



PEDIATRIC ENTERAL NUTRITION

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✓ Enteral nutrition (EN) is the **mode of choice** for nutrition delivery in the PICU.

✓ Early institution of EN is associated with beneficial outcomes:

- **Decrease infectious episodes**
- **Decrease length of hospital stay**
- **Decrease mechanical ventilation days**
- **Lower mortality**

Enteral nutrition:

- ❖ Indications
- ❖ Delivery Modes
- ❖ Components
- ❖ Monitoring
- ❖ Safety

INDICATIONS

- ✓ Enteral nutrition is the preferred mode of nutrition intake in **critically ill patients**.
- ✓ EN is physiologic, less severe, lower infection as compared to parenteral, and is cost effective.
- ✓ EN is indicated in children who have a **viable GI tract** and **when oral intake is either not possible or is insufficient to meet the nutritional needs**.
- ✓ The best time to begin EN during critical illness is **unclear**, but early feeding is preferred.
- ✓ **The use of vasopressor agents and neuromuscular blockers is not an obstacle to use EN.**

• **BOX 99.2** Barriers to Enteral Nutrient Delivery in the Pediatric Intensive Care Unit

Fasting before procedures

- Endotracheal tube–related procedures (intubation, extubation)
- Major operative procedures
- Other procedures requiring general anesthesia
- Bedside procedures requiring sedation
- Radiology suite or interventional radiology procedures

Fluid restriction

Delay in establishing enteric tube for feeding

- Delay or difficulty in enteric tube placement
- Malpositioned, obstructed, or displaced enteric tube

Gastrointestinal dysfunction

- Malabsorption, diarrhea, or severe constipation
- Ileus associated with opioid use or postoperative

Patients at risk of aspiration of gastric contents

Holding EN for perceived intolerance

- High gastric residual volume
- Abdominal distension or discomfort
- Vomiting or diarrhea

Failure to implement evidence-based uniform algorithmic approach to EN

- Delay in initiating EN

EN, Enteral nutrition.

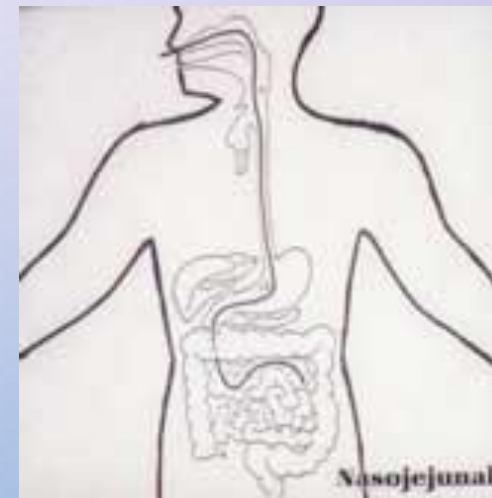
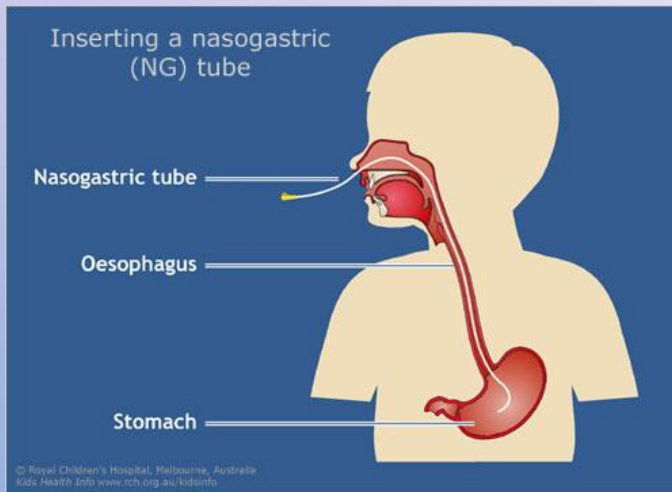
DELIVERY MODES

- I. **Nasogastric (NG), Nasoduodenal (ND) And Nasojejunal (NJ) Tubes**
- II. **Gastrostomy Tube (G Tube) And Gastrojejunostomy Tube (G-J Tube)**
- III. **Bolus Vs. Continuous Feedings**

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).



