Nutrition in Critical Illness

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Scope

• Metabolic response to critical illness
• Aim of nutritional management
• Timing of nutrition therapy
• Determination of nutrition requirement
• Nutritional management
  o Implement of EN
  o Implement of PN
Interrelationships Among Systemic Inflammatory Response Syndrome (SIRS), Sepsis, And Infection


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Metabolic Response to Stress

## Metabolic Response to Stress

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypovolemic/ Shock</strong></td>
<td><strong>Catabolism Predominates</strong></td>
<td><strong>Anabolism Predominates</strong></td>
</tr>
<tr>
<td>↓ Tissue perfusion</td>
<td>↑ Glucocorticoids, glucagon, catecholamines, insulin resistance</td>
<td>↓ Hypermetabolic rate</td>
</tr>
<tr>
<td>↓ O₂ consumption</td>
<td>↑ O₂ consumption</td>
<td>↓ Hormonal response &amp;</td>
</tr>
<tr>
<td>↓ Metabolic rate</td>
<td>Profound protein catabolism and ↑ excretion N</td>
<td>Body temp</td>
</tr>
<tr>
<td>↓ Blood volume</td>
<td>↑ Metabolic rate</td>
<td>Heart rate</td>
</tr>
<tr>
<td>↓ Body temperature</td>
<td>↑ Vascular permeability</td>
<td>Cardiac output</td>
</tr>
<tr>
<td></td>
<td>↑ Losses of K, PO₄, and Mg</td>
<td>Gradual restoration of body protein &amp; wound healing</td>
</tr>
<tr>
<td></td>
<td>↑ Cardiac output, body temp</td>
<td></td>
</tr>
</tbody>
</table>

- **Time for Resuscitation**
- **Time for Nutrition**
- **Time for Nutrition and rehabilitation**
Energy Expenditure During Critical Illness

Variations In Energy Expenditure During Critical Illness

Severity and phase of illness

<table>
<thead>
<tr>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>↑REE:</strong></td>
</tr>
<tr>
<td>- nutrition, vasopressor, inotropes</td>
</tr>
<tr>
<td><strong>↓REE:</strong></td>
</tr>
<tr>
<td>- β- locker, sedative, muscle relaxant, analgesic</td>
</tr>
<tr>
<td>- Mechanical ventilator, cooling</td>
</tr>
</tbody>
</table>

Chioléro R et al. Nutrition 1997; 13 (suppl): 45S-51S
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Δ REE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catecholamine (septic shock)</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>+15</td>
</tr>
<tr>
<td>NE</td>
<td>+25</td>
</tr>
<tr>
<td>DA</td>
<td>+4</td>
</tr>
<tr>
<td>DB</td>
<td>+6</td>
</tr>
<tr>
<td>β-blocker</td>
<td></td>
</tr>
<tr>
<td>Burn</td>
<td>-7</td>
</tr>
<tr>
<td>Head injury</td>
<td>-6</td>
</tr>
<tr>
<td>Sedative</td>
<td></td>
</tr>
<tr>
<td>Post op MV</td>
<td>-25-55</td>
</tr>
<tr>
<td>Barbiturate: head trauma</td>
<td>-32</td>
</tr>
<tr>
<td>Analgesic</td>
<td></td>
</tr>
<tr>
<td>Post op</td>
<td>-66</td>
</tr>
<tr>
<td>Critically ill</td>
<td>-9</td>
</tr>
<tr>
<td>Muscle relaxant</td>
<td></td>
</tr>
<tr>
<td>HI</td>
<td>-42</td>
</tr>
<tr>
<td>Mechanical ventilator</td>
<td></td>
</tr>
<tr>
<td>Post op</td>
<td>-11</td>
</tr>
<tr>
<td>ARDS</td>
<td>-25</td>
</tr>
<tr>
<td>Cooling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-8</td>
</tr>
<tr>
<td>Nutrition</td>
<td></td>
</tr>
<tr>
<td>Major burn</td>
<td>+20</td>
</tr>
</tbody>
</table>

*Nutrition* Vol. 13, No. 9(Suppl), 1997
Measure Energy Expenditure

- Sepsis Not Ventilated
- Septic Ventilated
- HI paralysed
- Trauma
- HI nonparalysed

Expected vs Measured:

- 2500
- 2000
- 1500
- 1000
- 500
- 0

References:
- McCall M et al. JPEN 2003;27: 27-35
Calorie Distribution Shift in Catabolism

Normal

- Fat: 25%
- Protein: 15%
- CHO: 60%

Catabolic

- Fat: 30%
- Protein: 25%
- CHO: 45%
## Substrate Utilization In Sepsis And Multiple Organ Failure

