Osmolality and renal solute load

**Renal Solute Load**
- Protein, Na, K, Cl content of the formula
- ↑ Solute load → ↑ obligatory water loss
- 40-60 ml are needed to excrete 1 g nitrogen
- patients who receive high N formulas and are not able to ingest free water are at risk of dehydration

Selecting an Enteral Formula

**Choice of formula depends on:**
- Patient’s medical history
- length of small bowel
- nutrient digestibility
- Functional capacity
- underlying disease
- nutritional status (to determine nutritional needs)
- fluid tolerance
- Feeding site (to select appropriate delivery method)

Enteral Formulas: Categories

- Polymeric formulas
  - Commercial
  - Blenderized
- Oligomeric formulas
- Disease-specific formulas
- Modular formulas (concentrated protein and carbohydrate preparations)

Classification of Formulas

- **Table 129-8**
  - Complete standard Polymeric formulas
    - Contain macronutrients in the form of intact protein, TG, and CHO polymers
    - Called complete because they contain all nutrients to meet RDAs
    - Can be used orally or through a tube

Complete standard Polymeric formulas

**Features**
- provide complete nutrition
- majority are lactose free, some have fiber
- 1 kcal/ml isotonic
- Well tolerated
- Can be used for gastric or small intestinal feedings.
- Any delivery method.
- Must be continuous drip for jejunal feedings.
- Protein, caloric density, and osmolality vary

Complete standard Polymeric formulas

**Patient must have:**
- Functional GI tract
- Normal digestion
- Normal absorption
Polymeric Formulas

- **Uses:**
  - Critically ill and non-critically ill
  - rehab patients
  - home EN
- **Calorie density:** 1-2 Kcal/ml
- **Protein:** 35-60 g/l
- **Osmolality:** 300-900 mOsmol/Kg

Monomeric Formulas

- **Partial hydrolyzed or elemental components**
- **Require less digestive and absorptive capacity**
- **Elemental:**
  - Proteins as free AA
- **Chemically defined:**
  - Proteins as oligopeptides, dipeptides and tripeptides

Monomeric Formulas

- **CHO** are in the form of oligosaccharides, sucrose, glucose
- **Fat:** MCTs with small LCTs to provide essential FA

Monomeric Formulas

- **Osmolality:** 500-700 mOsmol/Kg
- **Calorie:** 1 kcal/ ml
- **Protein:** 40-50 g/l

Monomeric Formulas

- **Indications for Use:**
  - Inflammatory bowel disease
  - Pancreatic insufficiency
  - Malabsorption
  - Short bowel syndrome
  - Radiation enteritis
  - Early enteral feeding
  - Intolerance to polymeric formula

Specialty Formulas

- Elemental
- Hepatic
- Respiratory
- Fiber
- Diabetic
- High Protein
- HIV/AIDS
- Immune or Intensive Care
- Re-hydration
- Supplemental Water
Disease State Specific Formula

- Based on specific metabolic needs such as organ failure or immune dysfunction
- Arginine, ribonucleic acid, and omega-3 FA are added to enhance immune function during critical illness or sepsis
- Glutamine to promote intestinal mucosal integrity and reduce infectious complications

Disease Specific Formula

- **Carnitine** is a conditionally essential nutrient, Required for transport of LCT
- **Taurine** is a sulfur continuing AA that improves fat absorption in patients with malabsorption
  - Essential for infant and children
  - Increased requirements during catabolic states

