Pediatric Enteral Nutrition

A Comprehensive Review

NASPGHAN
NORTH AMERICAN SOCIETY FOR PEDIATRIC GASTROENTEROLOGY, HEPATOLOGY AND NUTRITION

NASPGHAN FOUNDATION
For Children's Digestive Health & Nutrition

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

Delivery Modes/Tubes

Principles of Designing/Monitoring Pediatric EN Support

- *Age/Medical Condition*
- *Monitoring of Tolerance*
- *Safety*

EN Support in Special Populations

- *Premature Infant*
- *Inflammatory Bowel Disease*
- *Short Bowel Syndrome*
- *Cystic Fibrosis*
- *Cerebral Palsy*
- *Failure to Thrive*

Case-Based Module

- *Short Bowel Syndrome*
- *Malnutrition/Failure to Thrive*

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- 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

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History

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

Chernoff, R. *Nutr Clin Prac*. 2006;21:408-10.

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

Gramlich et al. *Nutrition*. 2004;20(10):843-8.
Kleinman et al. *J Pediatr Gastroenterol Nutr*. 2004;39:15–27.

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

1. Gramlich et al. *Nutrition.* 2004;20(10):843-8.

Progressive Intervention

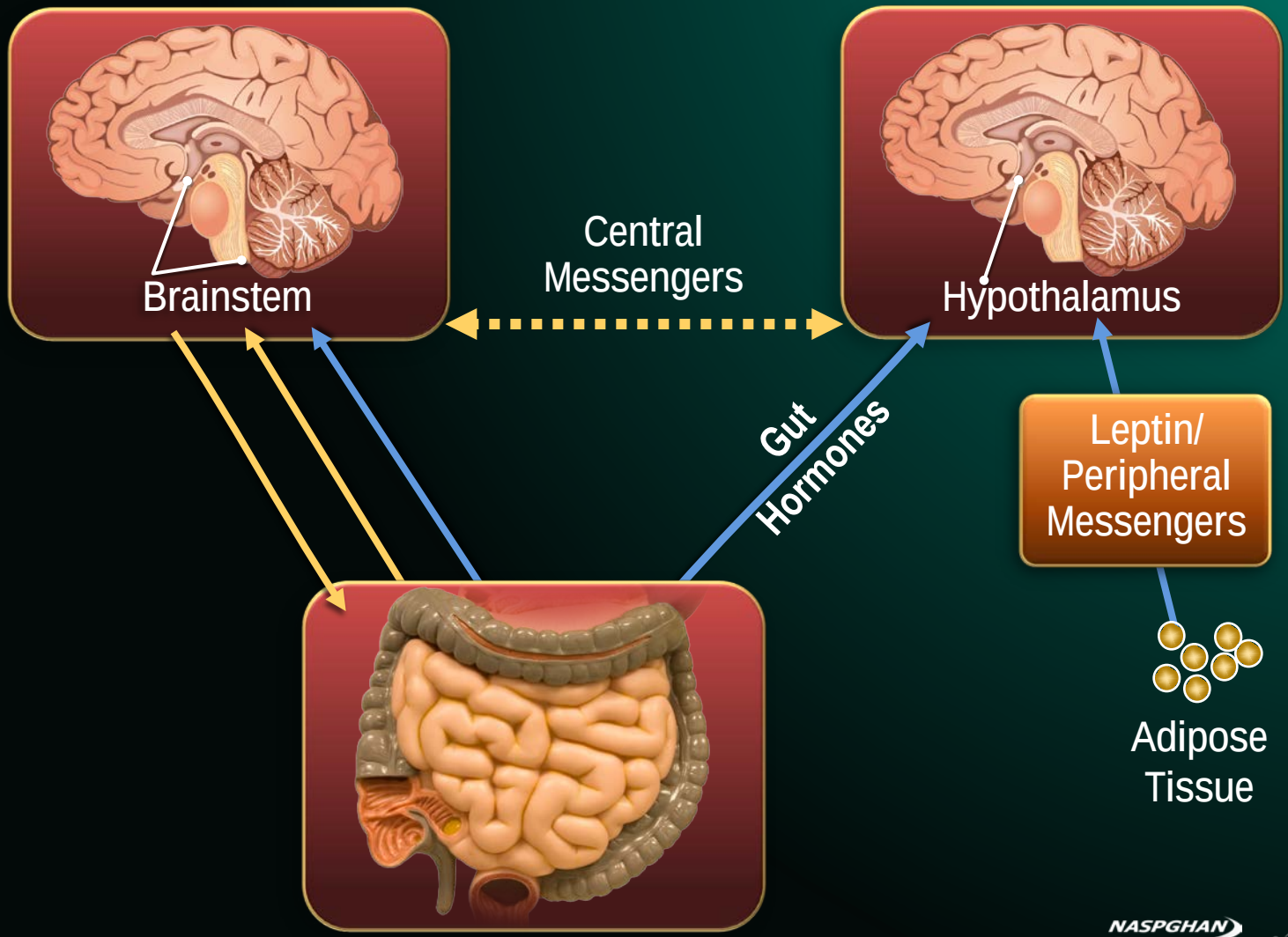
- Attempt oral feeding first. If the gut works, use it
  - There are no trials comparing enteral versus parenteral nutrition
  - EN is physiologic, has reduced, or less severe, incidence infection as compared to parenteral EN, and is cost effective [1]

- 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

1. Kawagoe et al. *Am J Infect Control.* 2001;29(2):109-14.

Appetite Regulation



Adapted from Sanger GJ. *Nature Reviews.* 2008;241-54.

Causes of Decreased Appetite

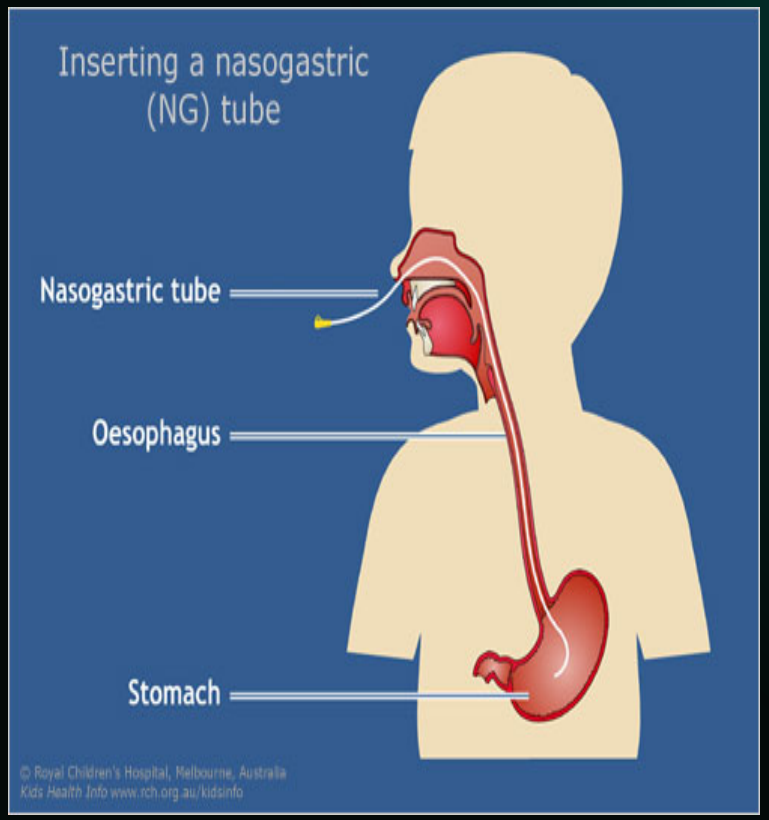
- Disease itself may decrease, e.g. uremia, poor perfusion
- Drugs used for therapy may decrease, e.g. chemotherapy
- Electrolyte limitations or micronutrient deficiencies may decease palatability, e.g. hyponatremia, Zn deficiency
- Diminished gastrointestinal motility, e.g. poor perfusion, biochemical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

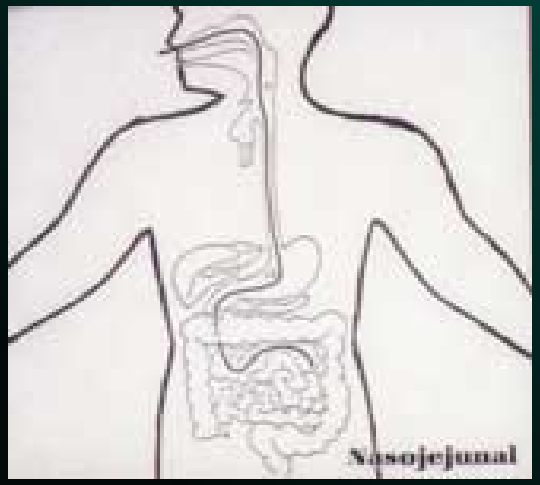
Nasogastric (NG), Nasoduodenal (ND) and Nasojejunal (NJ) Tubes



www.rch.org.au/kidsinfo/factsheets.cfm?doc_id=9766

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

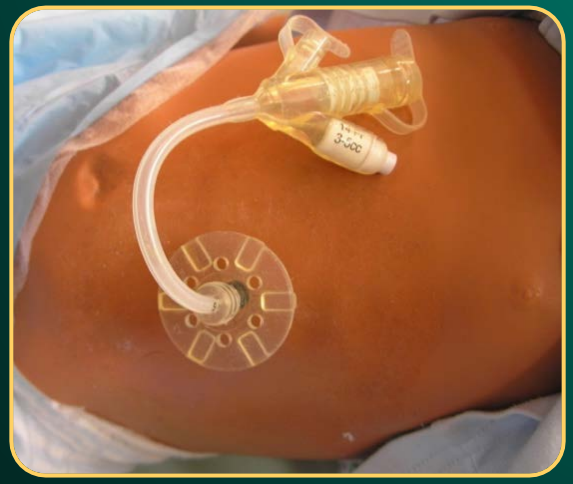
EN Feeding Methods: Gastric vs. Post-pyloric

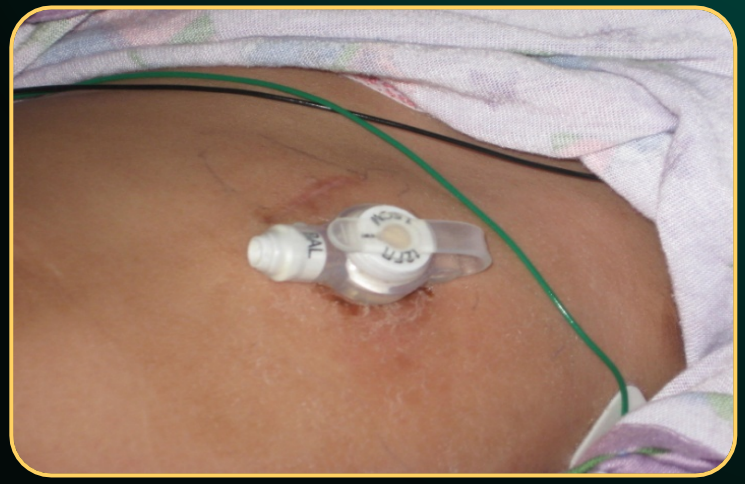
Site	Delivery Route	Indications	Potential Complications
Stomach	Orogastric (infants) NG	• Short-term nutrition support (6-8 wks) • Inadequate oral intake • Refusal to eat • Nocturnal feeds • Inability to suck or swallow	• Aspiration • Nasal mucosal ulceration • Tube occlusion • Pneumothorax • Bleeding/Epistaxis • Sinusitis/otitis
	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 Postpyloric	• ND • NJ • G-J • Jejunostomy	• 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