<table>
<thead>
<tr>
<th>Energy metabolism</th>
<th>Glucose metabolism</th>
<th>Lipid metabolism</th>
<th>Protein metabolism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Changes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ↑Energy expenditure</td>
<td>↑Glucose production</td>
<td>↑Lipolysis</td>
<td>↑Proteolysis</td>
</tr>
<tr>
<td>• ↑Gluconeogenesis</td>
<td>↑Lipid oxidation</td>
<td></td>
<td>Net protein breakdown</td>
</tr>
<tr>
<td>• ↑Lactate production</td>
<td></td>
<td></td>
<td>Synthesis of acute-phase proteins</td>
</tr>
<tr>
<td>• Hyperglycemia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Insulin resistance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Main mediators</strong></td>
<td>• Cortisol</td>
<td>• Cortisol</td>
<td>• Cortisol</td>
</tr>
<tr>
<td>• Fever, Pyrogen, Epinephrine, Cytokines</td>
<td>• Glucagon</td>
<td>• Epinephrine</td>
<td>• Cytokines</td>
</tr>
<tr>
<td>• Epinephrine Cytokines</td>
<td></td>
<td>• Growth hormones</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive acute phase protein</strong></td>
<td></td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>Clotting process</td>
</tr>
<tr>
<td>Prothrombin</td>
<td>Clotting process</td>
</tr>
<tr>
<td>Antihemophilic</td>
<td>Clotting process</td>
</tr>
<tr>
<td>Plasminogen A</td>
<td>Clotting process</td>
</tr>
<tr>
<td>Complement proteins (C1s, C1, C2, B, C3, C4, C5, C56, 1NH)</td>
<td>Complement cascade including cell lysis, opsonic action and target role in immune response</td>
</tr>
<tr>
<td>Pancreatic secretory trypsin inhibitor</td>
<td>Prevent damage to tissue</td>
</tr>
<tr>
<td>(\alpha)-Antitrypsin</td>
<td></td>
</tr>
<tr>
<td>(\alpha)-Antichymotrypsin</td>
<td></td>
</tr>
<tr>
<td>Haptoglobin</td>
<td>Binding of Hb, inhibit PG’s synthesis</td>
</tr>
<tr>
<td>Ceruloplasmin</td>
<td>Cu binding, antioxidant</td>
</tr>
<tr>
<td>C-reactive protein</td>
<td>complement activation, opsonization of DNA and cell debris</td>
</tr>
<tr>
<td><strong>Negative acute phase protein</strong></td>
<td></td>
</tr>
<tr>
<td>Albumin</td>
<td>Binding of other molecules, antioxidant and maintain plasma oncotic pressure</td>
</tr>
<tr>
<td>Prealbumin</td>
<td>Thyroxine transport and formation of complex with RBP</td>
</tr>
<tr>
<td>Retinol binding protein</td>
<td>Retinol transport protein</td>
</tr>
<tr>
<td>Transferrin</td>
<td>Fe absorption and transport protein</td>
</tr>
<tr>
<td>Fibronectin</td>
<td>Opsonization and enhance immune response</td>
</tr>
<tr>
<td>Insulin like growth factor</td>
<td>Promotion of liver and muscle protein synthesis and inhibit lipolysis</td>
</tr>
</tbody>
</table>

Inflammation And Immune Response In Stress
## Concept of Nutrition Management

<table>
<thead>
<tr>
<th>Nutrition Support</th>
<th>Nutrition Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preserve lean body mass</td>
<td>• Attenuate metabolic response to stress</td>
</tr>
<tr>
<td>• Maintain immune function</td>
<td>• Prevent oxidative cellular injury</td>
</tr>
<tr>
<td>• Avert metabolic complication</td>
<td>• Modulate immune response</td>
</tr>
</tbody>
</table>
Nutritional Therapy

- Early nutrition support
  - EEN
- Appropriate macro and micronutrient
  - Achieving target
  - Pharmaceutical
  - Formula
- Glycemic control
Critically Ill Patients

**ASPEN/SCCM**
- MICU/ SICU
- ICU stay > 2-3 d
- Not include patients with temporary monitoring
- Not include patients with minimal trauma or metabolic stress