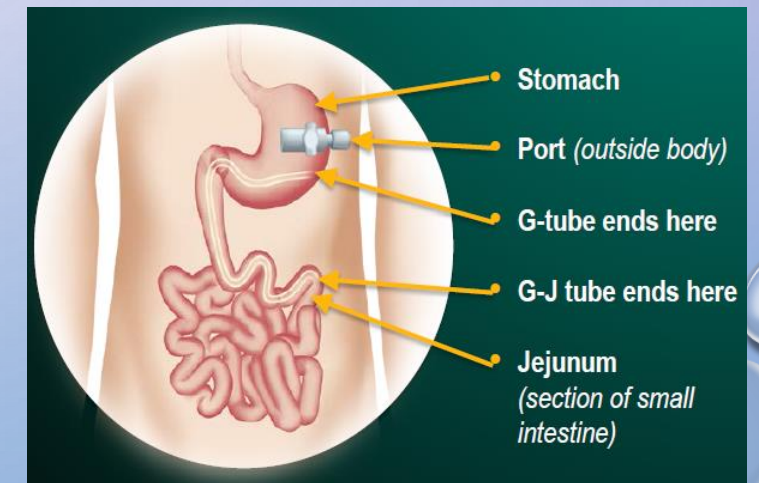
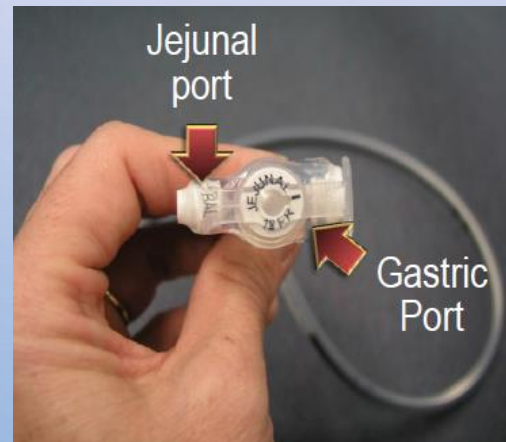
G Tube

Gastrojejunostomy Tube (G-J Tube)

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



✓ 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.



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

GASTRIC VS. POST-PYLORIC - I

Site	Delivery Route	Indications	Potential Complications
Stomach	Orogastric (infants) Nasogastric	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • Aspiration • Nasal mucosal ulceration • Tube occlusion • Pneumothorax • Bleeding • Epistaxis • Sinusitis • Otitis Media
	Gastrostomy	<ul style="list-style-type: none"> • Long term tube feeding • Congenital anomalies, such as tracheo-esophageal fistula, esophageal atresia • Esophageal injury/obstruction • Failure to thrive 	<ul style="list-style-type: none"> • Dislodgement • Aspiration • Tube deterioration • Bleeding • Tube occlusion • Pneumoperitoneum • Wound infection • Stoma leakage

GASTRIC VS. POST-PYLORIC - II

Site	Delivery Route	Indications	Potential Complications
Transpyloric Postpyloric	<ul style="list-style-type: none">• Nasoduodenal• Nasojejunal• Gastrojejunal• Jejunostomy	<ul style="list-style-type: none">• Congenital upper GI anomalies• Inadequate gastric motility• High aspiration risk• Severe GER• Functioning intestinal tract with obstruction above it	<ul style="list-style-type: none">• Pneumatosis intestinalis• Bleeding• Dislodgement• Tube deterioration• Tube occlusion• Bowel obstruction• Stomal leakage• Wound infection

BOLUS VS. CONTINUOUS FEEDINGS

Bolus (intermittent)