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

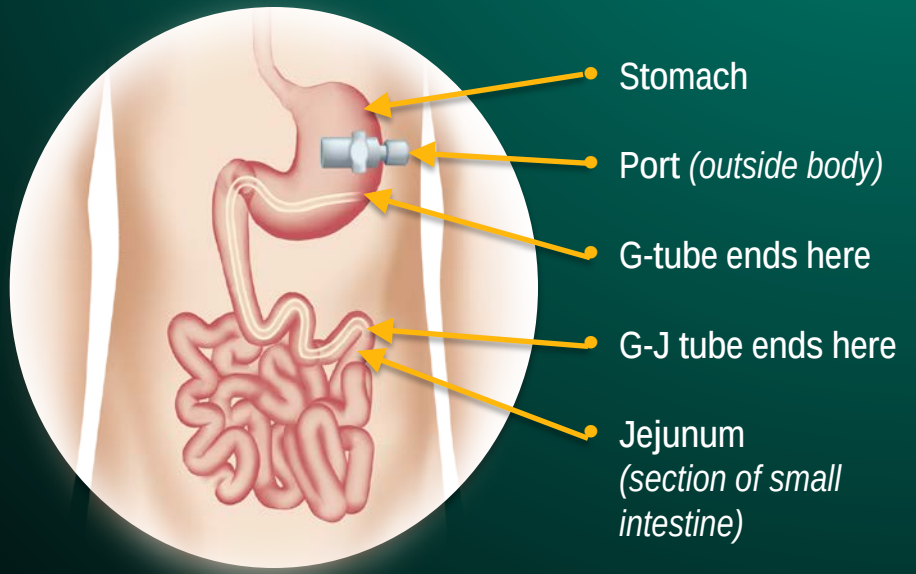




http://www.adamimages.com

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.



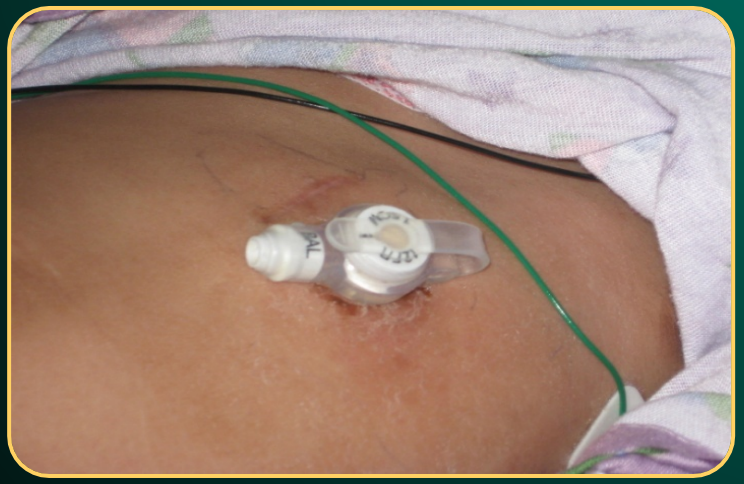
Why Use a G or J Tube?

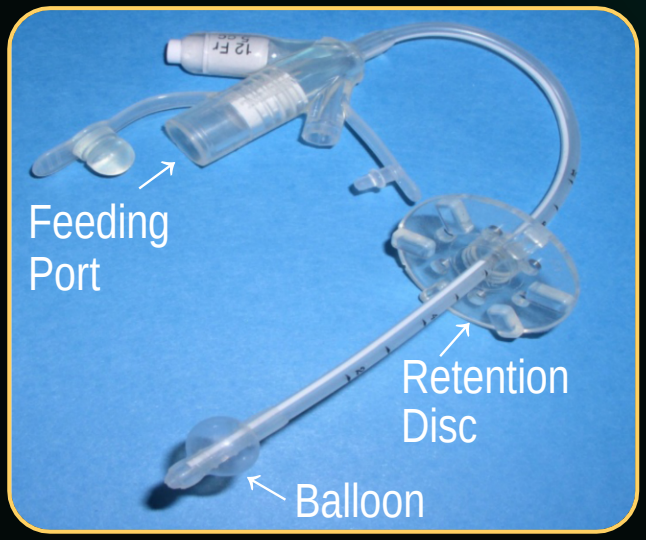
- A G tube allows need to EN to be met by feeding into the stomach

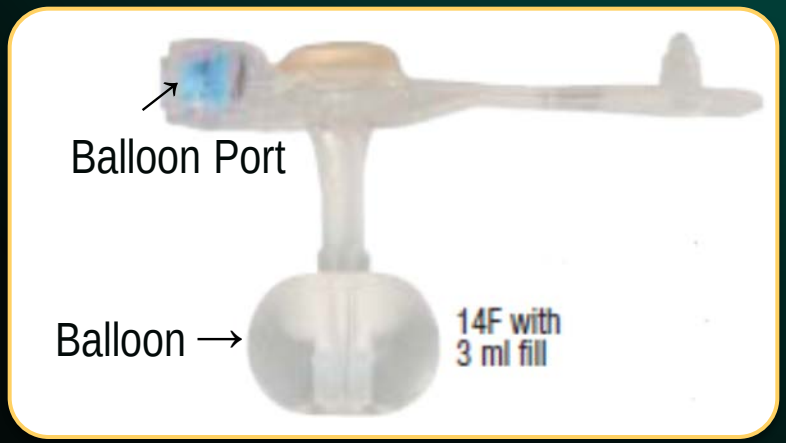
- A J tube can be used when needs for EN may not be met by feeding into the stomach, allowing EN feeding to occur past the stomach, i.e. in the jejunum
  - Cannot use bolus feeding technique beyond the pylorus due to dumping syndrome

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.

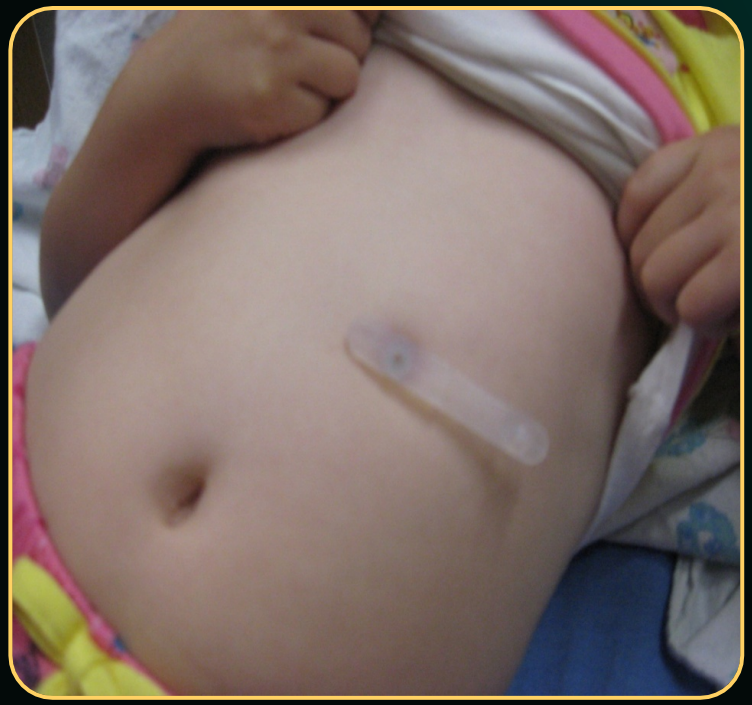




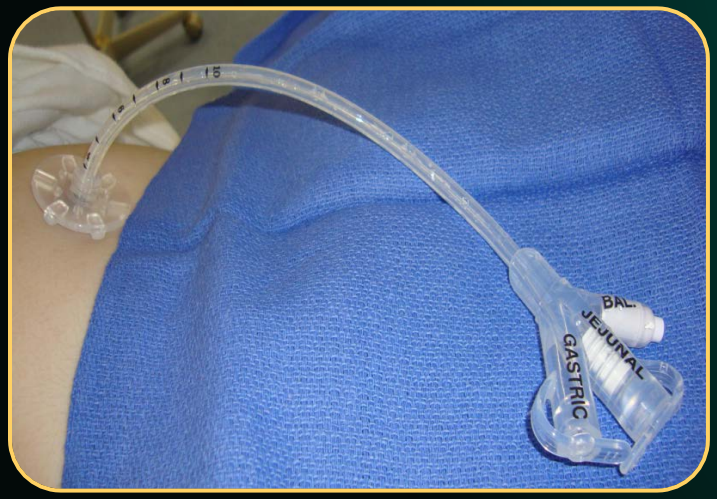


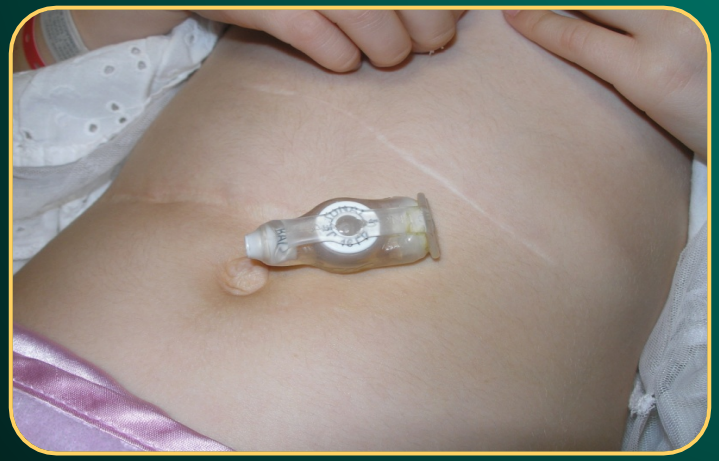
Replacement Gastrostomy Tubes

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.



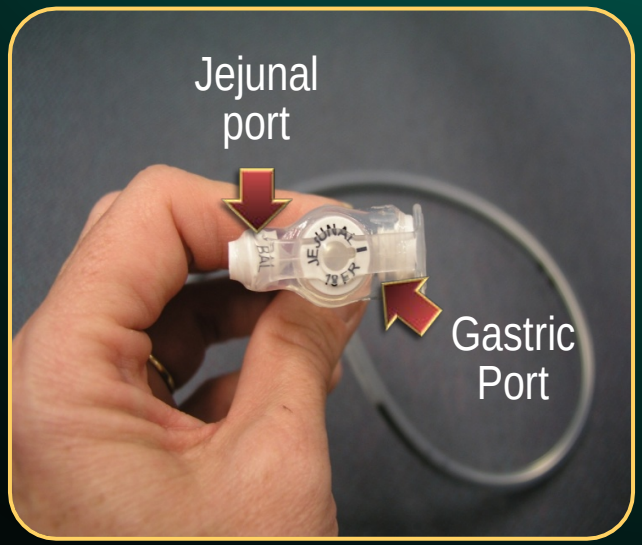
Balloon G-J Tubes





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

Parker et al. *J Pediatr.*1981;99:360-61.