**ESPEN**
- Intensive inflammatory response
- Sequential Organ Failure Assessment (SOFA) score >4
<table>
<thead>
<tr>
<th>SOFA score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiration</strong>  PaO₂/FiO₂ (mm Hg)</td>
<td>PaO₂/FiO₂</td>
<td>PaO₂/FiO₂</td>
<td>PaO₂/FiO₂</td>
<td>PaO₂/FiO₂</td>
<td>PaO₂/FiO₂</td>
</tr>
<tr>
<td>SaO₂/FiO₂</td>
<td>&gt;400 221–301</td>
<td>&lt;400 142–220</td>
<td>&lt;300 67–141</td>
<td>&lt;200 &lt;67</td>
<td>&lt;100 &lt;67</td>
</tr>
<tr>
<td><strong>Coagulation</strong>  Platelets 10^3/mm³</td>
<td>Platelets</td>
<td>Platelets</td>
<td>Platelets</td>
<td>Platelets</td>
<td>Platelets</td>
</tr>
<tr>
<td></td>
<td>&gt;150</td>
<td>&lt;150</td>
<td>&lt;100</td>
<td>&lt;50</td>
<td>&lt;20</td>
</tr>
<tr>
<td><strong>Liver</strong>  Bilirubin (mg/dL)</td>
<td>Bilirubin</td>
<td>Bilirubin</td>
<td>Bilirubin</td>
<td>Bilirubin</td>
<td>Bilirubin</td>
</tr>
<tr>
<td></td>
<td>&lt;1.2</td>
<td>1.2–1.9</td>
<td>2.0–5.9</td>
<td>6.0–11.9</td>
<td>&gt;12.0</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong>  Hypotension</td>
<td>Hypotension</td>
<td>Hypotension</td>
<td>Hypotension</td>
<td>Hypotension</td>
<td>Hypotension</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>No</td>
<td>MAP</td>
<td>Dopamine</td>
<td>Dopamine</td>
<td>Dopamine</td>
</tr>
<tr>
<td>Hypotension</td>
<td>hypotension</td>
<td>&lt;70</td>
<td>&lt;5 or</td>
<td>&gt;5 or</td>
<td>&gt;15 or</td>
</tr>
<tr>
<td></td>
<td>dop butamine</td>
<td>no</td>
<td>norepinephrine</td>
<td>norepinephrine</td>
<td>norepinephrine</td>
</tr>
<tr>
<td></td>
<td>(any)</td>
<td>&lt;0.1</td>
<td>&gt;0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CNS</strong>  Glasgow Coma Score</td>
<td>Glasgow</td>
<td>Glasgow</td>
<td>Glasgow</td>
<td>Glasgow</td>
<td>Glasgow</td>
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<tr>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>13–14</td>
<td>10–12</td>
<td>6–9</td>
<td>&lt;6</td>
</tr>
<tr>
<td><strong>Renal</strong>  Creatinine (mg/dL) or urine output (mL/d)</td>
<td>Creatinine</td>
<td>Creatinine</td>
<td>Creatinine</td>
<td>Creatinine</td>
<td>Creatinine</td>
</tr>
<tr>
<td></td>
<td>&lt;1.2</td>
<td>1.2–1.9</td>
<td>2.0–3.4</td>
<td>3.5–4.9 or</td>
<td>&gt;5.0 or</td>
</tr>
<tr>
<td></td>
<td>&lt;500</td>
<td>&lt;200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Nutritional Assessment

- Traditional tools (alb, PAB, and anthropometry): not validated in critical care (E)
  - Acute phase protein response
  - ↑or↓ (at least 25%) in response to inflammation
  - Change with vascular permeability and hepatic protein synthesis
  - Fluid retention

→ Not Accuracy

- Before initiation of feedings: assessment include...(E)
  - Weight loss
  - Previous intake
  - Level of disease severity
  - Co-morbid conditions
  - GIT function

Early Enteral Nutrition (EEN)

- **WHY ENTERAL?**
- **WHY EARLY?**
- **HOW EARLY IS EARLY?**
- **HOW MUCH?**
- **WHAT TO FEED?**
- **HOW TO FEED?**
Enteral Nutrition Advantage

- Maintain gut mucosal physiology
- Preserves gut barrier function
- Promote peristalsis
- May modulate immune response

Disuse Causes Loss of Functional and Structural Integrity
Increased Gut Permeability

Characteristics: Time dependent
Correlation to disease severity

Consequences: Risk of infection
Risk of MOFS
EN vs. PN

Anatomical changes

Effects Of Nutrition On Intestinal Mucosa

A: TPN
B: EN
C: IMN
D: Control

Enteral Nutrition Therapy: Benefits

- Maintains GI structure and function
- Reduces translocation of toxins and possibly bacteria
- Less expensive than PN therapy
- Fewer complications

“If the gut works, use it.”
Enteral Nutrition (EN) vs. Parenteral Nutrition (PN) in Critically Ill

- EN vs. PN: ⇐ mortality
- EN vs. PN: significant ↓ infectious complications
- EN vs. PN: ⇐ ventilator days or LOS
- EN: more cost savings

→ Recommendation: Strongly recommend the use of EN over PN in nutrition support for critically ill.
When To Start:
EN Be Started Within First 24-48 Hr (C) & Stepped To Goal In Next 48-72 Hr

- Initiating EN: as soon as fluid resuscitation is completed and hemodynamically stable
- “Window of opportunity”: first 24-72 hr
- Before 72 hour: less permeability, less activation/release of inflammatory cytokines
Early Vs. Delayed Nutrient Intake
Does Early EN Compared To Delayed Nutrient Intake Result In Better Outcomes In The Critically Ill Adult Patient?