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

Continuous

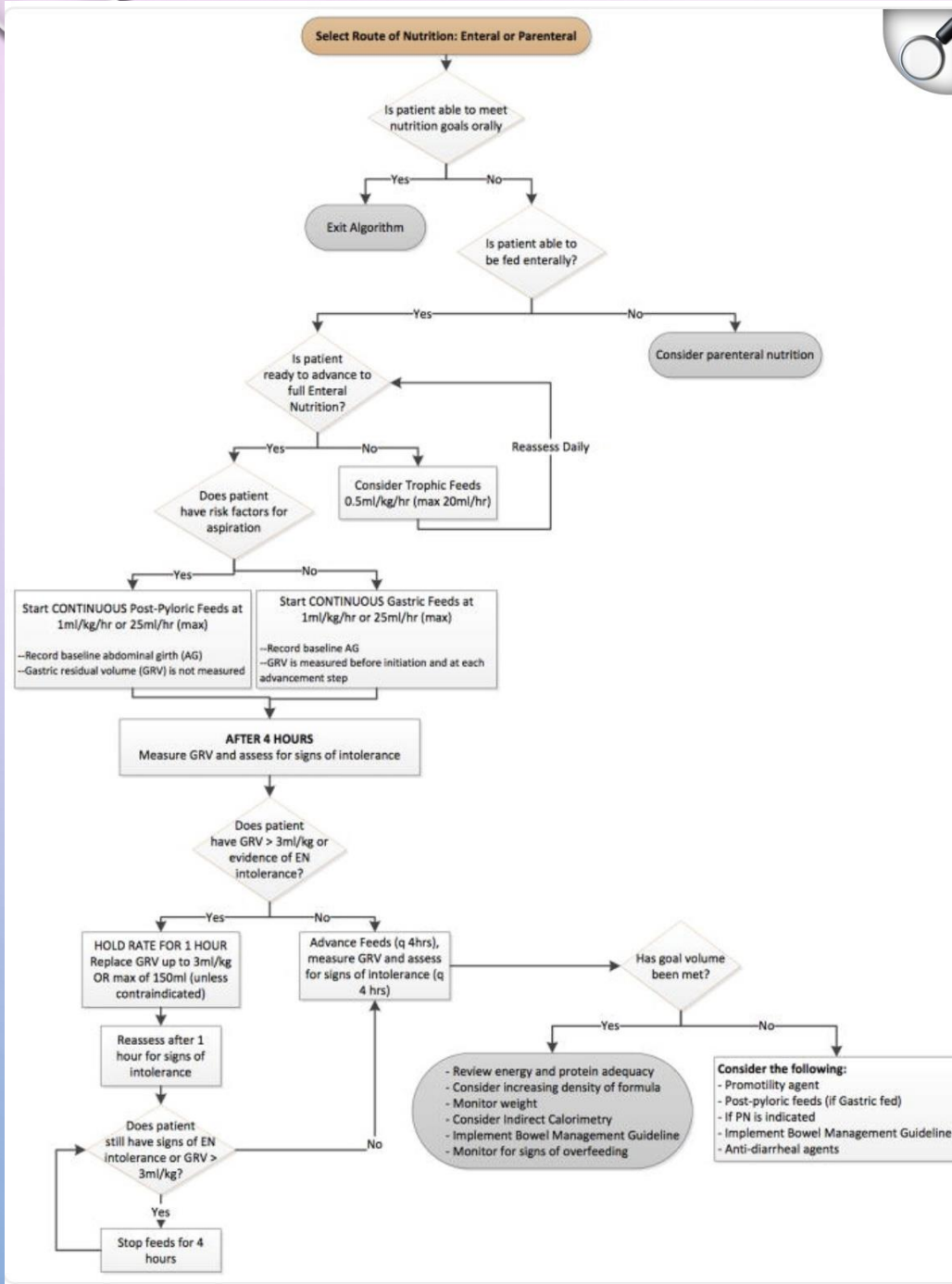
- Slow infusion may improve tolerance and absorption
- Can be given overnight to avoid disruption of daytime schedule and oral intake
- Encourages intestinal adaptation by constant mucosal stimulation
- Reduces need for parenteral calories

• 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



A stepwise enteral nutrition algorithm for critically ill children

Hamilton S, et al. Pediatr Crit Care Med. 2014;15(7):583-589.

COMPONENT

✓ **Protein**

✓ **Carbohydrate**

✓ **Fat**

PROTEIN

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
- ❖ There are no pediatric studies comparing whole diets with partially digested formulas concerning ICU outcomes.

CARBOHYDRATES

Main types of carbohydrates in formulas:

- lactose
- Sucrose
- Glucose polymers

Galactosemia: soy formulas, because they do not contain lactose

FAT

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

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

		Protein	Fat	CHO	Examples
Standard -Normal bowel function -Normal fluids requirements	Oral Tube	Whole protein	Long-chain fats	Lactose-free	<ul style="list-style-type: none"> • Nutren[®] Junior (1-10 yr) • Pediasure[®] (1-10 yr) • Ensure[®] (11yr-adult), Nutren[®] 1.0
	Tube	Whole protein	long-chain fats	Lactose-free	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Peptamen[®] Junior • Pediasure[®] Peptide (1-13 yr) • Nutramigen[®], Pregestimil[®] • Peptamen[®] 1.5 • Vital[®] HN

		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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Portagen[®] • Enfaport[®] • Pregestimil[®] • Tolerex[®] (Free amino acids) • Vital[®] HN
Disease Specific		Varies			<ul style="list-style-type: none"> • Nutren Glytol (diabetic) • Optisource[®] (bariatric surgery) • Pulmocare[®] • Suplena[®] (renal)