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

http://depts.washington.edu/growing/Nourish/Formula.htm.

Comparison of Formulas

Cow's Milk-Based Formulas [1]	Soy Formulas[2]	Casein Hydrolysate Formulas	Amino Acid-Based Formulas
• Widely available	• For vegans	• Hydrolysate first line for formula protein allergy[3]	• Amino acid–based formula if hydrolysate not tolerated[3]
• Cheap starting material	• Galactosemia and hereditary lactase deficiency (rare)	• Reflux guidelines recommended 2-week trial[3]	
• Constantly tweaked to attempt to simulate breast milk	• No proven benefit in infantile colic or fussiness.	• Data about prevention of atopic disease[4]	
	• Crossover with cow's milk formula protein allergy is high		

1. http://www.nal.usda.gov/wicworks/Topics/FG/Chapter4_InfantFormulaFeeding.pdf.
2. http://www.dhs.wisconsin.gov/publications/P4/P40077A.pdf.
3. Beck M. *Today's Dietitian*. 2009;11(9):16.
4. Jung AD. *Am Fam Physician*. 2001;64(11):1853-60.

Review of EN Components

Carbohydrates

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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®
- Which formulas contain sucrose?[1]
  - Alimentum® and soy formulas, except Prosobee®

PerIstein D. *Infant Formulas.* MedicineNet.com
Bhatia et al. *Pediatrics*. 2008;121:1062-68.

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%)

Green et al. In Corkins M, Ed. The ASPEN Pediatric Nutrition Core Curriculum. ASPEN; 2010.

DHA and ARA

- Docosahexaenoic acid (DHA) and arachidonic acid (ARA), both long-chain polyunsaturated fatty acids
- Present in breast milk; were not in formulas [1]
- Animal models showed increased visual acuity and neurologic development; some infant studies agree [2]
- No harmful effects found
- Now in most infant formulas
- A recent meta-analysis found no effect of DHA/ARA on cognitive development [3]

1. Groh-Wargo et al. *Pediatr Res*. 2005;57:712-18.
2. Uauy et al. *J Pediatr*. 2003;143(4 Suppl):S17-25.
3. Qawasmi et al. *Pediatrics*. 2012;129(6):1141-9.

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)

Weizman et al. *Pediatrics*. 2005;115:5-9.

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

1. Corkins M, ed. *Dietary Sources in Pediatric Nutrition Support Handbook.* ASPEN; 2011.
2. Tolia et al. *J Pediatr Gastroenterol Nutr.* 1992 Oct;15(3):297-301.
3. Billeaud et al. *Eur J Clin Nutr*. 1990 Aug;44(8):577-83.

Elemental Pediatric Formulas

- AA–based
- Contain MCT
- Use for allergic?
- Short bowel
  - Better emptying
  - Absorption immediately

Corkins M, ed. *Dietary Sources in Pediatric Nutrition Support Handbook.* ASPEN; 2011.

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

Buchanan et al. *Aliment Pharmacol Ther.* 2009;30(5):501-7.

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

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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

Site	Delivery Route	Indications	Potential Complications
Stomach	Orogastric (infants) Nasogastric	• Short-term nutrition support (6-8 wks) • Inadequate oral intake due to increased needs or anorexia of chronic disease • Refusal to eat • Nocturnal feeds • Inability to suck or swallow	• Aspiration • Nasal mucosal ulceration • Tube occlusion • Pneumothorax • Bleeding • Epistaxis • Sinusitis • Otitis Media
	Gastrostomy	• 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

Texas Children's Hospital. *Texas Children's Hospital Pediatric Nutrition Reference Guide*, 9th Edition, 2009.

Enteral Feeding Methods
Gastric Vs. Post-pyloric - II

Site	Delivery Route	Indications	Potential Complications
Transpyloric Postpyloric	• Nasoduodenal • Nasojejunal • Gastrojejunal • Jejunostomy	• Congenital upper GI anomalies • Inadequate gastric motility • High aspiration risk • Severe GER • Functioning intestinal tract with obstruction above it	• Pneumatosis intestinalis • Bleeding • Dislodgement • Tube deterioration • Tube occlusion • Bowel obstruction • Stomal leakage • Wound infection

Bolus vs. Continuous Feeds

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

Age	Initiation	Advance	Suggested Tolerance Volumes
0 - 12 months	10 – 15 mL/kg every 2 to 3 hours	10 to 30 mL per feed	20 to 30 mL/kg every 4 to 5 hours
1 - 6 years	5 – 10 mL/kg every 2 to 3 hours	30 to 45 mL per feed	15 to 20 mL/kg every 4 to 5 hours
> 7 years	90 to 120 mL every 3 to 4 hours	60 to 90 mL per feed	330 to 480 mL every 4 to 5 hours

- Continuous Feedings

Age	Initiation	Advance	Suggested Tolerance Volumes
0 - 12 months	1 to 2 mL/kg/hour	1 to 2 mL/kg every 2 to 8 hours	6 mL/kg/hour
1 - 6 years	1 mL/kg/hour	1 mL/kg every 2 to 8 hours	1 to 5 mL/kg/hour
> 7 years	25 mL/hour	25 mL every 2 to 8 hours	100 to 150 mL/hour

Monitoring /Evaluation

		Initial	Hospital	Outpatient
Anthropometrics	Weight Height	Daily Baseline	Daily Monthly	Weekly- monthly Monthly or at clinic
Intake	Calories, protein, fluid	Daily	Weekly	Monthly
GI Tolerance	Abdominal girth, residuals , emesis	As ordered, reported	As ordered, reported	As reported
Stool/ Ostomy	Volume , frequency, consistency	Daily	Daily	Report changes in stool pattern
Tube Placement	Prior to each feeding	Prior to each feeding	Prior to each feeding	Prior to each feeding
Tube Site	Daily	Daily	Daily	Daily

Green et al. In Corkins M, Ed. *The ASPEN Pediatric Nutrition Core Curriculum. ASPEN;* 2010.

Monitoring/ Evaluation - I

Problem	Prevention/Intervention
Diarrhea/ Abdominal Cramping	• Decrease delivery rate • Recognize or avoid drugs that result in diarrhea • Consider fiber containing products • Consider osmolarity and addition of modular additives • Semi-elemental or elemental formula if indicated
Vomiting/ Nausea	• Ensure formula is always at room temperature prior to tube feedings • Elevate head of bed • Consider postpyloric or continuous feeding
Hyperglycemia	• Reduce flow rate • Use formulas with minimal simple sugars • Consider insulin if clinically indicated

Monitoring/ Evaluation - II

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

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 malabasorption
    - Unable to tolerate long chain fats related to liver function, pancreatic function or malabsorption
  - Volume tolerance
    - Fluid restricted

Formula - I

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

Formula - II

		Protein	Fat	CHO	Examples
Abnormal bowel function -Related to allergy, malabsorption, short gut	Amino acid Based	Free amino acids	Mix of MCT and LCT fat	Corn syrup solids	• Elecare® infant, Elecare® Jr, • Neocate®, Neocate® Jr • Nutramigen® AA • Tolerex® (Free amino acids)
Fat malabsorption -Related to chylothorax Pancreatitis	Fat Mal-absorption	Intact whole protein / casein	Contain 55% or greater MCT oil, DHA, ARA	Corn syrup solids	• Portagen® • Enfaport® • Pregestimil® • Tolerex® (Free amino acids) • Vital® HN
Disease Specific		Varies			• Nutren Glytol (diabetic) • Optisource® (bariatric surgery) • Pulmocare® • Suplena® (renal)

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

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

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

	Hydrolysate	Elemental	Elemental
Protein	Casein hydrolysate	100% free AA	100% free AA
CHO	Corn syrup solids, modified corn starch	Fructose, galactose, lactose, gluten, soy free	Sucrose, lactose, galactose free
Fat	Mix vegetable oil with DHA, ARA. May contain MCT oil	Vegetable oils 33% fat calories as MCT DHA, ARA	5% fat calories as MCT
mOsm	320	335	320
	-Gluten, lactose, and galactose free -Probiotic: *Lactobacillus rhamnosis* (LGG)	-Gluten, lactose, and galactose free -Powder	-Gluten, lactose, and galactose free -Powder

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

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

Specialty Pediatric Formulas

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

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

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

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

Texas Children's Hospital. *Texas Children's Hospital Pediatric Nutrition Reference Guide*, 9th Edition, 2009.

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

	Enlive 31 kcal/oz	Resource Breeze 32 kcal/oz	Pediasure Clear 30 kcal/oz
Protein	Whey protein isolate (3.7 grams/100 mL)	Whey protein isolate (3.8 grams/100 mL)	Whey protein isolate (3.1 grams/100 mL)
CHO	Maltodextrin, sucrose	Sugar, corn syrup solids	Corn syrup solids, sugar
Fat	None	None	None
mOsm	796	750	430 - 440
Formulation	RTF: lactose & gluten free	RTF: lactose & gluten free	RTF: lactose & gluten free
Flavors	Apple, mixed berry	Orange, wild berry, peach	Peach, berry pomegranate

Texas Children's Hospital. *Texas Children's Hospital Pediatrics Nutrition Reference Guide*. 9th Edition; 2009.

Principles of Designing/Monitoring Pediatric EN Support

Monitoring of Tolerance

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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

Metheny et al. *J Neurosc Nurs*. 2005;37:320-25.

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 intolerance[1]

1. Marshall et al. *Int Crit Care Nurs*. 2006;22:95-105.

Gastric Residual Volumes: Consensus

Consensus statement: Grade C evidence[1]

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.

1. Bankhead et al. *J Parenter Enteral Nutr.* 2009;33:122-67.

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 [1]
- **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 [3,4]
- **Recommendation:** start NG unless there is a heightened risk for intolerance

1. Metheny. *J Parenter Enteral Nutr*. 2002;26(6Suppl):S2-S31.
2. van der Voot et al. *Crit Care*. 2001;5:216-20.
3. Ho et al. *Intens Care Med.* 2006;32(5):639-49.
4. Marik et al. *Crit Care.* 2003;7(3):R46-51.

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

Ho et al. *Intens Care Med.* 2006;32:639-49.
Marik et al. *Crit Care*. 2003;7(3):R46-51.