- EEN vs. delayed: Trend towards ↓ mortality
- EEN vs. delayed: Significant ↓ infectious complications
- EEN vs. delayed: ⇔ on ICU or hospital LOS
- EEN vs. delayed: Improves nutritional intake

→ Recommendation: EEN (within 24-48 hr after fully resuscitate) in critically ill patients
EN Should be Withheld Until Patient Is Fully Resuscitated And/Or Stable (E)

- Hemodynamic unstable prone to
  - GI dysmotility
  - Sepsis
  - Subclinical ischemia/reperfusion injury of intestinal microcirculation

- Hold if
  - MAP <60 mmHg
  - Escalating dose of inotropic/vasopressors

- Giving with caution: stable low dose pressor agents

ASPEN Guideline. JPEN 2009; 33; 277
Initiation of EN:
Presence Or Absence Of Bowel Sounds Or Passing Flatus /Stool: Not Required For Initiation EN (B)

- +/- of bowel sounds or passing flatus /stool: Not required for initiation EN(B)

- Good function of GI:
  - Mucosal integrity / absorptive capacity
  - Motility and contractility \( \rightarrow \) represent BS
    - Fluid and air must be present for BS
    - NG decompress, BS may not be heard despite of good function
  - Normal amount of GALT
# Enteral Nutrition: Contraindications

<table>
<thead>
<tr>
<th>Absolute</th>
<th>Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Complete bowel obstruction</td>
<td>• Severe postprandial pain</td>
</tr>
<tr>
<td>• Severe small bowel ileus with abdominal distention</td>
<td>• Short bowel syndrome</td>
</tr>
<tr>
<td>• Complete inability to absorb nutrients through the GI tract</td>
<td>• Intractable vomiting</td>
</tr>
<tr>
<td>• Severe diarrhea</td>
<td>• Severe diarrhea</td>
</tr>
</tbody>
</table>
Dosing of Enteral Feeding
How Much EN Should Critically Ill Patients Receive?

- **Measured by indirect calorimetry: (More accuracy)**
  - Weir equation: Total energy = 3.9 VO$_2$(L) + 1.1 VCO$_2$(L)
- **Calculated by predictive equations (less accuracy)**
  - Harris-Benedict x 1.3-1.5 for stress
  - Ireton-Jones Equations**
  - Penn State equations
- **ASPEN Guidelines:**
  - Indirect calorimetry
  - 25 - 30 kcal/kg per day*
  - 22-25 kcal/kg IBW/d in BMI ≥ 30 kg/m$^2$
- **ESPEN Guidelines:**
  - Indirect calorimetry- if unavailable→
  - Acute/initial phase: if 20-25 kcal/kg/d may be a less favorable outcome
  - Anabolic recovery phase: 25-30 kcal/kg/d
  - Severe malnutrition: 25-30 kcal/kg/d
  - (increase to target in 2-3d)

---

Provide >50%-65% Of Goal In 1st Wk To Achieve Clinical Benefit Of EN (C)

- Impact of EEN on outcome: dose-dependent effect
- “Trickle” or “Tophic” feeding
  - 10-30 cc/hr
  - Prevent mucosal atrophy
  - Not adequate for endpoint desired
- To improve outcome: >50-60% of goal required
  - Prevent increase intestinal permeability
  - Early return of cognitive function
  - Outcome of IMN in critically ill

ASPEN Guideline. JPEN 2009; 33; 277
Does Achieving Target Dose Of EN → Better Outcomes In The Critically Ill Adult Patient?

- Significantly ↑ calorie intake/lower calorie deficit
- Conclusions: Early enhanced EN vs. slower rate
- May ↓ mortality
- May ↓ in hospital LOS
- Trend towards ↓ # infections and complications in HI

Recommendation: Strategies to optimize delivery of nutrients should be considered
  - starting at target rate and use protocol feeding
  - higher threshold of GRV
  - use of prokinetics
  - SB feedings

2009 Canadian CPGs www.criticalcarenutrition.com
Protein Requirement

- **ASPEN Guideline**
  - BMI < 30 kg/m²
  - 1.2-2.0 g/kg actual body (70:1-100:1 of NPC: gN)
    (2 g/kg/day in patients with trauma, severe burns, and head injury, CRRT)
  - BMI ≥ 30 kg/m²
  - ≥2.0 g/kg IBW/d for BMI 30-40 kg/m²
  - ≥2.5 g/kg IBW/d for BMI ≥ 40 kg/m²