Disease Specific Formula

- **Renal failure**
  - Calorically dense formula
  - Electrolyte free or reduced e.g. Nepro ®
  - Higher than normal concentration of essential AA in combination with NEAA
  - Recycling of urea nitrogen for NEAA reduces the accumulation of BUN
  - require vitamin and mineral supplementation
<table>
<thead>
<tr>
<th>Disease-Specific Formula</th>
<th>Disease-Specific Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hepatic Insufficiency</strong></td>
<td><strong>Hepatic Disease</strong></td>
</tr>
<tr>
<td>• Altered protein metabolism and protein loss</td>
<td><strong>Recommendations</strong></td>
</tr>
<tr>
<td>• Altered carbohydrate metabolism</td>
<td>• High caloric density with low sodium content</td>
</tr>
<tr>
<td>- glucose intolerance</td>
<td>• Moderately high calorie:nitrogen ratio</td>
</tr>
<tr>
<td>- low hepatic glycogen stores</td>
<td>• High in branched chain AAs and low in aromatic AAs</td>
</tr>
<tr>
<td>• Malabsorption of fat and fat-soluble vitamins</td>
<td>• Non-digestible soluble fiber</td>
</tr>
<tr>
<td>• Inability to elongate or desaturate essential fatty acids</td>
<td>• Long-chain fatty acids and supplemental MCT</td>
</tr>
<tr>
<td>• Vitamin and mineral deficiencies (e.g., B-complex and Zn)</td>
<td>• Supplemented with fat soluble vitamins, Zn, folic acid and B complex vitamins</td>
</tr>
<tr>
<td>• Impaired urea synthesis with hyperammonemia and hepatic encephalopathy</td>
<td>• Low copper, iron, manganese content</td>
</tr>
<tr>
<td>• Fluid and sodium retention</td>
<td><strong>Pulmonary failure</strong></td>
</tr>
<tr>
<td>• Reduced appetite/oral intake and taste impairment</td>
<td>• Contain substantial amount of fat → 40-55% of calories</td>
</tr>
<tr>
<td></td>
<td>• Fat oxidation produced less CO₂ → reducing work load of the lungs</td>
</tr>
<tr>
<td></td>
<td>• Lower amount of carbohydrate</td>
</tr>
<tr>
<td></td>
<td>• high fat → delayed gastric emptying and related problems</td>
</tr>
<tr>
<td></td>
<td>• Calorie concentrated formula e.g. Pulmocare</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disease State Specific Formula</th>
<th>Disease State Specific Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hepatic failure</strong></td>
<td><strong>Glucose Control</strong></td>
</tr>
<tr>
<td>• Increased amount of branched AA to 45-50% of protein</td>
<td>• For patients with hyperglycemia</td>
</tr>
<tr>
<td>• Reduced amounts of aromatic AA</td>
<td>• Contain 40-50% of calories from fat</td>
</tr>
<tr>
<td>• To reduce risk of hepatic encephalopathy e.g. Hepatic-aid and Nutra-hip</td>
<td>• Fiber enriched</td>
</tr>
<tr>
<td>• require vitamin and mineral supplementation</td>
<td>• High fat → delayed gastric emptying and related problems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disease State Specific Formula</th>
<th>Disease State Specific Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glucose Control</strong></td>
<td><strong>Stress/ Critically ill</strong></td>
</tr>
<tr>
<td>• For patients with hyperglycemia</td>
<td>• BCAA enriched &gt; 35% of protein</td>
</tr>
<tr>
<td>• Contain 40-50% of calories from fat</td>
<td>• BCAA are used as energy in Sk.MS</td>
</tr>
<tr>
<td>• Fiber enriched</td>
<td>• Supplementation will reduce MS breakdown</td>
</tr>
<tr>
<td>• High fat → delayed gastric emptying and related problems</td>
<td>• AAA not reduced (not interchangeable with hepatic formulas)</td>
</tr>
<tr>
<td>• Low carbohydrate content</td>
<td>• high nitrogen content</td>
</tr>
<tr>
<td>- Monosaccharides (fructose)</td>
<td></td>
</tr>
<tr>
<td>- Glucose polymers</td>
<td></td>
</tr>
<tr>
<td>• Increased monounsaturated fat (MUFA)</td>
<td></td>
</tr>
<tr>
<td>• Added fiber</td>
<td></td>
</tr>
</tbody>
</table>
Disease State Specific Formula

**Stress/ Critically ill**
Non BCAA enriched:
- May contain arginine, glutamine or modified fat

Disease-Specific Formula

**Cancer-Induced Weight Loss**

- Complex metabolic syndrome - anorexia, fatigue, early satiety
- Significant weight loss & muscle wasting
- Etiology is multifactorial
  - Pro-inflammatory cytokines
  - Acute phase response
  - Abnormal metabolism
  - Proteolysis inducing factor (PIF)
- Cannot correct by additional calories alone

Negative Prognosis & QOL

Recommendations
- High protein and Zn to build muscle
- Low fat to avoid early satiety
- Low in sucrose for better patient acceptance
- High in fermentable fibers
- Eicosapentaenoic acid (EPA)
- Antioxidants (vitamins A, C, E and Se)
- Folate and iron for anemia

Modular Formulas

- Single nutrient components
- Can be added to available formulas to enhance specific substrate content
- The nutrient complexity should be based on the patients’ digestive capacity

**Proteins**
- Added to increase nitrogen content
- Powder form
- Contain AA, caseinates, or whole protein

Modular Formulas

**CHO**
- Can be added for calorie enhancement
- Usually glucose polymers
- Available; as solid or liquid with variable calorie content