Principles of Designing/Monitoring Pediatric EN Support

Safety

Refeeding Syndrome (RFS)

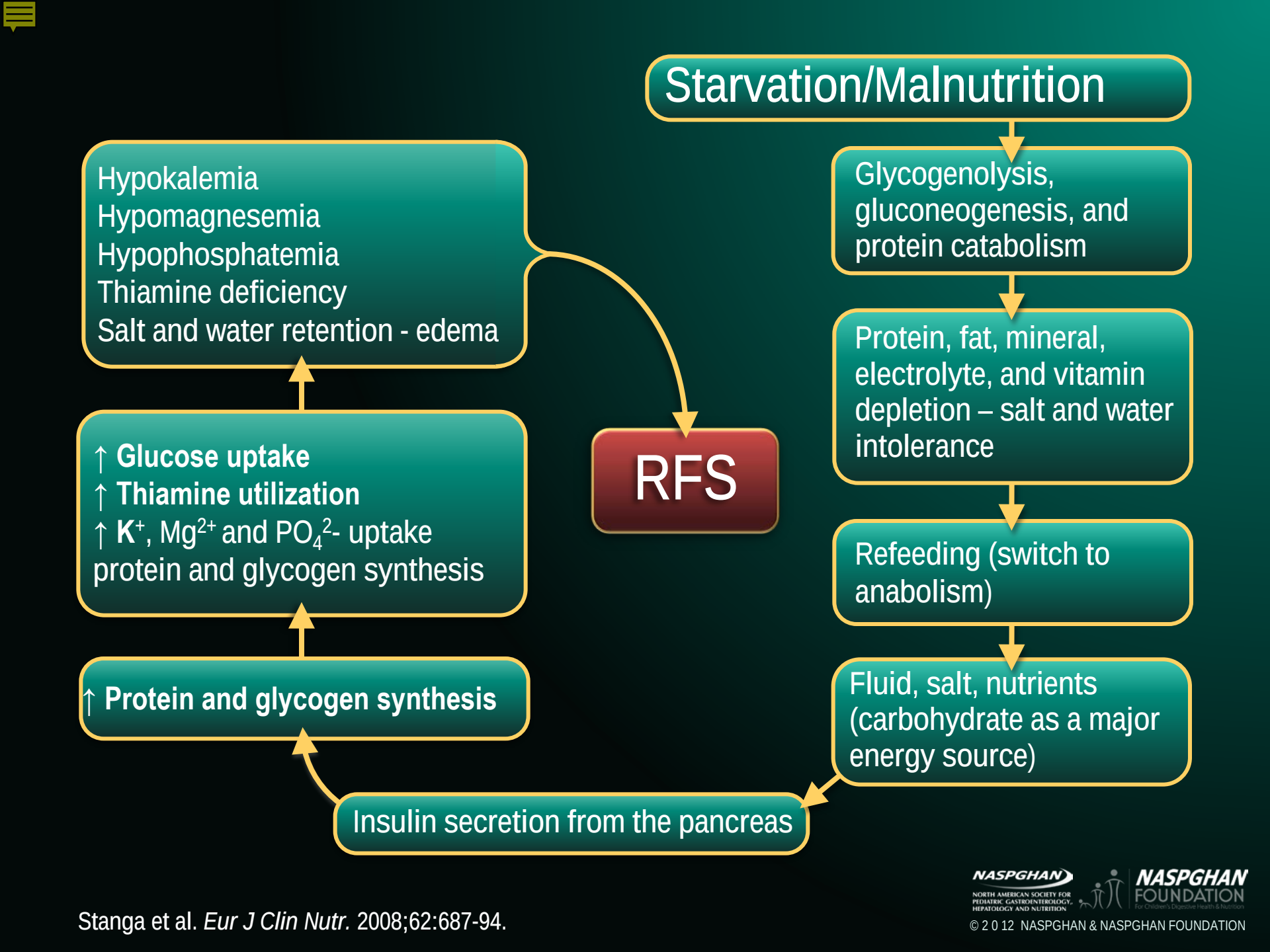
- RFS is a term used to describe the metabolic and clinical changes that can occur during nutritional support of a malnourished patient
  - Normally occurs within 3-4 days after initiating feeds
  - Signs/symptoms include weakness, muscle pain, ataxia, paresthesia, confusion, arrhythmia, seizures
  -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

Solomon et al. *J Parenter Enteral Nutr*. 1990;14:90-97.
Schnitker et al. *Ann Intern Med*. 1951;35:69-96.

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.

Dunn et al. *Nutr Clin Pract*. 2003;18:327-32.



Stanga et al. *Eur J Clin Nutr.* 2008;62:687-94.

Serum Abnormalities During Refeeding

Serum abnormalities are often seen in patients during refeeding and may include:

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

Crook et al. *Nutrition.* 2001;17:632-37.
Brooks et al. *Pharmacotherapy.* 1995;15:713-26.

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

Solomon et al. *J Parenter Enteral Nutr*. 1990;14:90-97.
Brooks et al. *Pharmacotherapy.* 1995;15:713-26.

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

Mehanna et al. *BMJ*. 2008;336:1495-98.
Kraft et al. *Nutr Clin Pract*. 2005;20:625-33.
Dunn et al. *Nutr Clin Pract*. 2003;18:327-32.

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.
Palesty et al. *Nutr Clin Pract*. 2006;21:147-54.

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Mehanna et al. *BMJ*. 2008;336:1495-98.
Palesty et al. *Nutr Clin Pract*. 2006;21:147-54.

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

Afzal et al. *Clin Nutr*. 2002;21:515-20.

Electrolyte/Micronutrient Replacements

K	2-4 mmol/kg daily
Phos	0.3-0.6 mmol/kg daily
Mg	0.2 mmol/kg daily IV or 0.4 mmol/kg daily orally

Multivitamin and mineral supplementation

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

Afzal et al. *Clin Nutr*. 2002;21:515-20.

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

	< 1000g	1000-1500g
Fluids (ml/kg)	160-220	135-190
Energy (Kcal/kg)	130-150	110-130
Protein (g/kg)	3.8-4.4	3.4-4.2
Carbohydrate (g/kg)	9-20	7-17
Fat (g/kg)	6.2-8.4	5.3-7.2

Corkins M, Ed. *Dietary Sources in Pediatric Nutrition Support Handbook.* ASPEN; 2011.

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

Berseth. *Clin Perintol.* 1995;22:195-205.
Slangle et al. *J Ped.* 1988;113:526-31.

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]

1. Bombell et al. *Cochrane Neonatal Group*. 2009. CD000504.
2. McClure et al. *Acta Paed.* 2002;91:292-6.

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

Groh-Wargo et al. *Nutr Clin Pract.* 2009;24: 363-76..

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

1. Morgan et al. *Cochrane Neonatal Group.* 2011. CD001241.

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 [1] (*NNH 33*)
    - When used as base for HMF [2] (*NNT12.5*)

1. Sullivan et al. *2009 PAS Meeting;* A2155.1.
2. Quigley et al. *Cochrane Neonatal Group.* CD002971.

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

Ehrenkranz et al. *J Pediatr Gastroenterol Nutr.* 1989;8:58-67.
Greer et al. *J Peds.* 1988;112:961-9.

What If Breast Milk Is Unavailable?

- Preterm formula should be offered if:
  - Less than 1800g or less than 34 weeks at birth [1]
- 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 [2]

1. Corkins, ed. *Dietary Sources in Pediatric Nutrition Support Handbook*. ASPEN; 2011.
2. Lucas et al. *Arch Dis Child.* 1992;67:324-7.

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

Corkins, ed. *Dietary Sources in Pediatric Nutrition Support Handbook:* ASPEN; 2011

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®, Neosure®) at discharge [2,3]
- Continue HMF until 2.4 - 2.7 kg [1]

1. Corkins, ed. *Dietary Sources in Pediatric Nutrition Support Handbook:* ASPEN; 2011
2. Bishop et al. *Arch Dis Child.* 1993; 68: 573-78.
3. Lucas et al. *Arch Dis Child.* 1992;67:324-7.

Screening for Nutrition Risk in Preterm Infants

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

Groh-Wargo et al. *Nutr Clin Pract.* 2009;24: 363-76.

Overview of EN Support in Special Populations

IBD

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

Murch SH. *Nutrition.* 1998;14(10):780-3.

History of EEN

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

Elemental diet [5,6]

Polymeric diet [7]

First-line induction in Europe and Japan [8,9]

1. Anderson et al. *Am J Dig Dis.* 1973;18:633-40.
2. Fischer et al. *Am J Surg.* 1973;125:165-75.
3. Navarro et al. *La Nouvelle presse medicale*. 1978;7:183-88.
4. Ricour et al. *Archives francaises de pediatrie*. 1977;34:505-13.
5. Morin et al. *Gastroenterol.*1980;79:1205-10.
6. Logan et al. *Gut.* 1981;22:383-87.
7. Ludvigsson et al. *Acta Paediatr*. 2004;93:327-35.
8. Volkert et al. *Clin Nutr.* 2006;25(2):330-60.
9. Konno et al. *Pediatr Int*. 2006;48(3):349-52.

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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

1. Grogan et al. *Inflamm Bowel Dis.* 2012;18:246-53.
2. Ludvigsson et al. *Acta Paediatr*. 2004;93:327-35.
3. Wilschanski et al. *Gut.* 1996;38:543-48.

Data

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

1. Day et al. *J Gastroenterol Hepatol.* 2006;21:1609-14.
2. Dziechciarz et al. *Aliment Pharmacol Ther.* 2007;26:795-806.
3. Knight et al. *Clin Nutr.* 2005;24:775-79.
4. Fell et al. *Aliment Pharmacol Ther.* 2000;14:281-89.
5. Baert et al. *Gastroenterology.* 2010;138:463-68; quiz e410-461.
6. Newby et al. *Cochrane Database Syst Rev*. 2005;CD003873.
7. Whitten et al. *J Gastroenterol.* 2010;45:399-405.
8. Zachos et al. *Cochrane Database Syst Rev*. 2007;CD000542.

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]

1. Levine et al. *J Pediatr Gastroenterol Nutr.* 2003;36:464–9.
2. Critch et al. *J Pediatri Gastroenterol Nutr.* 2012;54:298-305.
3. Konno et al. *Pediatr Int.* 2006;48(3):349-52.

Proposed Mechanisms of Action

- Reformation of gut microflora [1]
- Complete nutritional repletion; provision of micronutrients
- Correction of intestinal permeability
- Restriction of dietary antigen
- Decreased intestinal synthesis of inflammatory mediators [2]

1. Critch et al. *J Pediatri Gastroenterol Nutr.* 2012;54:298-305.
2. Kanauchi et al. *Curr Pharm Des.* 2005;11:1047-53.
3. Wedrychowicz et al. *J Pediatr Gastroenterol Nutr.* 2011;53:150-55.

Concerns

- Palatability/adherance
- Cost
- Refeeding syndrome

Other Diets for IBD

Low fiber/low residue

- UC
- Stricturing disease
- Typically use low residue with active colitis and move to higher fiber with mucosal healing

Popular diets

- Specific Carbohydrate Diet
- Gluten free
- Lactose free

Other Enteral Supplements

- Fish oil
  - Anti-inflammatory
    - Inconclusive
    - More mouse studies than human [1,2]
- Probiotics
  - Restoration of gut microflora [3-5]

1. Turner et al. *Inflamm Bowel Dis.* 2011;17:336-45.
2. Cooney et al. *Journal of Proteome Research.* 2012;11:1065-77.
3. Mack DR. *Nutrients.* 2011;3:245-64.
4. Meijer et al. *J Clin Gastroenterol.* 2011;45:S139-144.
5. Thomas et al. *Amer J Physiol Gastrointest Liver Physiol.* 2011;301:G1083-92.

