Nutrition and the ICU
Objectives

- Recognize the importance of early nutritional support in the ICU
- Assessment and monitoring of nutritional status
- Determine how to estimate specific nutritional requirements
- Enteral vs. Parenteral
- Specific nutrition for specific patients
Start with all the Equations

- See equation sheet
- Won’t bore you
- Your are welcome
<table>
<thead>
<tr>
<th>Classification</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class III Obesity</td>
<td>➤40</td>
</tr>
<tr>
<td>Class II Obesity</td>
<td>35 to 39.9</td>
</tr>
<tr>
<td>Class I Obesity</td>
<td>30 to 34.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25 to 29.9</td>
</tr>
<tr>
<td>Normal</td>
<td>18.5 to 24.9</td>
</tr>
<tr>
<td>Class I Malnutrition</td>
<td>17 to 18.4</td>
</tr>
<tr>
<td>Class II Malnutrition</td>
<td>16 to 16.9</td>
</tr>
<tr>
<td>Class III Malnutrition</td>
<td>&lt; 16</td>
</tr>
</tbody>
</table>
Monitoring Nutritional Status

- Physical exam
  - Height
  - Weight
  - Mid upper arm circumference (low = overall weight loss)
  - Triceps skin fold thickness (low = significant depletion of fat stores) **unreliable in critically ill
  - Mid arm muscle circumference (= protein depletion)
# Negative Acute Phase Reactants

<table>
<thead>
<tr>
<th>Protein</th>
<th>Half-Life</th>
<th>Binds With</th>
<th>2-Day Trauma Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin</td>
<td>20 Days</td>
<td>Anions, Drugs, Free Fatty Acids</td>
<td>Negative Acute Phase</td>
</tr>
<tr>
<td>Transferrin</td>
<td>8 Days</td>
<td>Iron</td>
<td>Negative Acute Phase</td>
</tr>
<tr>
<td>Ceruloplasmin</td>
<td>5-7 Days</td>
<td>Copper</td>
<td>Weak Acute Phase Reactant</td>
</tr>
<tr>
<td>Prealbumin</td>
<td>2 Days</td>
<td>Thyroxine, Retinol-Binders</td>
<td>Negative Acute Phase</td>
</tr>
<tr>
<td>Retinol-Binding Protein</td>
<td>12 Hours</td>
<td>Vitamin A</td>
<td>Negative Acute Phase</td>
</tr>
</tbody>
</table>
Indicators of Nutritional status

- Albumin – not reliable because will fall rapidly as a response to the severity and duration of stress and administration of IV albumin may falsely elevate.
- Transferrin – increase in pregnancy and iron deficiency anemia
- Prealbumin – inaccurate in hyperthyroidism, renal failure
# Positive Acute Phase Reactants

<table>
<thead>
<tr>
<th>Protein</th>
<th>Half-Life</th>
<th>Binds With</th>
<th>2-Day Trauma Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>α1-Antitrypsin</td>
<td>16 Days</td>
<td>Proteases</td>
<td>Strong Positive Acute Phase</td>
</tr>
<tr>
<td>α1-Acid Glycoprotein</td>
<td>6 Days</td>
<td>Drugs</td>
<td>Strong Positive Acute Phase</td>
</tr>
<tr>
<td>α2-Macroglobulin</td>
<td>2-4 Days</td>
<td>Endopeptidases and Proteases</td>
<td>Neutral- No Change in Concentration</td>
</tr>
<tr>
<td>C-Reactive Protein</td>
<td>5 Hours</td>
<td>Damaged Cells, Bacteria, Platelets, Lymphocytes</td>
<td>Very Strong, Rapid Increase (Usually 20-to 1,000-fold)</td>
</tr>
</tbody>
</table>
Stress-Induced Changes in Resting Metabolic Expenditure

- Major Burns
- Sepsis Peritonitis
- Skeletal Trauma
- Elective Operation
- Starvation

Resting Metabolism (In %)

Days

Normal Range
Starvation vs. Injury

Nitrogen Dynamics

- Major Burns
- Skeletal Trauma
- Severe Sepsis
- Infection
- Elective Operation
- Partial Starvation
- Total

Nitrogen Excretion g/day

Days

Normal Range
Nitrogen Balance

- Measure of protein intake and output
  - Calculate the difference between the nitrogen intake and the nitrogen lost in the stool, urine, skin, wounds, and fistulae
  - 24-hour sample
  - Output measured by UUN + 4g (for skin and stool)
  - Goal is zero difference
  - Surgical patients often have a negative balance

Critically ill patients typically require 1.0 to 1.5g of protein per kg of IBW to stay in positive nitrogen balance.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Kcal/kg per day</th>
<th>Adjustment over BEE</th>
<th>Grams of protein/kg per day</th>
<th>Nonprotein calories: Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal/ moderate malnutrition</td>
<td>25 – 30</td>
<td>1.1</td>
<td>1.0</td>
<td>150:1</td>
</tr>
<tr>
<td>Mild stress</td>
<td>25 – 30</td>
<td>1.2</td>
<td>1.2</td>
<td>150:1</td>
</tr>
<tr>
<td>Moderate stress</td>
<td>30</td>
<td>1.4</td>
<td>1.5</td>
<td>120:1</td>
</tr>
<tr>
<td>Severe stress</td>
<td>30 – 35</td>
<td>1.6</td>
<td>2.0</td>
<td>90-120:1</td>
</tr>
<tr>
<td>Burns</td>
<td>35 – 40</td>
<td>2.0</td>
<td>2.5</td>
<td>90-100:1</td>
</tr>
</tbody>
</table>
Indirect Calorimetry