- **ESPEN Guideline**
  - 1.3-1.5 g/kg IBW/d

- **Assessment of adequacy**
  - Nitrogen balance: limit
  - Serum protein marker: not useful

Fluid and Electrolytes

Fluid
- 30-40 mL/kg or
- 1 to 1.5mL/kcal expended

Electrolytes/Vitamins/Trace Elements
- Enteral feedings: begin with RDA values
## Fluid volume and caloric density

### Approximate water content in EN base on caloric density

<table>
<thead>
<tr>
<th>Caloric density</th>
<th>% water content</th>
<th>Water content/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1.2</td>
<td>80-85</td>
<td>800-850</td>
</tr>
<tr>
<td>1.5</td>
<td>75</td>
<td>750</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>700</td>
</tr>
</tbody>
</table>
Mode of Feeding: Bolus feeding

- Administration of 200-400 ml over 5-10 mins at regular intervals (5-8 feeds)
  - Cause bloating and diarrhea
  - More likely to generate higher GRV
  - Bolus delivery into jejunum can cause a “dumping syndrome” and should therefore be avoided

GRV = Gastric residual volume
Intermittent Feeding Method

- Moderate rates of feed provision via either gravity or pump
- Resembles normal feeding and digestion patterns
- Test feeding: water or dextrose (sucrose) solution
- 250-500 ml/over 30-60 minutes/5-8 times/d
- Start with
  - full strength
  - small volume and rate (≤ 250 mL/20 min)
- Slowly increase, < 500 mL infused over 30 minutes
Mode of Feeding: Continuous infusion

- Start with 25-40 ml/hr increment 25 ml/12 hr, titrate up to 120 ml/hr, full strength
- Commonly used for very ill patients but it should be changed for intermittent infusion ASAP
- Should not be given overnight in patients who are at risk of aspiration
- Head lift 30-45°
- Benefit: may help
  - diarrhea
  - prevent “dumping” in enteric feeding
- Flaw
  - $\uparrow$ intra-gastric pH levels $\rightarrow$ promote bacterial growth

Trophic feeding: $\sim10$ ml/hr
EN Tolerance

• Tolerance of EN should be monitored
  o Complaints of pain, discomfort
  o Nausea, vomiting
  o Abdominal distention
  o Bowel movement (diarrhea or constipation)
  o High gastric residual volume (GRV)
  o Abdominal radiographs

• Avoided inappropriate cessation of EN:
  o Holding EN for high GRV alone: avoided
  o NPO time for investigation or procedures: be minimized (C)
  o ↓ inadequate nutrition
  o ↓ prolonged ileus

ASPEN Guideline. JPEN 2009
Position and GER/aspiration

- Aspiration: supine vs. semirecumbent MV patients*
- Semirecumbent decreases GER compared to supine#

Factors in Stress Patients That Cause ↓GET

- Hyperglycemia
- Opiates
- Dopamine
- Increased ICP
- Electrolyte abnormalities
- Ischemia
- Hypoxia
- Sepsis
- Burn, trauma, surgery
- Hyperosmolar formula
A Tight Correlation Exists Between Gastric Residual Volume And Aspiration

- **Study 1**: very sensitive and specific marker for aspiration (dyes)
  - Cutoff values > 150 ml: sensitivity 1.9%, PPV 36.1%, NPV 70%
  - Cutoff values >400 ml: sensitivity 8.1%, PPV 37.5%, NPV 70.3%

- **Study 2**: incidence of aspiration
  - Cutoff 0-50 ml vs 400-500 ml: not difference
GRV and Aspiration: Pro

GRV > 500, 2 consecutive GRV 150-500, or vomiting, 43%

without intolerance, 2%

P = 0.01

Cutoff GRV and EN intake

Goal calorie achieved

Taylor and colleagues

Montejo and colleagues
Cutoff GRV and EN intake

Overall Complication

GI Complication

Taylor and colleagues

Montejo and colleagues
GRV Cutoff And Intolerance

- Pinilla and colleagues: 150 vs. 250
  - Not diff in vomiting and GI intolerance
- Lukan: 200 vs. 400 mL

Lukan JK. AJCN 2002;75:417S
- GRVs alone correlated with ↑sedation, ↑use of catecholamines, and ↓caloric intake
- When GRVs + vomiting (intolerance)
  - ↑pneumonia, ICU length of stay, and ICU mortality

GRVs alone did not correlate with ICU mortality, hospital mortality, or incidence of pneumonia
Gastric Residual Volume (GRV)

- ASPEN 2005/ESPEN 2006: cutpoint GRV
  - NG: 200 ml
  - Gastrostomy: 100 ml
- GRV: **not correlated** with
  - Pneumonia
  - Gastric emptying
  - Rate of regurgitation/aspiration
- ↑ cut off value did **not increase** risk
- ↓ cut off value did **not reduce** risk but may adversely affect outcome
- Trend of residual volume is more benefit
- NEW guideline
  - GRV 250-500 ml: raise concerned
  - >500 ml