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

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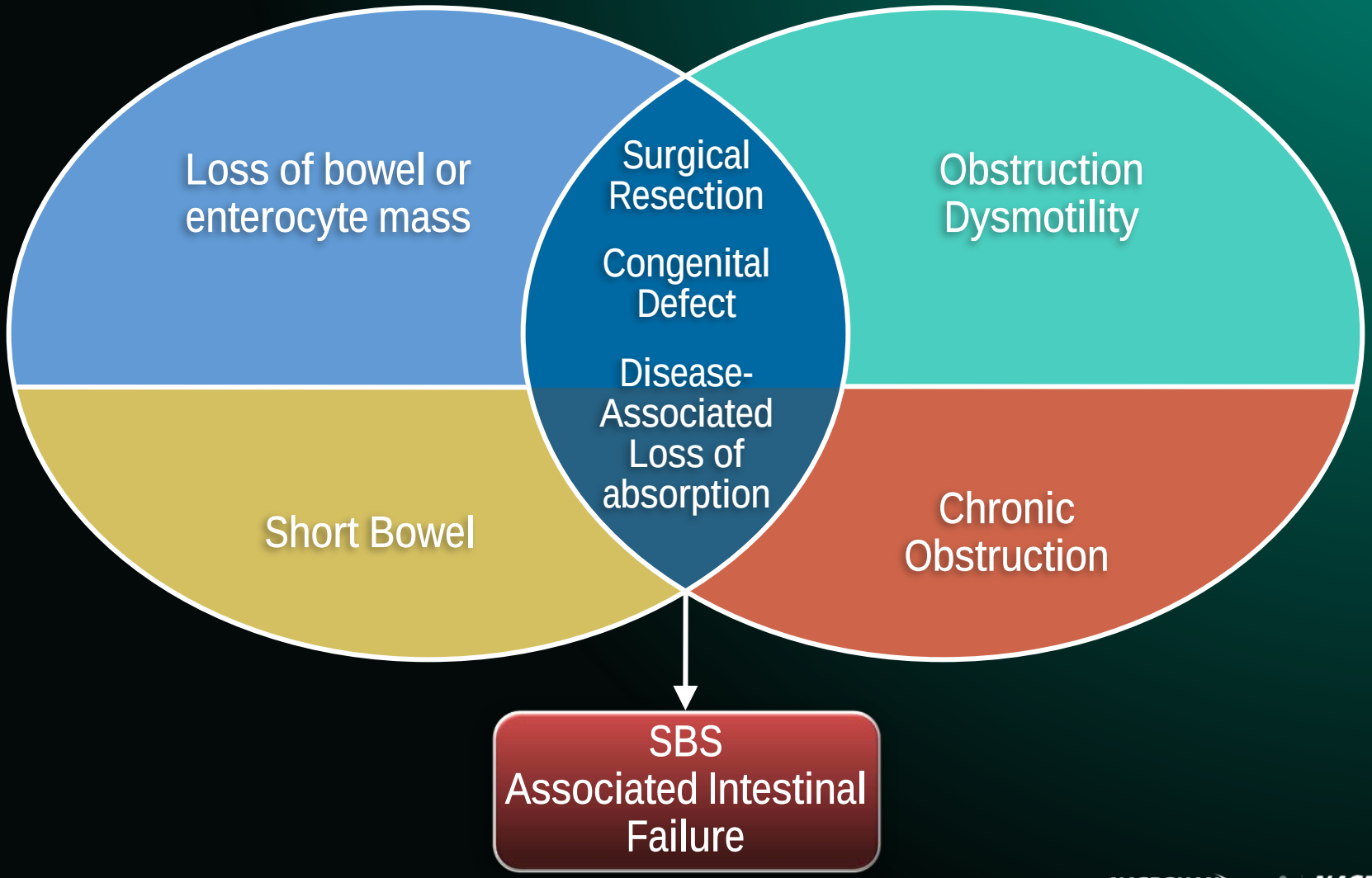
Short Bowel Syndrome (SBS)/Intestinal Failure

- 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

Cole et al. *Pediatrics.* 2008;122(3):e573-82.
O'Keefe et al. *Clin Gastroenterol Hepatol*. 2006;4(1):6-10.
Goulet et al. *Eur J Ped Surg.* 2005;15(2):95-101.

Proposed New Definition



O'Keefe et al. *Clin Gastroenterol Hepatol.* 2006;4(1):6-10.

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.

Goulet et al. *Gastroenterology.* 2006;130(2 Suppl 1):S16-28.
Jeejeebhoy et al. *Gastroenterology.* 2006;130(2 Suppl 1):S60–66.
Sondheimer. *J Pediatr*. 1998;132:80–84.

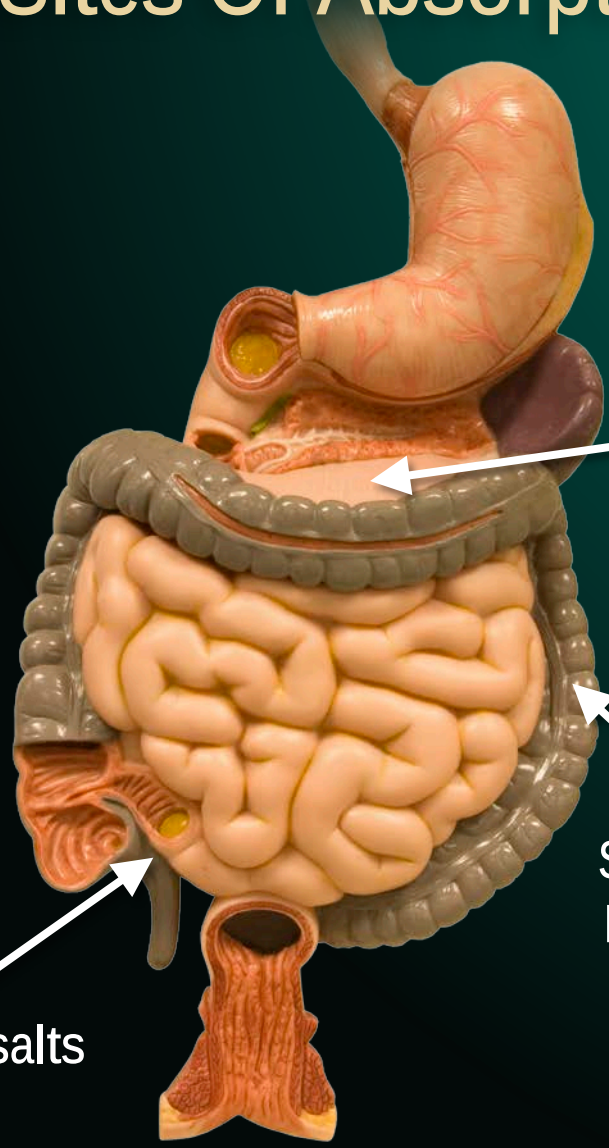
Principles of Nutritional Care of SBS

- 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

Wessel et al. *Semin Perinatol.* 2007;31(2):104-111.
Sondheimer et al. *J Pediatr.* 1998;132:80.

Sites Of Absorption

Carbohydrates
Fats
Proteins
Calcium
Magnesium
Trace elements
vitamins



IRON AND FOLATE

Water and Electrolytes

Short chain Fatty acids

Vitamin B12 and bile salts

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Nutritional Consideration with Bowel Loss

Jejunum

- Primary site for digestion and absorption of most nutrients
- Loss does not result in severe malabsorption because ileum has a large capacity to compensate for increased absorption

Ileum

- 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

Ileocecal Value

- Slows down transit time
- Prevents reflux of colonic contents into Small Bowel
- Reduce absorption of vitamin B 12
- Deconjugate bile salts
- Reduce bile salt absorption

Colon

- Loss of “colonic brake”
- Loss of water and electrolyte resorptive capacity
- Loss of ability to salvage calories from malabsorbed carbohydrates.

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Nutrition Therapy

- TPN – ensure adequate nutrition and hydration
- Enteral feeding
  - Formula type
  - Route: oral, NG, GT
  - Bolus vs. continuous
  - Progression to solids

Goday PS. *Clinical Perinat.* 2009(36):101-10.
Joly et al. *Gastroenterology.* 2009(136):824-31.

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

Forchielli et al. *Adv Pediatr.* 2003;50;245–67.
Sondheimer et al. *J Pediatr Gastroenterol Nutr. 1998;*27(2):131-7.

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.
Vanderhoof et al. *J Parenter Enteral Nutr.* 1984;8(6):685-89.

Frequency For Monitoring Growth Children With SBS

Measurements	Comment	Initial Period	Long-Term Follow-up
Weight (kg)	Preterm infants	Daily	Every 2-4 weeks
	Age > 1 year	Twice a week	1-6 month
Head circumference (cm)	Birth to 3 year	Every 2 weeks	1-3 month
Length (cm)	Birth to 3 year	Every 2-4 weeks	1-3 month
Height (cm)	Age **≥ 2 year**	Every 4 weeks	1-6 month

Frequency For Monitoring Nutrient Status In Children With SBS - I

Measurements	Comment	Initial Period	Long-Term Follow-up
Electrolytes, Ca, Phos, Mg	Patients on PN	Twice a week	Every 2-4 weeks
Transaminases, direct bilirubin, GGT	Patients on PN	Every 1-2 weeks	1-3 month
Total protein, prealbumin		Every 2-4 weeks	1-3 month
Complete blood count, reticulocyte count		Every 2-4 weeks	1-3 month
PT/PTT/INR, Iron studies Vitamin/Trace elements		Baseline/ as indicated	As indicated

Frequency For Monitoring Nutrient Status In Children With SBS - II

Measurements	Comment	Initial Period*	Long-Term Follow-up
Iron studies (Fe, transferrin, % saturation, TIBC)		baseline	as indicated
Vitamin A		baseline	3 months
Vitamin E	**α**-tocopherol:cholesterol ratio <2.47 mg/g consistent with deficiency	baseline	3 months
Vitamin D (25-hydroxyvitamin)	Also consider seasonal factors influencing risk of deficiency	baseline	3 months
Vitamin B12	↓ **plasma B12 accompanied** by ↑ **urine methylmalonic acid** confirms deficiency	baseline	3-6 months
Trace Minerals (Cu, Zn, Se, Mn)		as indicated	3-6 months

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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 (Ω3) v n-6 (Ω6) fatty acids
- Reduced production of proinflammatory cytokines, e.g. TNFα, IL-6 & 8
- Improves cholestasis of children with PNALD

Diamond et al. *J Pediatr Gastroenterol Nutr.* 2009;48:209-15.
Gura et al. *Pediatrics.* 2008;121(3):e678-86.
Kohl et al. *J Pediatr Gastroenterol Nutr.* 2007;44(2):237-44.