Hydration Formulas

- Do not require IV access
- Economical

**Contain glucose**
- Glucose stimulates active transport systems which stimulate passive salt and water uptake

**Uses**
- Reduce diarrheal sequelae
- Replenish ostomy drainage fluid and electrolyte losses
**Initiating an EN Regimen**
- Determine rate and strength of formula
- Should be individualized to patient
- Start at half strength dilution at a rate of 25-50 ml/hr
- Increase in 25 ml/hr increments every 6-8 hrs to maximal rate
- Increase formula strength in the next days
- The process should not take more than 3 days

**Formula Selection**
- Energy, protein, & fluid needs.
- Electrolyte restrictions
- Disease state.
- Capacity and capability of the GI tract.
- Feeding tube constraints.
- Method of delivery.
- Cost and availability both in the hospital and at home.

**Complication of concomitant drug administration**
- Tube occlusion
- Adverse effects due to change in dosage form
- Alteration of medication Phk and PD

**Drug incompatibility with EN**
Mixing liquid medication with EN →
Physical incompatibilities
- Granulation
- Gel formation
- Separation
- Precipitation

**Complication of concomitant drug administration**
- Inhibited drug absorption within the small bowel, Reduced bioavailability
- Desired pharmacological effect not achieved
- Gel formation may clog small bore tubes
- Table 129-11

**Risks:** these incompatibilities occur more when formula contains
- intact proteins
- Acidic syrups

**Recommendation to avoid:**
- Avoid admixture whenever possible
- Esp. in non-aqueous preparations and syrups
Complication of concomitant drug administration
Factors to Consider

1-Anatomic location of the tube:
- Tubes beyond the pylorus alter drug dissolution because stomach bypassed
- Antacids and sucralfate have therapeutic effect to occur within the stomach

Complication of concomitant drug administration

2-Drug administration in relation to meal
- Many drugs are best absorbed on empty stomach
- Bolus → give medication between feedings
- Continuous feeding → interruption of feeding for drug administration followed by flushing with water

Complication of concomitant drug administration

3-Proper medication dosage:
- Compressed tablets or contents of hard or soft gelatin capsule can be mixed with water
- Flush tube with water prior and after administration of medication to prevent clogging

Factors to Consider

1. Administer medications by mouth when feasible; consider enteral feeding tube as an alternative route.
2. Determine location of the feeding tube tip, because pre- or post-pyloric drug instillation can alter effectiveness.
3. Liquid dosage forms should be used if available. Dosage and frequency adjustment are required if changing from a sustained-release drug to administer a non-sustained-release liquid form.
4. Hypersoluble medications require dilution.
5. The contents of hard or soft gelatin capsules reconstituted with 10–15 mL of water and crushed compressed tablets reconstituted with 15–30 mL of water can be administered when a liquid form is unavailable.
6. Do not crush and administer sustained-release or enteric-coated medications.
7. Flush the feeding tube with water prior to administering a medication. Do not mix medications. Administer each medication separately, flushing with water between medications. Flush with water after medication administration completed.
8. In general, do not add medications to the enteral formula. Exceptions exist for the adding of hypertonic electrolyte injection to enteral formulas. Be aware of specific drug-enteral product incompatibilities.

TABLE 3.8-11. General Considerations for Medication Administration by Enteral Feeding Tubes

<table>
<thead>
<tr>
<th>Dosage Form</th>
<th>Administered by Enteral Feeding Tube</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral liquids</td>
<td>Yes</td>
<td>May be crushed and administered without altering therapeutic drug response. Use the oral feeding tube.</td>
</tr>
<tr>
<td>Powdered oral liquids</td>
<td>Yes</td>
<td>Powdered oral liquids may be administered without altering therapeutic drug response. Use the oral feeding tube.</td>
</tr>
<tr>
<td>Hard capsules</td>
<td>Not recommended</td>
<td>Crushing a sustained-release drug form destroys its therapeutic effect; discontinue therapy.</td>
</tr>
<tr>
<td>Soft gelatin capsules</td>
<td>Yes</td>
<td>May be crushed and administered without altering therapeutic drug response. Use the oral feeding tube.</td>
</tr>
<tr>
<td>Discontinued</td>
<td>No</td>
<td>Use the oral feeding tube.</td>
</tr>
<tr>
<td>Enteral nutrition</td>
<td>Yes</td>
<td>Use the oral feeding tube.</td>
</tr>
<tr>
<td>Intravenous</td>
<td>Yes</td>
<td>Use the oral feeding tube.</td>
</tr>
<tr>
<td>Inhaled</td>
<td>Yes</td>
<td>Use the oral feeding tube.</td>
</tr>
</tbody>
</table>
### Enteral Feeding Complications