ASPEN Guideline. JPEN 2009
To optimize Nutrient Delivery

ASPEN: Nurse driven feeding protocol* (C)
- Designate more rapid startups
- Goal infusion rate
- Specific orders for handling GRV
- Frequency of flushes

Canadian Recommendation#:
- Starting at target rate and use protocol feeding
- Higher threshold of GRV
- Use of prokinetics
- SB feedings

*ASPEN Guideline. JPEN 2009. #2009 Canadian CPGs www.criticalcarenutrition.com
Reduce Risk Of Aspiration

- **Head of the bed (HOB):** 30° - 45° (°C)
- **High-risk** (ET with MV, NG, >70yr, altered conscious) **OR** patients with gastric feeding intolerance:
  - → continuous infusion
  - Prokinetic drugs or narcotic antagonists (naloxone) should be initiated
  - Post-pyloric tube placement considered ©
Diarrhea from EN need further evaluation (E)
  - Hyperosmolar drugs: elixir, mixture, antacid
  - Prokinetic drugs
  - C. difficile
  - Formulation changing

Diarrhea:
  - Slow rate: adequate, rarely need dilution

Soluble fiber or small peptide formula: may be useful

Should be
  - Hemodynamic stable
  - Avoid in bowel ischemia, severe dysmotility
Selection of Appropriate Enteral Formulation
What should We feed the critically ill

• High energy intake
  o Not required
  o Not prevent catabolism
  o Increased risk of complication
  o Intolerance to feeding, PN
• Adequate protein intake!!!!
• High protein (N) formula
• 1:1-2:1

Jeejeebhoy KN. Nutrition in Clinical Practice 2004; 19: 477-480
Immune-modulating Enteral Formulations
(+Arg, Gln, nucleic acid, ω3 FA, and antioxidants)

- Benefit in
  - Major elective GI surgery
  - Trauma (index score >20)
  - Burn > 30%
  - Head & neck cancer
  - Critical illness on mechanical ventilation
    Surgical ICU patients (A), Medical ICU patients (B)
  - Use in caution in severe sepsis (APACHE >15)

- Benefit of IMN = dose dependent
- Need at least 50%-65% of goal energy requirements (C)
Glutamine (Gln)

<table>
<thead>
<tr>
<th>Conditionally indispensible amino acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism</td>
</tr>
<tr>
<td>- Systemic antioxidant effect</td>
</tr>
<tr>
<td>- Maintenance of gut integrity</td>
</tr>
<tr>
<td>- Induce heat shock proteins</td>
</tr>
<tr>
<td>- Fuel source for rapid replicating cell</td>
</tr>
</tbody>
</table>

| ESPEN CPG 2006:                      |
|  - Gln should be added in STD EN in Trauma and Burn (A) |
|  - Insufficient data for surgical or heterogeneously critically ill |

| ASPEN CPG 2009                        |
|  - Should be considered in burn, trauma, and mixed ICU patients (B) |
Arginine (Arg)

- Myeloid suppressor cell regulate Arginine
- Arg necessary for normal T lymphocyte function
- Arg deficiency impact production of nitric oxide
- Nitric oxide syntase
  - iNOS : shunt splanchnic blood flow
  - eNOS : Increase microcirculation
- ↑ risk and mortality in severe sepsis in medical ICU
Fish oils

- ω-3 fatty acid in fish oil
  - EPA eicosapentaenoic
  - DHA docosohexaenoic
- ω-3 displace ω-6 from cell membrane of immune cell
  - Reduce systemic inflammatory response
  - Reduce active prostaglandin and leukotriene
- EPA and DHA
  - Precursors of proresolving mediators: resolvins, protectin, lipoxin
  - Down regulate NFκB, ICAM-1 and E-selectin
  - Decrease neutrophil attachment and transepithelial migration
  - Reduce risk of ARDS and sepsis
Omega-3 And Omega-6 Fatty Acids Pathways In Humans

**Omega-3 Fatty Acids**
(e.g. canola, flaxseed oil, fish oils)

- **Alpha-Linolenic Acid**
  - \(\text{delta-6-desaturase}\)
  - **Steridonic Acid**
    - \(\text{delta-5-desaturase}\)
    - **Eicosatraenoic Acid**
      - \(\text{cyclooxygenase}\)
      - \(\text{lipoxygenase}\)
      - **EPA**
        - (e.g. fish oils)
      - **DHA**
        - (e.g. fish oils)

- **PGE3** (anti-inflammatory)
- **LTB5** (anti-inflammatory)