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

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EN: Cystic Fibrosis

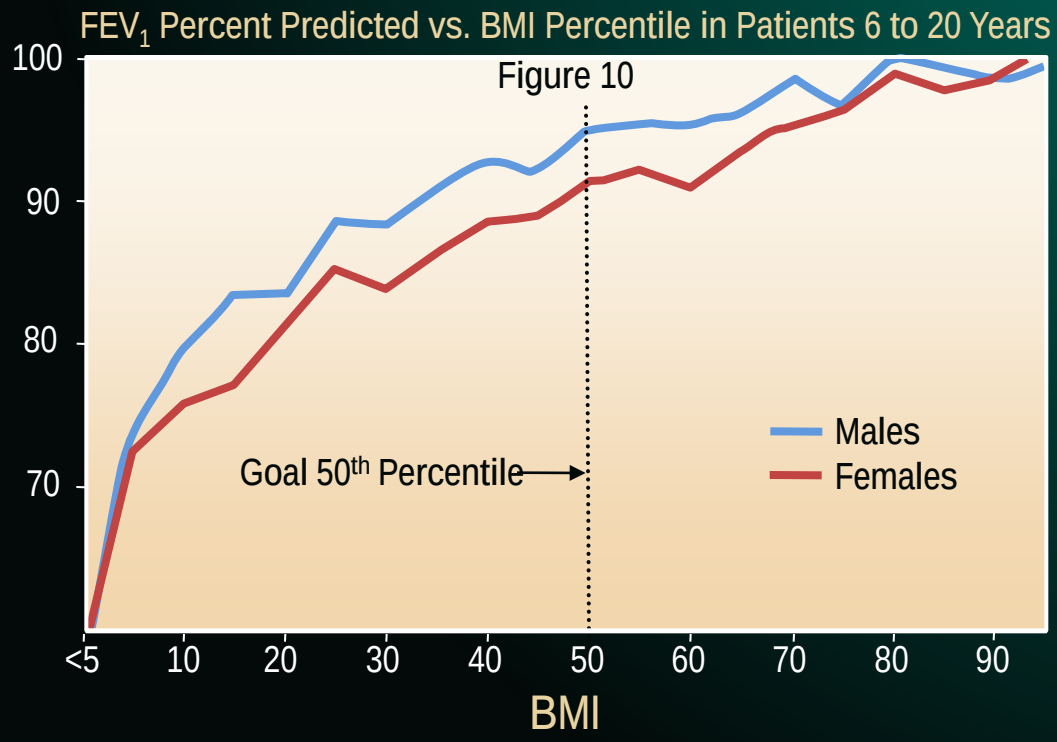
- Long term survival is linked to nutritional status
- Lung disease, airway inflammation & infection result in appetite suppression & increased energy expenditure
- Descriptive studies looking at correlation of nutritional status & pulmonary function
  - Improved survival associated with changes in dietary 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 $\geq 50^{th}$ percentile
  - Ages 2-20 year: BMI percentile $\geq 50^{th}$ percentile
  - BMI for males: 23, BMI for females: 22

Stallings et al. *J Am Diet Assoc.* 2008;108(5):832-39.
McPhail et al. *J Pediatr.* 2008;153(6):752-57.

Association Between BMI Percentile & FEV1

FEV_1 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.[7]



FEV_1 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

Michel et al. *Pediatr Clin N Am.* 2009;56(5):1123-41.
Maqbool et al. *Cystic Fibrosis.* Informa Healthcare USA Inc. 2010.

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

Michel et al. *Pediatr Clin N Am.* 2009;56(5):1123-41.
Maqbool et al. *Cystic Fibrosis*. Informa Healthcare USA Inc. 2010.

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)

Ramsey et al. *Am J Clin Nutr.* 1992;55(1):108-16.
Borowitz et al. *J Pediatr Gastroenterol Nutr.* 2002;35(3):246-59.

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

Ramsey et al. *Am J Clin Nutr.* 1992;55(1):108-16.
Borowitz et al. *J Pediatr Gastroenterol Nutr.* 2002;35(3):246-59.

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)

Borowitz et al. *J Pediatr Gastroenterol Nutr.* 2002;35(3):246-59.

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

Borowitz et al. *J Pediatr Gastroenterol Nutr.* 2002;35(3):246-59.

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

Borowitz et al. *J Pediatr Gastroenterol Nutr.* 2002;35(3):246-59.

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

Bradley et al. *Pediatr Pulmonol.* 2012;47(8):743-8.
Erskine et al. *Nutr Clin Pract.* 2007;22(2):223-32.

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

Bradley et al. *Pediatr Pulmonol.* 2012;47(8):743-8
Erskine et al. *Nutr Clin Pract.* 2007;22(2):223-32.

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; ¼ tsp after
- 0.5 - 2 year: if water has < 0.3 ppm, give fluoride 0.25 mg/dl

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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 $\geq$ 50th percentile for children aged 2-20 years or weight for length $\geq$ 50th 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

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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

Kuperminc et al. *Dev Disabil Res Rev.* 2008;14(2):137-46.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.
Hendersen et al. *Pediatr.* 2002;141(5):644-51.
Jones et al. *J Pediatr Gastroenterol Nutr*. 2001;33(5):602-5.

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 would healing and peripheral circulation
  - Ameliorate GER

Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.
Stevenson et al. *Pediatr.* 2006;118(3):1010-18.
Sampson-Fang et al. *J Pediatr.* 2002;141(5):637-43.

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

Kuperminc et al. *Dev Disabil Res Rev.* 2008;14(2):137-46.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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

Oeffinger et al. *Dev Med Child Neurol.* 2010;5(9):e195-201.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.
Stevenson et al. *Pediatrics.* 2006;118(3):1010-18.
Gauld et al. *Dev Med Child Neurol.* 2004;46(7):475-80.

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 3rd percentile. Remember that not everyone belongs on the 50th percentile

Stevensen et al. *Pediatrics.* 2011;128(2):e436-7.
Brooks et al. *Pediatr.* 2011;128(2):e299-307.
Day et al. *Dev Med Child Neurol.* 2007;49(3):167-71.
Marchand et al. J *Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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

Stevensen et al. *Pediatrics.* 2011;128(2):e436-7.
Brooks et al. *Pediatr.* 2011;128(2):e299-307.
Day et al. *Dev Med Child Neurol.* 2007;49(3):167-71.
Marchand et al. J *Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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)

Stevensen et al. *Pediatrics.* 2011;128(2):e436-7.
Brooks et al. *Pediatr.* 2011;128(2):e299-307.
Day et al. *Dev Med Child Neurol.* 2007;49(3):167-71.
Marchand et al. J *Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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 10-15th 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

Dahlseng et al. *Acta Paediatr.* 2012;101(1):92-8.
Kuperminc et al. *Dev Disabil Res Rev.* 2008;14(2):137-46.
Mahant et al. *Arch Dis Child.* 2009;94(9):668-73.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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 recieve maintenance fluids

Dahlseng et al. *Acta Paediatr.* 2012;101(1):92-8.
Kuperminc et al. *Dev Disabil Res Rev.* 2008;14(2):137-46.
Mahant et al. *Arch Dis Child.* 2009;94(9):668-73.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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

Arowsmith et al. *Dev Med Child Neurol.* 2012;54(2):170-5.
Schoendorfer et al. *Br J Nutr.* 2012;107(10):1476-81.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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

Savage et al. *J Parenter Enteral Nutr.* 2012;36(1 Suppl):118S-123S.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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

Savage et al. *J Parenter Enteral Nutr.* 2012;36(1 Suppl):118S-123S.
Marchand et al. *J Pediatr Gastroenterol Nutr*. 2006;43(1):123-35.

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

Critical Illness and EN

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

Benefits	Limitations
Reduce gut atrophy	More likely to *underfeed*
Improve gut motility	*Contraindications*: nonfunctional gut: anatomical disruption, obstruction, ischemia, peritonitis; Severe shock states
Reduced infections (enhanced gut immune function and avoidance of translocation)	Frequent interruptions for fasting for diagnostic and other procedures limit efficacy, especially in malnourished patients
Cost effective	Risk of aspiration
Less likely to *overfeed*	

Braunschweig et al. *Am J Clin Nutr.* 2001;74(4):534-42.

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

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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.
2. Simpson et al. *Intensive Care Medicine*. 2005;31(1):12-23.
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

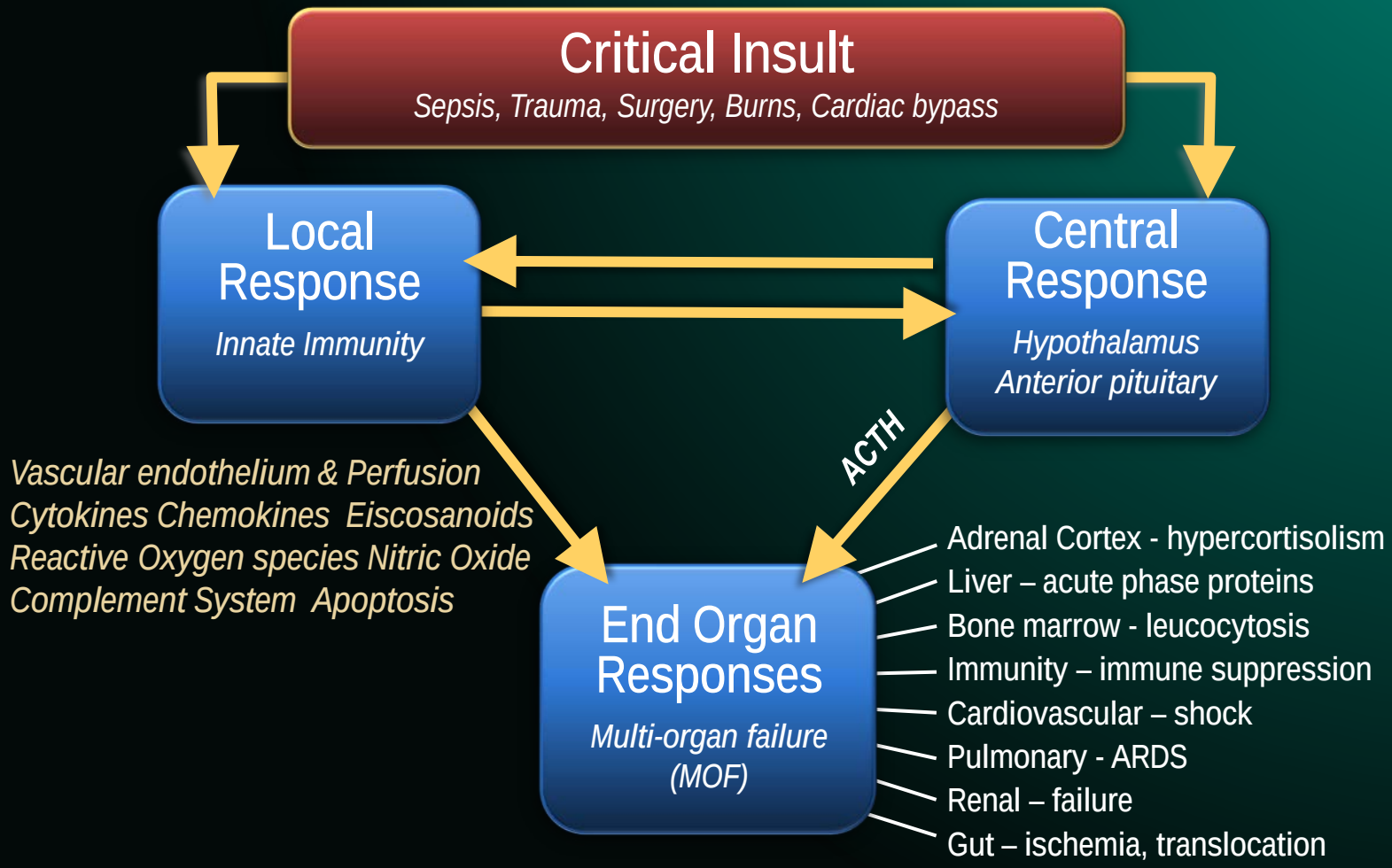
1. Franklin et al. *J Parenter Enteral Nutr.* 2011;35(3):337-42.
2. Andersen et al. *Cochrane Database Syst Rev.* 2006;(4):CD004080.
3. Lewis et al. *BMJ.* 2001 Oct 6;323(7316):773-6.

