepsis, Trauma, Surgery, Burns, Cardiac bypass

Local Response
Innate Immunity

Vascular endothelium & Perfusion
Cytokines Chemokines Eicosanoids
Reactive Oxygen species Nitric Oxide
Complement System Apoptosis

Central Response
Hypothalamus Anterior pituitary

End Organ Responses
Multi-organ failure (MOF)

Adrenal Cortex - hypercortisolism
Liver – acute phase proteins
Bone marrow - leucocytosis
Immunity – immune suppression
Cardiovascular – shock
Pulmonary – ARDS
Renal – failure
Gut – ischemia, translocation

Central Response
Hypothalamus Anterior pituitary

ACTH

End Organ Responses
Multi-organ failure (MOF)

Adrenal Cortex - hypercortisolism
Liver – acute phase proteins
Bone marrow - leucocytosis
Immunity – immune suppression
Cardiovascular – shock
Pulmonary – ARDS
Renal – failure
Gut – ischemia, translocation
Critical Illness Cycles: SIRS to CARS
(Compensatory Anti-inflammatory Response Syndrome)

Risk Factors
- Shock severity
- Tissue Injury
- Host Factors
- Transfusions

Second Hits
- Transfusions
- Recurrent Shock
- Operations

Infections
- Malnutrition
- ?PN

Severe SIRS -> Early MOF
Moderate SIRS
Severe Immunosuppression
CARS
Moderate Immunosuppression
Severe Immunosuppression

Implications for EN

- Prolonged stay in PICU will involve use of EN during SIRS and CARS

- Increased metabolism particularly relevant during recovery
  - Increased further with EN (TEF)
  - Protein & energy required for tissue repair
  - Eventual recovery of growth potential
Critical Illness & Intermediary Metabolism

- Hyperglycemia
- Hypertriglyceridemia
- High free fatty acid (FFA) levels
- High lactate levels
- Disturbed normal energy substrate balance
  - mobilizes both substrates at once
- Risk of overfeeding with PN
  - increases hyperglycemia and hypertiglyceridemia
Implications for EN

• EN risk of underfeeding greater than overfeeding
  – Gastrointestinal tolerance
  – Restriction and interruptions

• Energy requirements met <50% time\(^1\), especially
  – Post-surgical patients
  – Interruptions for fasting (diagnostic/other procedures)
  – Fluid restriction in cardiac patients \(^1\)

• Risk of worsening PEM over PICU stay\(^2\)
  – At least 20% children admitted to PICU malnourished

Gastrointestinal Intolerance

• Gastrointestinal intolerance observed in over half pediatric patients ¹
  – Vomiting
  – Abdominal distention
  – Constipation
  – Diarrhea

• Other than shock not predicted by clinical severity ²,³

• Management includes use of feeding protocols, consider transpyloric feeding ⁴-⁶

Transpyloric EN (TEN)

• May be indicated for intolerance with gastroparesis (vomiting and/or large aspirates) to provide EN ¹

• Often used to reduce aspiration in the ICU setting, but not supported by pediatric trials ¹,²

• NG tubes easier to place and less radiation ²

• TEN can cause gastrointestinal complications, including small bowel perforation ³

EN and Gut Ischemia

• Splanchnic blood flow increases with EN \(^1\)

• Poor perfusion of the postprandial gut will create an imbalance in oxygen supply vs. demand and potentially cause ischemia
  
  – Use EN with caution in patients with shock or hemodynamic instability and increased risk of ischemia (post cardiac surgery)

• EN is possible in the sickest children who attain hemodynamic stability with maximal support e.g. ECMO \(^2,3\)

Special Enteral Formula - Immunomodulation

• Diets enriched in pharmaconutrients to alter immunological response to sepsis/trauma

• Limited pediatric data to support at this time
  – Will modulate cytokines ¹
  – But may not alter clinical outcomes ²,³

• Adult data confusing ⁴-⁶
  – May depend on patient selection (surgical, medical, septic), timing of administration, which nutrients in what patient, route, and site of inflammation (gut vs. systemic)

Special Enteral Formula - Glutamine

• No pediatric data available to support EN supplementation

• Adult data supports reduction of septic complications by addition of glutamine to PN ¹

• PN supplementation not supported by trials in neonates and infants ²,³

Special Enteral Formula - Prebiotics and Probiotics

• Critical illness promotes dysbiosis
  – Antibiotics and acid suppression
  – Dysmotility due to sedation, analgesia, and paralysis
  – EN: may worsen ¹ may improve ² or do nothing

• Synbiotic formula (pre and probiotics) may be safe ³ or not ⁴

• Limited pediatric studies on efficacy but not supportive ⁵

EN and Chylothorax

- Treatment limiting enteral long chain triglycerides
  - potential for essential fatty acid deficiency exists

- Use formulae enriched in medium chain triglycerides
  (transport directly to portal system)

- May limit need for total parenteral nutrition support ~70% of the time \(^1\-^3\)

- Replace chest tube drainage (protein & electrolytes) and provide fat soluble vitamins

Overview of EN Support in Special Populations

Failure to Thrive
Causes of FTT

• Inadequate intake of calories
• Loss of calories
  – Vomiting, maldigestion, malabsorption
• Increased caloric need
  – Cardiorespiratory disease, liver disease, renal disease, chronic infections
• Inability to utilize calories consumed
  – Chromosomal, endocrine and metabolic disorders
• Psychosocial, emotional
Initial Interventions in FTT