**Omega-6 Fatty Acids**
(e.g. corn, safflower, sunflower oils)

- **Linoleic Acid**
  - \(\text{delta-6-desaturase}\)
  - **Gamma-Linolenic Acid (GLA)**
    - (e.g. borage, evening primrose oils)
  - **Dihomo-Gamma-Linolenic Acid**
    - **PGE1** (anti-inflammatory)
  - **Arachidonic Acid**
    - \(\text{cyclooxygenase}\)
    - \(\text{lipoxygenase}\)
    - **PGE2** (pro-inflammatory)
    - **TXA2** (pro-inflammatory)
    - **LTB4** (pro-inflammatory)
ARDS / ALI

• Should be received anti-inflammatory lipid (ω3 fish oils (EPA), borage oil (GLA)) and antioxidants EN (Grade: A)

• Result
  o Reduce length of stay in ICU
  o Reduce duration of mechanical ventilation
  o Reduce rate of organ failure
  o Reduce mortality
Antioxidant Vitamins And Trace Minerals

- Vit C, Vit E (Antioxidant effect)
- Selenium
- Use in caution in renal impairment
- Should be provided to all ICU patients (B): ↓ mortality and ventilator day

2009 Canadian CPGs www.criticalcarenutrition.com
When To Use Parenteral Nutrition
When to Use PN

**Unable To Meet Energy Requirements** (Target Goal Calories)

- **ASPEN**: not achieve target after 7-10 days by EN alone, consider initiating supplemental PN (E)
  - Initiating PN prior 7-10 d: not improve outcome and may be detrimental to the patient
  - In PCM: Initiate PN as soon as possible following admission and adequate resuscitation (C)

- **ESPEN**: not achieve target after 2 days, considered supplemental PN

**Not expected to be on normal nutrition** in 3 days, consider PN within 24-48 hr (EN C/I or not tolerate) (c) (ESPEN)
Maximize Efficacy of Parenteral Nutrition
Permissive Underfeeding
ASPEN/SCCM ICU Nutrition CPGs

- In all ICU receiving PN
  - mild PUF (~80%) at least initially served as ultimate goal (C)
  - When stable → ↑ to requirement (E)

- In obese, use EN goal guideline

- “PUF”
  - Avoid insulin resistant
  - Reduce infection
  - Reduce length of mechanical ventilation use
  - Reduce hospital length of stay
  - Esp. in Obesity
Glycemic Control

Van den Berge 2001
Surgical ICU
More hypoglycemia

Van den Berge 2006
Medical ICU
More hypoglycemia

Brunkhorst 2008
More hypoglycemia
# The NICE SUGAR Study Investigators 2009

## Intensive Control (N=3010) vs. Conventional Control (N=3012)

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Intensive Control (N=3010)</th>
<th>Conventional Control (N=3012)</th>
<th>Odds Ratio for Death (95% CI)</th>
<th>P Value for Heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative admission</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>272/1111</td>
<td>222/1121</td>
<td>1.31 (1.07–1.61)</td>
<td>0.10</td>
</tr>
<tr>
<td>No</td>
<td>557/1898</td>
<td>529/1891</td>
<td>1.07 (0.93–1.23)</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>195/615</td>
<td>165/596</td>
<td>1.21 (0.95–1.55)</td>
<td>0.60</td>
</tr>
<tr>
<td>No</td>
<td>634/2394</td>
<td>586/2416</td>
<td>1.12 (0.99–1.28)</td>
<td></td>
</tr>
<tr>
<td>Severe sepsis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>202/673</td>
<td>172/626</td>
<td>1.13 (0.89–1.44)</td>
<td>0.93</td>
</tr>
<tr>
<td>No</td>
<td>627/2335</td>
<td>579/2386</td>
<td>1.15 (1.01–1.31)</td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>41/421</td>
<td>57/465</td>
<td>0.77 (0.59–1.18)</td>
<td>0.07</td>
</tr>
<tr>
<td>No</td>
<td>788/2587</td>
<td>694/2547</td>
<td>1.17 (1.04–1.32)</td>
<td></td>
</tr>
<tr>
<td>APACHE II score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;25</td>
<td>106/227</td>
<td>261/244</td>
<td>1.14 (0.95–1.37)</td>
<td>0.84</td>
</tr>
<tr>
<td>&lt;25</td>
<td>442/2080</td>
<td>387/2066</td>
<td>1.17 (1.01–1.36)</td>
<td></td>
</tr>
<tr>
<td>Corticosteroids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>134/392</td>
<td>140/378</td>
<td>0.88 (0.66–1.19)</td>
<td>0.06</td>
</tr>
<tr>
<td>No</td>
<td>695/2616</td>
<td>611/2634</td>
<td>1.20 (1.06–1.36)</td>
<td></td>
</tr>
<tr>
<td>All deaths at day 90</td>
<td>829/3010</td>
<td>751/3012</td>
<td>1.14 (1.02–1.28)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Intensive Control Better  Conventional Control Better
Intensive Insulin Therapy
- Rate of Hypoglycemia (≤40 mg/dl) -