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]

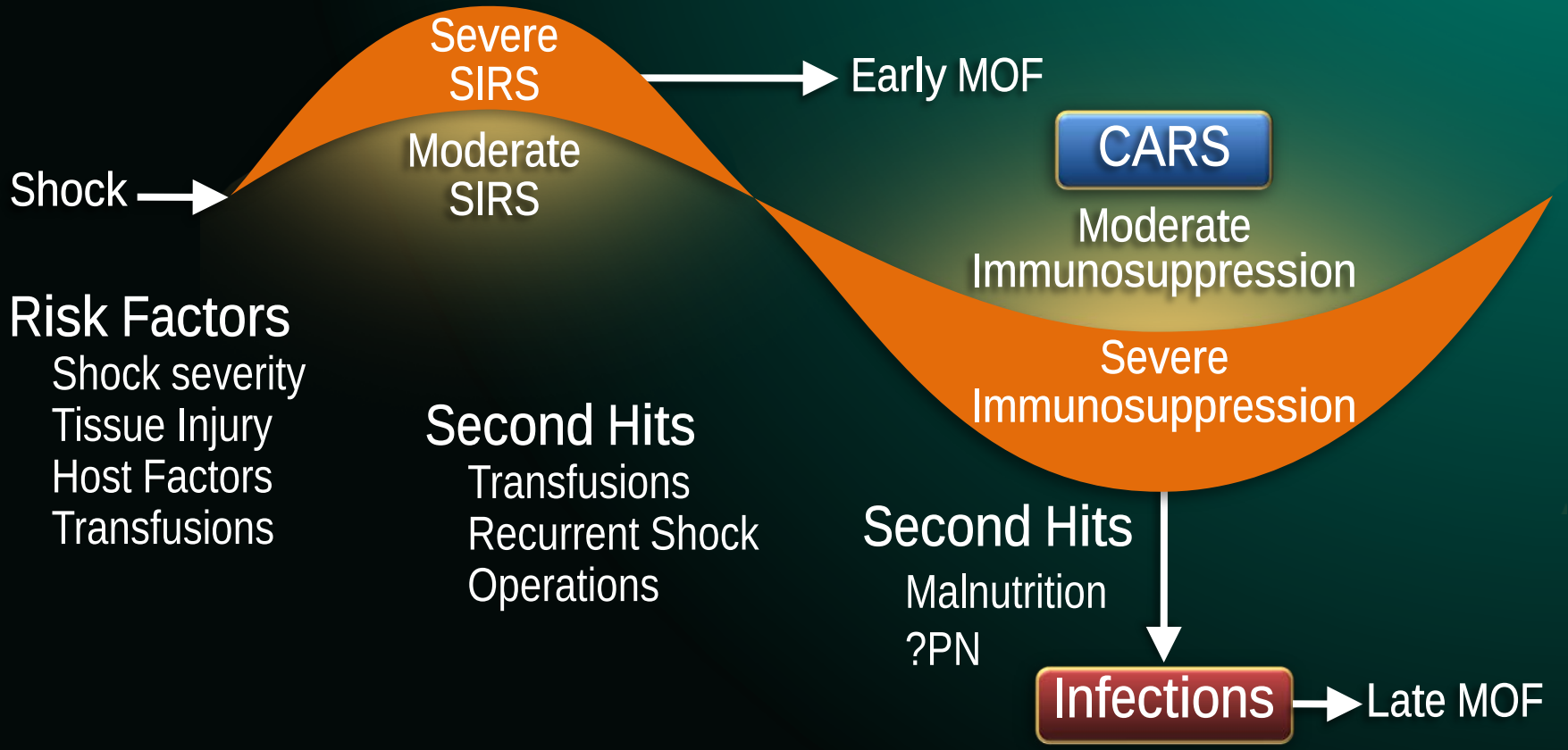
1. Simpson et al. *Intensive Care Med*. 2005;100(2):527-33.
2. Peter et al. *Crit Care Med.* 2005;33(1):213-20.
3. Gramlich et al. *Nutrition*. 2004;20(10):843-8.
4. Heyland et al. *J Parenter Enteral Nutr*. 2003;27(5):355-73.
5. Braunschweig et al. *Am J Clin Nutr.* 2001;74(4):534-42.
6. Dhaliwal et al. *Intensive Care Med* 2004;30(8):1666-71.
7. Heidegger et al. *Curr Opin Crit Care*. 2008;14(4):408-14.

The Systemic Inflammatory Response Syndrome:



Critical Illness Cycles: SIRS to CARS

(Compensatory Anti-inflammatory Response Syndrome)



Adapted from Moore et al. *E Nutr Clin Pract.* 2009;24:297-304.

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

1. Hulst et al. *Clin Nutr.* 2004;23(6):1381-9.
2. Rogers et al. *Nutrition.* 2003;19(10):865-8.

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]

1. Rogers et al. *Nutrition.* 2003;19(10):865-8.
2. Sanchez et al. *Br J Clin Nutr.* 2009;102(2):191-4.
3. Lopez-Herce et al *Eur J Clin Nutr.* 2008;62(3):395-400.
4. Braudis et al. *Pediatr Crit Care Med.* 2009;10(4):460-66.
5. Petrillo-Albarano et al. *Pediatr Crit Care Med.* 2006;7(4):340-4.
6. Kozar et al. *J Surg Res.* 2002;104(1):70-5.

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]

1. Meert et al. *Chest.* 2004;126(3):872-8.
2. Kamat et al. *Pediatr Crit Care Med.* 2008;9(3):299-303.
3. Lopez-Herce et al. *Nutrition J*. 2008;31(7):6.

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]

1. Gatt et al. *Crit Care Med.* 2009;37(2):523-7.
2. Hanekamp et al. *Pediatr Crit Care Med.* 2005;6(3):275-9.
3. Jaksic et al. *J Parenter Enteral Nutr*. 2010;34(3):247-53.

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)

1. Briassoulis et al. *Intensive Care Med.* 2005;31(6):851-8.
2. Briassoulis et al. *Nutrition.* 2005;21(7-8):799-807.
3. Briassoulis et al. *Pediatr Crit Care Med.* 2006;7(1):56-62.
4. Pontes-Arruda et al. *J Parenter Enteral Nutr.* 2008;32(6):596-605.
5. Marik et al. *Intensive Care Med.* 2008;34(11):1980-90.
6. Heyland et al. *Intensive Care Med.* 2003;29(5):669-71.

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]

1. Novak et al. *Crit Care Med.* 2002;30(9):2022-9.
2. Poindexter et al. *Pediatrics.* 2004;113(5):1209-15.
3. Tubman et al. *Cochrane Database Syst Rev.* 2008;(1):CD001457.

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]

1. Bliss et al. *Ann Inter Med*. 1998;129(12):1012-9.
2. Heyland et al. *Crit Care Med.* 1999;27(11):2399-406.
3. Simakachorn et al. *J Pediatr Gastroenterol Nutr.* 2011;53(2):174-81.
4. Land et al. *Pediatrics.* 2005;115(1):178-81.
5. Honeycutt et al. *Pediatric Crit Care.* 2007;8(5):452-8.

EN and Chylothorax

- Treatment limiting enteral long chain triglycerides
  - potential for essential fatty acid deficiency exists
- Use formulae enriched in medium chain triglycerides (transport direct 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

1. Cormack et al. *Ann Thor Surg.* 2004;77(1):301-5.
2. Nguyen et al. *J Card Surg.* 1996;10(4 Pt 1):302-8.
3. Allen et al. *J Pediatric Surg.* 1991;26(10):1169-74

Overview of EN Support in Special Populations

Failure to Thrive

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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

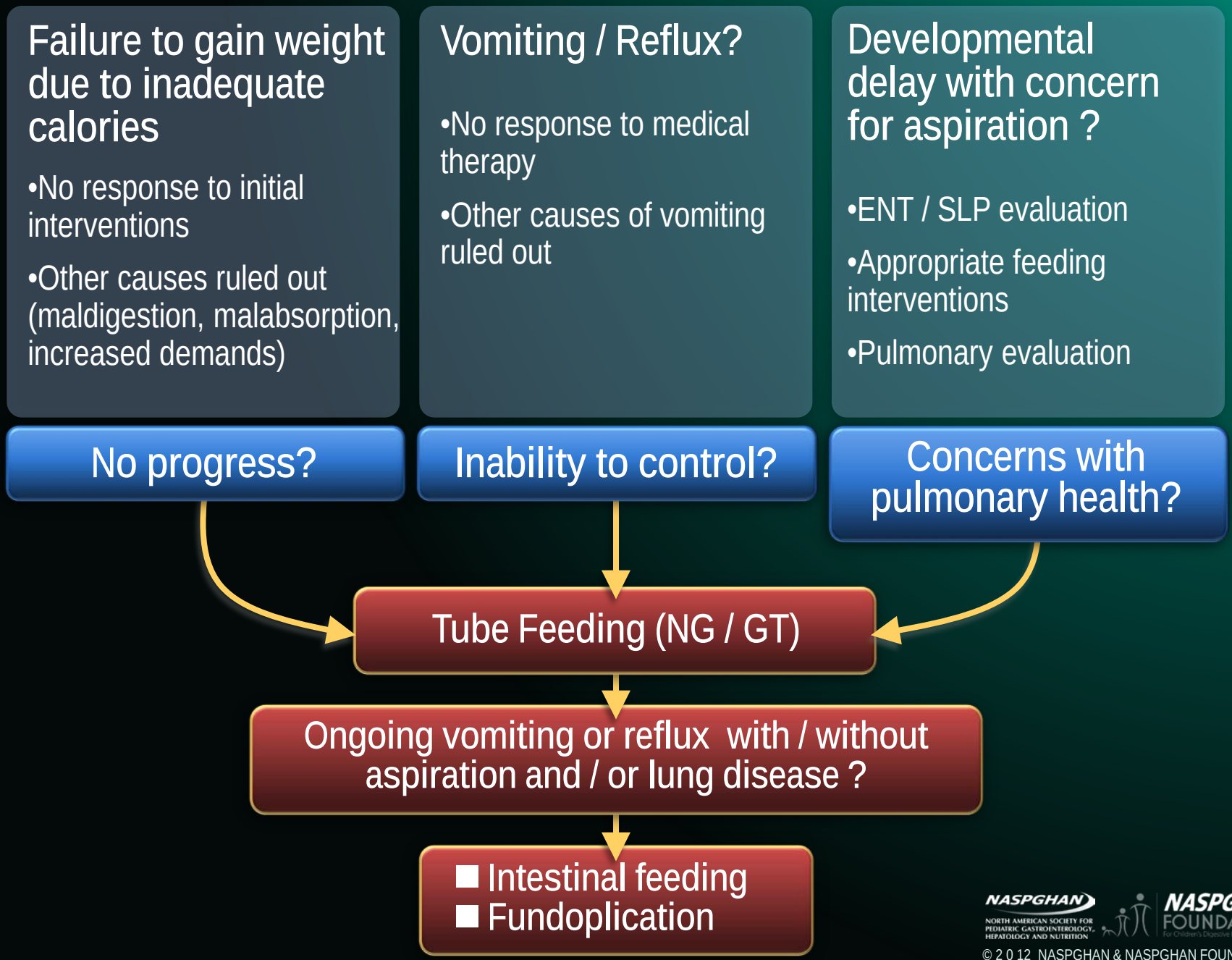
- Increase caloric values of all foods
- Increase calorie content of beverage consumed
  - Add calories to pumped breast milk or provide supplemental bottles of formula
  - Increase calorie concentration of formula
  - Provide 30 cal/oz beverage to child who is over one year of age
- In children with 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



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

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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

Beath et al. *Transplantation.* 2008;85(10):1378-84.