- Mechanical
- Gastrointestinal
- Metabolic
- Infectious

### Mechanical

- Feeding tube obstruction
- Feeding tube dislodged
- Nasal irritation
- Skin irritation/excoriation at ostomy site

### Tube Occlusion

#### Causes

1. **Non-medications related factors:**
   - Pump malfunction
   - Lack of periodic flushing
     - Tube should be flushed flowing each feed
     - 20 ml q 8 hr in CI
     - 10-20 ml for medication administration
     - 5 ml between multiple medications
   - Formula characteristics
     - Protein source
   - Tube characteristics
     - Bore size

2. **Medication-related factors:**
   - Administration method
     - Mixing with formula has greatest potential for tube occlusion due to viscosity or physical form of the medication and formula
   - Dosage form (use liquid preparation)
   - PH
   - Viscosity (dilute before administration)

### Prevention of Feeding Tube Obstruction

- Flush the feeding tube, especially before and after medication administration and bolus/intermittent feedings
- Use liquid formulations of medicines where possible (but be careful of osmolarity)
- Do not mix medications with enteral feedings unless shown to be compatible
- Avoid crushing sustained-release or enteric-coated tablets

### Restoring Tube Patency

- Must be replaced if patency cannot be restored
- Flush with warm water
- When specific cause is identified and the character of the substance known e.g. solubility, PH
- Acidic liquids may extend occlusion especially if denatured protein are present
- If water fails use activated pancreatic enzyme preparation
### Technical Complications of EN

<table>
<thead>
<tr>
<th>Condition</th>
<th>Causes</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occluded tube</td>
<td>- Insoluble complex of formula and medication&lt;br&gt;- Undisclosed feeding formula</td>
<td>- Instillation of water&lt;br&gt;- Meat tenderizer&lt;br&gt;- Pancreatic enzymes&lt;br&gt;- Passing endoscopic cytology brush&lt;br&gt;- Adherence to appropriate flushing</td>
</tr>
<tr>
<td>Tube displacement</td>
<td>- Self-extubation&lt;br&gt;- Vomiting or coughing&lt;br&gt;- Inadequate fixation (Jejunostomy)</td>
<td>- Securing tube&lt;br&gt;- Ongoing assessment of appropriate placement</td>
</tr>
</tbody>
</table>

### Metabolic Complications of EN

<table>
<thead>
<tr>
<th>Complication</th>
<th>Causes</th>
<th>intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperglycemia</td>
<td>Stress response&lt;br&gt;High CHO formula&lt;br&gt;Stressors&lt;br&gt;DM</td>
<td>Monitor finger stick glucose q6&lt;br&gt;Order Sliding Scale&lt;br&gt;Monitor Inns and Outs</td>
</tr>
<tr>
<td>Glycosuria</td>
<td>Can lead to dehydration, coma, or death</td>
<td>Monitor finger stick glucose q6&lt;br&gt;Order Sliding Scale&lt;br&gt;Monitor Inns and Outs</td>
</tr>
<tr>
<td>Excess CO₂ production</td>
<td>High % of calories from CHO or excess calories</td>
<td>† Fat calories and / or ↓ total calories</td>
</tr>
<tr>
<td>Hyponatremia</td>
<td>Dilutional (fluid excess, SIADH)&lt;br&gt;Inadequate Na intake&lt;br&gt;Excess GI losses</td>
<td>Use full strength formula&lt;br&gt;Add salt to tube feeding&lt;br&gt;Use diuretics if appropriate&lt;br&gt;Replace GI losses</td>
</tr>
<tr>
<td>Hyperkalemia</td>
<td>Potassium sparing medication&lt;br&gt;Potassium containing medication&lt;br&gt;Renal failure</td>
<td>Monitor serum K&lt;br&gt;Change medications&lt;br&gt;Monitor renal function&lt;br&gt;Use low potassium formula</td>
</tr>
<tr>
<td>Hypercoagulability</td>
<td>Warfarin antagonism due to high vit K content</td>
<td>Change formula to low vit K MONITOR COAGULATION status</td>
</tr>
</tbody>
</table>