![Graph showing rate of hypoglycemia](image)

- Conventional
- Intensive

Van den Berghe, 2001: 0.8 vs. 5.1 (p<0.001)
Van den Berghe, 2006: 3.1 vs. 4.5 (p<0.001)
VISEP, 2008: 18.7 vs. 17.6 (p<0.001)
NICE-SUGAR, 2009: 6.8 vs. 0.5 (p<0.001)
GluControl, 2006: 3.9 vs. 14.5 (p<0.001)
Guideline Recommendation

- ASPEN: Serum glucose range of 110-150 mg/dl (E)
- ESPEN: blood glucose range of 4.5-6.1 (80-110)
## ASPEN Guideline Recommendations in Adult Hospitalized Patients With Hyperglycemia

<table>
<thead>
<tr>
<th><strong>Desired blood glucose goal range in patients receiving nutrition support</strong></th>
<th><strong>Recommendation</strong></th>
<th><strong>Grade</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target blood glucose 140–180 mg/dL (7.8–10 mmol/L).</td>
<td>Strong</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Hypoglycemia defined in patients receiving nutrition support?</strong></th>
<th><strong>Recommendation</strong></th>
<th><strong>Grade</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hypoglycemia: blood glucose &lt;70 mg/dL (&lt;3.9 mmol/L).</td>
<td>Strong</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>DM specific EN formulas be used for patients with hyperglycemia</strong></th>
<th><strong>Recommendation</strong></th>
<th><strong>Grade</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cannot make recommendation at this time</td>
<td>Further research</td>
</tr>
</tbody>
</table>

Adapted from A.S.P.E.N. Clinical Guidelines: Nutrition Support of Adult Patients With Hyperglycemia. JPEN 2012 June 29[Epub ahead of print]
Intravenous Lipid Emulsion

- **IVLE:** provide energy and ensure essential fatty acid
- **ESPEN:** IVLE (LCT, MCT or mixed): 0.7-1.5 g/kg/d over 12-24 hr (B)
  - Mixed MCT/LCT: well tolerate
  - Olive oil base: well tolerate (B)
  - Fish oil enriched lipid emulsion: effects on cell membrane and inflammation (B)

- **ASPEN:**
  - In the first week, PN without soy based lipids (D)


Maximize Efficacy of PN

- PN stop when EN ≥ 60% of target energy requirements (Grade: E)
- Increase EN volume → reduce PN volume
- Avoid overfeeding
Refeeding Syndrome: Nutrition Recovery Syndrome

Starvation / Malnutrition

Glycogenolysis, gluconeogenesis and protein catabolism

Protein, fat, mineral, electrolyte and vitamin depletion - salt and water intolerance

Refeeding (switch to anabolism)

Fluid, salt, nutrients (CHO major energy source)

Refeeding syndrome

↑ Glucose uptake
↑ Utilization of thiamine
↑ Uptake of K⁺, Mg²⁺ & PO₄³⁻

↑ Protein and glycogen synthesis

Insulin secretion

Hypokalaemia
Hypomagnesaemia
Hypophosphataemia
Thiamine deficiency
Salt and water retention - oedema
ICU Guideline: Enteral Nutrition - Managing The Refeeding Syndrome

- Obtain serum K, PO₄, Mg prior to EN initiation. Follow serum K, PO₄, Mg daily and for 2 days after goal rate achieved. Replete as per protocol.
  
  Note: correct low serum K, PO₄, Mg prior to EN initiation.

- Initiate and titrate EN as follows (see table below):
  
  Day 1-2: Goal kcal - 20 kcal/kg
  Day 2-3: Goal kcal - 25 kcal/kg
  Day 3-5: Goal kcal - final goal rate

- Provide thiamine (100 mg) daily x 5 - 7 days.
  
  Note: Slower feed rate progression required in
  1) Severe malnourishment
  2) Absence of metabolic stress
  3) Inability to access electrolyte daily
  4) Expected delayed electrolyte replacement

Conclusion

- Early nutrition support
  - EEN

- Appropriate macro and micronutrient
  - Achieving target
  - Pharmaceutical
  - Formula/ type of lipid/ Gln

- Glycemic control
CAN WE FEED?
CAN WE FEED?

- **C**: Critical illness severity
- **A**: Age
- **N**: Nutritional risk screen
- **W**: Wait for full resuscitation
- **E**: Energy requirement
- **F**: Formula selection
- **E**: Enteral access
- **E**: Efficacy of support
- **D**: Determinant of tolerance