• Meals/snacks
  – At the table or in the high chair

• Structured meals and snacks
  – No more than 20-30 minutes to eat/drink
  – Feed every three hours

• Only water between meals and snacks
  – Stop all juice and soda
Oral Supplementation

• Increase caloric values of all foods

• Increase calorie content of beverage consumed
  – Add calories to pumped breast milk or provide supplemental bottles of formula
  – Increase calorie concentration of formula
  – Provide 30 cal/oz beverage to child who is over one year of age

• In children with vomiting, attempt to control vomiting with appropriate treatment

• In children with increased calorie needs, maximally concentrate all liquids and provide calorie-dense foods e.g. oils, butter, fat sources
EN and FTT

• In FTT, EN is usually required in
  – Children with significant developmental delay
  – Children with neurological disorders that may affect swallowing and predispose to aspiration
  – Children with increased calorie needs, e.g. cardiorespiratory disease

• In each of these conditions, a trial of NG feeds may be appropriate
  – Children who require NG feeds for greater than four to eight weeks may benefit from gastrostomy tube placement
FTT: Benefits of Gastrostomy (GT)

• Optimize nutrition
  – Fluid, calories, micronutrients

• Optimize feeding tolerance
  – Slow feedings, use “medical” formulas as needed, intestinal delivery as needed

• Optimize medical care
  – Access for medications and nutrition after operative procedures

• Optimize skill acquisition and behavioral therapy
Failure to gain weight due to inadequate calories
- No response to initial interventions
- Other causes ruled out (maldigestion, malabsorption, increased demands)

Vomiting / Reflux?
- No response to medical therapy
- Other causes of vomiting ruled out

Developmental delay with concern for aspiration?
- ENT / SLP evaluation
- Appropriate feeding interventions
- Pulmonary evaluation

No progress?

Inability to control?

Concerns with pulmonary health?

Tube Feeding (NG / GT)

Ongoing vomiting or reflux with / without aspiration and / or lung disease?
- Intestinal feeding
- Fundoplication
Management of Children with Feeding Tubes

- There is a paucity of data on how children with feeding tubes should be optimally managed
  - There are no pediatric studies to document pulmonary effects of allowing OR restricting drinking water in children who aspirate thin liquids
  - There are no studies on optimal tube feeding regimens to balance oral feeds with tube feeding to maintain growth and development
Cased-based Learning

EN Support in Short Bowel Syndrome
Case Report

- Female infant born at 27 weeks gestation
- Twin fetal death in-utero
- Ventilated for 2 days
- CPAP until 1 week
- Full enteral feeds by 10 days
- Indomethacin for PDA day 12 (feeds held)
- Day 15 ↑residuals, sleepy, abdominal distension, acidosis, pneumatosis intestinalis
Case Report

• Laparotomy
  – ~20 cm beyond Trietz viable
  – Next 50 cm “marginal”
  – Remaining midgut resected

• 2nd look 2 days later
  – All “marginal” bowel dead
  – Parents offered option of withdrawing care
  – remnant 17 cm proximal jejunum → stoma
  – Left-sided colon
Risk factor for Chronic intestinal failure which should trigger involvement of multi professional team or intestinal rehabilitation center

- Prematurity and young age
- Poor mucosal integrity, ischaemia
- Lack of ICV <25 cm residual small bowel
- Intractable diarrhea
- Early catheter infection (before 3 months)
- More than 3 catheter infections or more frequently than 1 per mo
- Excess lipid (soybean based) (>3.5 g/kg/d)
- Lack of enteral feeding

Case Report Continued

Day 30  PDA ligated
Day 52  stoma take-down
Day 73  feeds started
Day 77  transfer to Intestinal care service

• CLD on nasal $O_2$
• ROP stage 2 zone 2
• Bilateral IVH grade 2 with evidence of cerebral ischemic changes
• Feeds at 1 ml/hr
• Still on regular morphine
Conjugated Bilirubin

What happened to change patient’s laboratory and clinical course
Case Report Continued

• Advanced feeds and discharge home 4 weeks later – subsequently has come off oxygen PHT resolved, feeds at 50 ml/hr off lipids

• Please note no cycling TPN, no pushing bolus feeds, no ursodiol
Weight-for-age percentiles: Girls, birth to 36 months

Length-for-age percentiles: Girls, birth to 36 months
Case-based Learning

EN Support in Malnutrition/Failure to Thrive
Case Study

• 2 ½ month-old child born prematurely (30 weeks) with chronic lung disease on nasal cannula oxygen

• Failure to gain weight with oral feeds
  – Significant feeding difficulties with choking and coughing
  – Video swallow study showed that he had aspiration with all textures of formula

What would you do at this point?
Case Study (continued)

• NG tube placed for nutrition

• He was allowed oral feeds 3 times a day with feeds limited to 5 minutes at a time

• He is now 5 months old and is growing well

• He still has a nasogastric tube in place and still requires nasal canula O₂

• He is able to feed orally for about 10 minutes at a time but gets most of feeds through his NG tube

What do you do now?
Case Study (continued)

- He has a G-J tube placed and continues to work with speech therapy and advances on solids but will not take any liquids by mouth
- He has no vomiting

What do you do now?
Case Study- Follow-up

• Gradually transition to gastric feeds and convert G-J into gastrostomy feeds once tolerated

• Continue gastric feeds to ensure appropriate growth while working on oral feeds
  – As oral skills improve, gradually wean enteral supplementation
  – When child is growing well without enteral supplementation for 3-6 months, GT can be removed