■ FORMULA	■ INDICATIONS	■ CONTRAINDICATIONS
Cow's milk-based formulas, iron-fortified	Healthy term infants	Cow's milk protein intolerance; lactose intolerance
Cow's milk-based, lactose-free formulas	Lactase deficiency/lactose intolerance	Cow's milk protein intolerance; galactosemia (enough galactose remains)
Cow's milk-based, low mineral/electrolyte formula	Hypocalcemia/hyperphosphatemia renal disease	Cow's milk protein intolerance (Note: This is a low-iron formula; iron should be supplied from other sources.)
Cow's milk-based, high (86%) medium-chain-triglyceride formula	Severe fat malabsorption, chylothorax	Monitor for signs of essential fatty acid deficiency if used for prolonged periods
Cow's milk-based follow-up formula	Older infants who are eating solid foods	No advantage over breastfeeding or standard infant formula for the first year of life (according to the American Academy of Pediatrics)
Soy-based formula (milk-free, lactose-free)	Galactosemia; hereditary or transient lactase deficiency; documented IgE-mediated allergy to cow's milk; vegetarian-based diet	Birth weight <800 g, prevention of colic or allergy cow's milk protein induced enterocolitis or
with fiber casein hydrolysate formulas	Allergies; intact protein sensitivity	Note: Infants with severe cow's milk protein allergies may react to whey protein hydrolysate formula
Amino acid-based	Malabsorption because of gastrointestinal or hepatobiliary disease and not responsive to hydrolyzed protein formulas	
Human milk fortifiers	Preterm/low-birth-weight infants	Fortifiers are low in iron; additional iron should be supplied from other sources
Preterm formulas	Preterm/low-birth-weight infants	
Preterm discharge formulas	Former preterm/low-birth-weight infants from hospital discharge through 9 mo of age	

IMMUNONUTRITION

- Refer to the concept that nutrition provides not only energy but also substances that are lacking in the critically ill and/or that modify the inflammatory and immune responses.
- Immune stimulating properties of nutrients, such as **glutamine, arginine, ω -3 chain fatty acids, probiotics, nucleic acids, and antioxidants.**
- Conflicting results in Both safety and cost benefits
- One small pediatric study demonstrated a decrease in morbidity but no affect on mortality or length of stay.
- A randomized trial in adults demonstrated higher mortality in patients with critical illness who received enteral immunonutrition compared with standard nutrition.
- **NOT currently recommended in children with critical illness**

MONITOR/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.

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Problem	Prevention/Intervention
Diarrhea/ Abdominal Cramping	<ul style="list-style-type: none"> • 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 <p style="color: red; margin-left: 600px;">Osmolarity < 460 mOsm/kg for intragastric Osmolarity 300-310 mOsm/kg for duodenal or jejunal</p>
Vomiting/ Nausea	<ul style="list-style-type: none"> • Ensure formula is always at room temperature prior to tube feedings • Elevate head of bed • Consider postpyloric or continuous feeding
Hyperglycemia	<ul style="list-style-type: none"> • Reduce flow rate • Use formulas with minimal simple sugars • Consider insulin if clinically indicated

Problem	Prevention/Intervention
Constipation	<ul style="list-style-type: none">• Ensure optimal fluid intake• Increase free water intake• Change to a product containing fiber
Gastric Retention of Formula	<ul style="list-style-type: none">• 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	<ul style="list-style-type: none">• 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

MONITORING OF TOLERANCE

TABLE 98.6

CAUSES OF GASTROINTESTINAL INTOLERANCE

■ CAUSE	■ EXAMPLES
Site and speed of nutrition delivery	High delivery speed, postpyloric feeding
Diet type	Low fiber content, high osmolarity
Drug-related	Laxatives, antibiotics, proton pump inhibitors, nonsteroidal anti-inflammatory drugs, medications that contain magnesium, antihypertensives
Infectious	Contaminated food, excessive bacterial growth in the small bowel, <i>Clostridium difficile</i>
Lactose deficiency	Primary and secondary
Poor fat absorption	Pancreatic dysfunction, hepatic disease, celiac disease

- ✓ No standard practices on how, when and what is a high value gastric residual volume (GRV)
- ✓ No studies that prove correlation of GRV with intolerance
- ✓ High residual volume is not necessarily indicative of intolerance, conversely the low residual volume does not indicate tolerance.
- ✓ EN intolerance can be a sign of intestinal hypoperfusion.

Consensus statement:

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. *(Bankhead et al. J parenter enteral nutr. 2009;33:122-67)*



INTOLERANCE INTERVENTIONS:

- Drip feedings-continuous
- Trans-pyloric feedings
- Consider trial of promotility agents either to advance tube or enhance emptying/feeding tolerance

SAFETY

✓ **Aspiration**

✓ **Refeeding syndrome**

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.
 - ✓ a randomized control trial of mechanically ventilated children, shows similar incidence of aspiration and intolerance in post pyloric tube compared with gastric tube feeding.
- **Recommendation:** start NG unless there is a heightened risk for intolerance

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



○ **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**
- 

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

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**

THANKS FOR ATTENTION