### Infectious Complications

- Formula contamination
- Unsanitary equipment
- Failure to follow appropriate protocols re handling of enteral feedings/changing of bags and tubing

### Gastrointestinal Complications

- Diarrhea
- Constipation
- Gastric distention/bloating
- Gastric residuals/delayed gastric emptying
- Nausea/vomiting
### GI Complications of EN

<table>
<thead>
<tr>
<th>Diarrhea</th>
<th>Drug related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hyperosmolar medication</td>
</tr>
<tr>
<td></td>
<td>Elixir containing large amount of sorbitol</td>
</tr>
<tr>
<td></td>
<td>Antibiotic induced bacterial overgrowth</td>
</tr>
<tr>
<td></td>
<td>Antacid containing Mg</td>
</tr>
<tr>
<td></td>
<td>Malabsorption</td>
</tr>
<tr>
<td></td>
<td>Mucosal atrophy</td>
</tr>
<tr>
<td></td>
<td>Chronic pancreatitis</td>
</tr>
<tr>
<td></td>
<td>Cystic fibrosis</td>
</tr>
<tr>
<td></td>
<td>Rapid GI transit</td>
</tr>
<tr>
<td></td>
<td>Inadequate surface area</td>
</tr>
<tr>
<td></td>
<td>Radiation enteritis</td>
</tr>
<tr>
<td>Tube feeding-related</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rapid administration</td>
</tr>
<tr>
<td></td>
<td>Formula</td>
</tr>
<tr>
<td></td>
<td>Hyperosmolarity</td>
</tr>
<tr>
<td></td>
<td>Low fiber content</td>
</tr>
<tr>
<td></td>
<td>Lactose intolerance</td>
</tr>
<tr>
<td></td>
<td>Bacterial contamination</td>
</tr>
</tbody>
</table>

- Use continuous infusion of chemically defined formula
- Pharmacological intervention indicated to control diarrhea
- Use should be limited
- Osmotic may produce constipation
  - Opiums
  - Decrease GI motility and secretion
  - ↓ fluid to be reabsorbed in small intestine and colon
  - Transient time
  - Diphenoxylate
  - Same MOA as opiates
  - Loperamide ↓ GI motility
  - 2-3X potent as diphenoxylate

### Nausea/Vomiting Treatment
- Consider reducing/discontinuing narcotic medications
- Switch to a low fat formula
- Administer feeding solution at room temperature
- Reduce rate of infusion by 20-25 ml/hr
- Administer prokinetic agent (metoclopramide, erythromycin, domperidone, bethanechol)
- Check gastric residuals
- Consider antiemetics

### Aspiration

**Patients at risk**
- Mechanically ventilated patients
- Patients with swallowing disorders

### Aspiration Prevention
- Keep head of bed elevated 30-45 degrees during and 30-40 minutes after feedings
- Feed post-pylorically
- Small, frequent feedings or continuous drip
- Use of promotility agents
- Monitoring of gastric residuals may be helpful in identifying delayed gastric emptying and increased risk of aspiration
**Aspiration**

| Aspiration | 1- Improper patient's positions  
|            | 2- Atony causing regurgitation  
|            | 3- Feeding tube malposition  
|            | 4- Compromised esophageal sphincter  
|            | 5- Diminished gag reflex  |
| Infections | Long-term use of polyvinylchloride tubes |
| Aspiration Pneumonia | 1- Keep patient head at 30-45 degree angle during feeding and 30-60 min after  
| Otitis media | 3- Verify position by x-ray  
| Sinusitis | 4- Use small bore tube  
| | 5- Not allowing large volume to accumulate in the stomach  
| | - Gastric residuals after 30 min < 200 ml  
| | - Infuse feeding into small bowel  |

**Therapeutic nutrition and disease outcome**

**2- Reduce disease-related morbidity and mortality**

- Measured by:
  - Length of hospital stay  
  - Infectious complications  
  - Patient's sense of well-being  

- Difficult to document because other factors affect them:
  - Age  
  - Underlying comorbidity  
  - Extent of injury  
  - Immunocompetence  
  - End-organ complications

**Therapeutic nutrition and disease outcome**

- Table 129-14

**Goals of EN:**

**1- Nutriton Outcomes**

- Reverse protein calorie malabsorption  
- Promote growth and development in infants and children  
- Maintain adequate nutritional state  

**Assessed by:**

- Objective measure of body composition, protein and energy balance  
- Subjective outcomes for physiological muscle function and wound healing

- **160**

- **162**