Case Report Continued

Day 30 PDA ligated

Day 52 stoma take-down

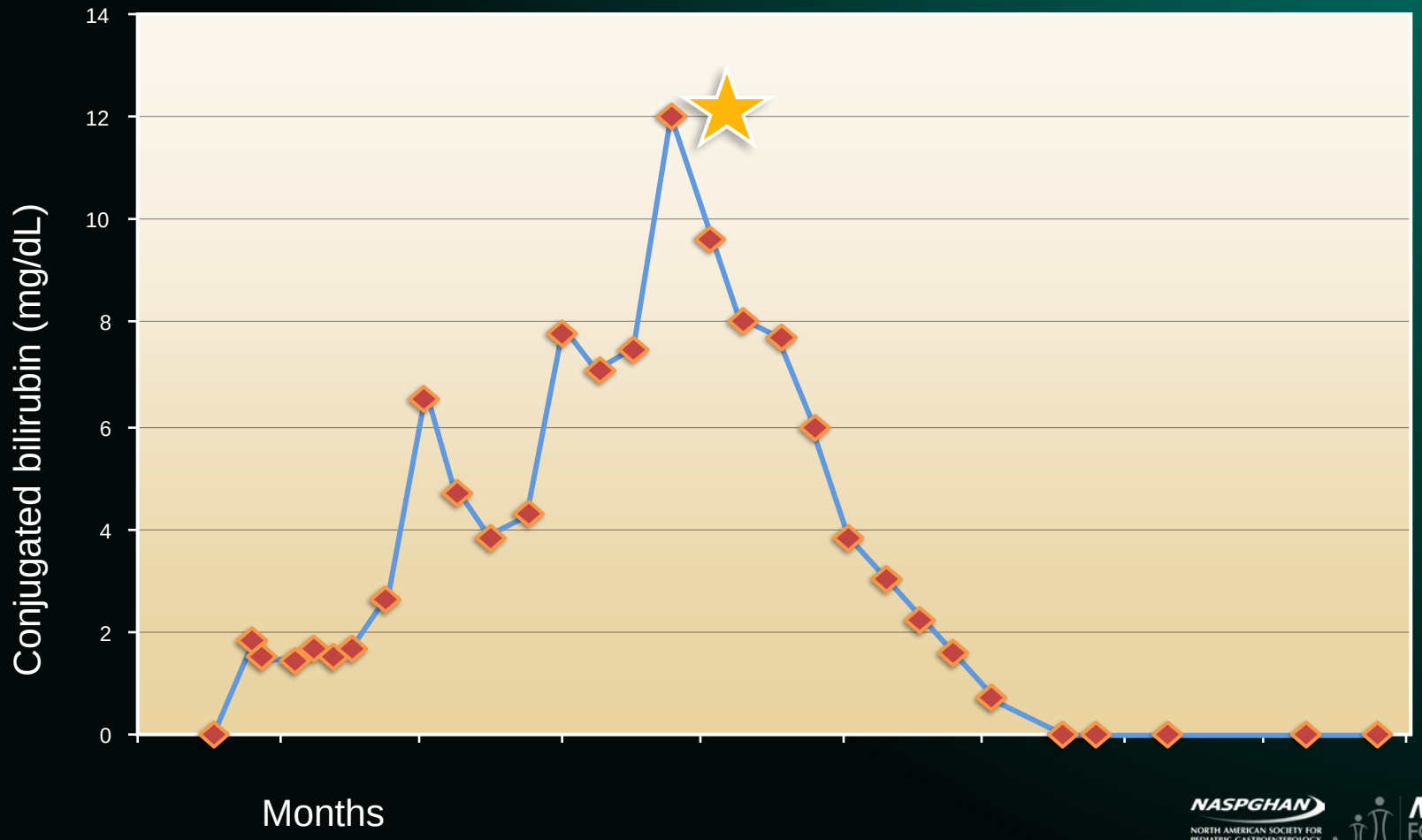
Day 73 feeds started

Day 77 transfer to Intestinal care service

- CLD on nasal O_2
- ROP stage 2 zone 2
- Bilateral IVH grade2 with evidence of cerebral ischemic changes
- Feeds at 1 ml/hr
- Still on regular morphine

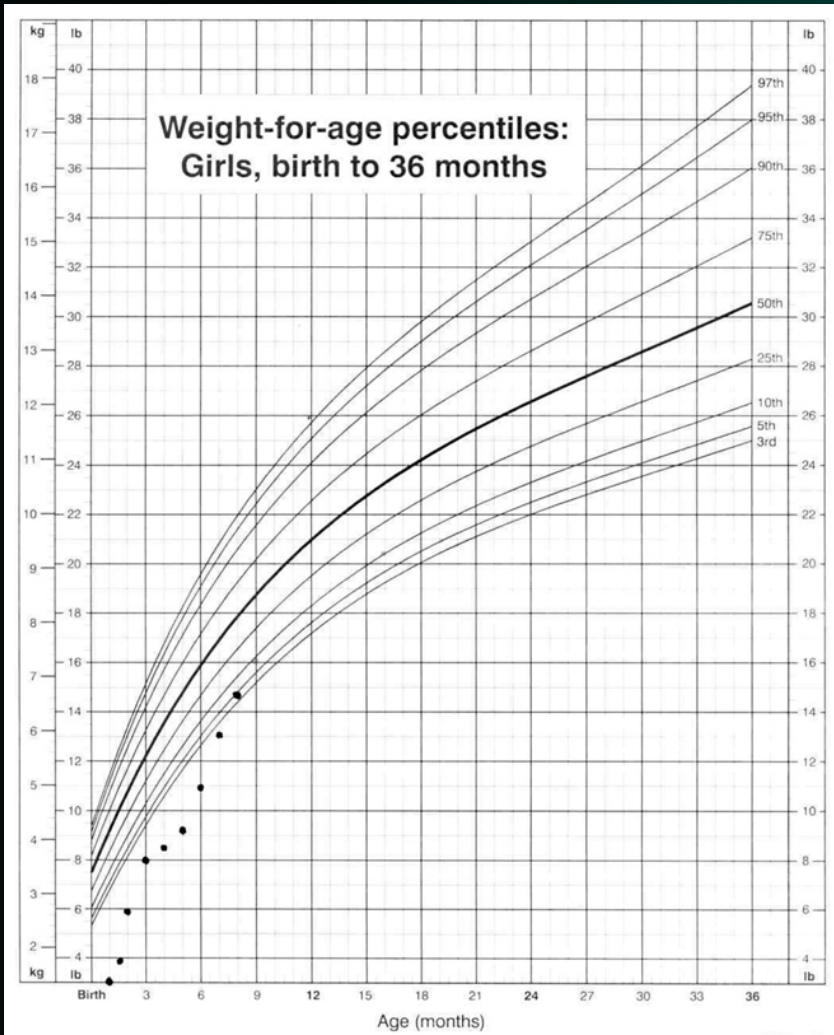
Conjugated Bilirubin

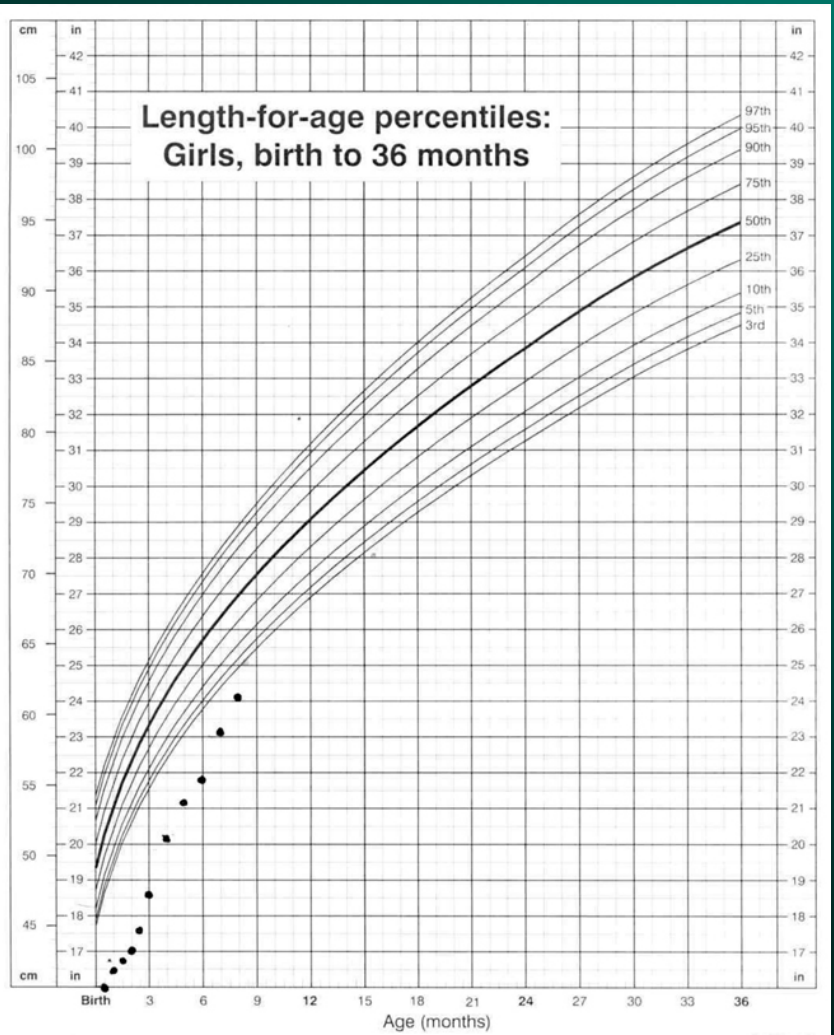
What happened to change patient's laboratory and clinical course



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





Case-based Learning

EN Support in
MaInutrition/Failure to Thrive

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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 O_2
- 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