- An open circuit metabolic monitor
- Attach to vent
- Samples inspired and expired O2 and CO2
- Provides a continuous measurement of energy expenditure
- Inaccurate if FiO2 > 60%
The respiratory quotient (RQ) is calculated from the ratio:

\[ RQ = \frac{\text{CO}_2 \text{ produced}}{\text{O}_2 \text{ consumed}} \]
<table>
<thead>
<tr>
<th>Name of the substance</th>
<th>Respiratory Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>1</td>
</tr>
<tr>
<td>Triolein (Fat)</td>
<td>0.7</td>
</tr>
<tr>
<td>Oleic Acid (Fat)</td>
<td>0.71</td>
</tr>
<tr>
<td>Tripalmitin (Fat)</td>
<td>0.7</td>
</tr>
<tr>
<td>Proteins</td>
<td>0.8 - 0.9</td>
</tr>
<tr>
<td>Malic acid</td>
<td>1.33</td>
</tr>
<tr>
<td>Tartaric acid</td>
<td>1.6</td>
</tr>
<tr>
<td>Oxalic Acid</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Respiratory Quotient

- Patients who are underfed and are using dextrose as the sole nutritional substrate have RQ < 0.82
- Overfeeding has RQ > 1.0
- RQ = 1.0, pure CHO metabolism
- RQ = 0.7, fat metabolism
- RQ < 0.7, ketogenesis
## Malnutrition

<table>
<thead>
<tr>
<th>Degree of Malnutrition</th>
<th>Albumin (g/dL)</th>
<th>Transferrin (mg/dL)</th>
<th>Prealbumin (mg/dL)</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>2.7 to 3.5</td>
<td>151 to 200</td>
<td>10 to 15</td>
<td>14%</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.0 to 2.6</td>
<td>100 to 150</td>
<td>5 to 9</td>
<td>27%</td>
</tr>
<tr>
<td>Severe</td>
<td>&lt; 2.0</td>
<td>&lt; 100</td>
<td>&lt; 5</td>
<td>64%</td>
</tr>
</tbody>
</table>
Malnutrition sequelae

- **>10% weight loss:**
  - Increased LOS
  - Increased incidence of nosocomial infections
  - Increased mortality

- **7–10 days of malnutrition:**
  - Impaired complement and Ig production
  - Dysfunctional leukocyte chemotaxis, phagocytosis, oxidative burst
  - Poor tissue repair
  - Loss of muscle function: ventilator dependence

- **Up to 50% of inpatients are malnourished**
Metabolic Principles: Fat

- Fat 9 kcals/gram
  - Increased gluconeogenesis and mobilization of triglycerides in the stressed state
  - Fat stored are rapidly depleted during times of stress
- Optimally, 25% of nonprotein calories
- Major source of fuel during starvation
- During minor stress, CHO and fat utilization are indistinguishable in terms of Nitrogen balance
- At some point during sepsis, fat utilization is impaired
Protein 4 kcals/g
  - Excessive urinary losses are encountered
  - Muscle is the primary source for this nitrogen
  - Protein is converted into glutamine and alanine
    - Glutamine is utilized by the enterocytes
    - Alanine is used to aid in synthesis of glucose and transfer of nitrogen form muscles to the viscera
Metabolic Principles: Carbohydrates

- Carbohydrates 4 kcals/g
  - Fasting blood glucose levels are elevated during times of stress
  - May have profound insulin resistance in the injured patient

- “Protein-sparing effect” by Gamble (1940)
  - As little as 100g glucose per 24h will decrease urinary urea production
  - Suppresses hepatic gluconeogenesis (avoids protein breakdown)
  - Exogenous glucose obviates need for amino acids as energy fuel
  - D5½NS @ 84 mL/hr = 100g dextrose per day
Metabolic Principles

- Basal energy expenditure
  - Harris–Benedict equation.
  - Men: $\text{REE} = 13.75 \times \text{Wt} + 5.00 \times \text{Ht} - 6.76 \times \text{Age} + 66.47$
  - Women: $\text{REE} = 9.56 \times \text{Wt} + 1.84 \times \text{Ht} - 4.68 \times \text{Age} + 655.10$

- Resting Energy Expenditure: basal energy rate plus any extra requirements due to stressors
  - $\text{MR} = 4.83 \times \text{O2 Consumption (VO2)}$

- **a trauma, septic, or burn patient may have a REE of 110–200%**
Nutritional Options

- Controlled Starvation
- Enteral nutrition
- TPN
- Oral Supplementation
Lewis et al. *BMJ* 2001 Meta-analysis

- Early use of oral or enteral intake associated with a statistically significant decrease in infection rates (RR 0.72)
- Early feeding (within 24–48 hours) did not increase breakdown of gastrointestinal anastomoses. Trended toward a decrease in breakdown.
- A trend toward decreased mortality in those fed early. P=0.08
- Underfeeding better than overfeeding
Oral Supplementation

- Concentrated high amounts of calories with protein and micronutrients and vitamins.
- No strong evidence that it benefits outcome.
- **contain Vitamin K…can make controlling Coumadin a challenge.**
In ICU

- Stress response accelerates the rate of glucose production from amino acids for as long as the inflammatory response is present.
- Metabolic rate increases by about 10% for every 1-degree Celsius increase in temperature.
<table>
<thead>
<tr>
<th></th>
<th>Jevity</th>
<th>Osmolite</th>
<th>Glucerna</th>
<th>Promote</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kcal/ml</td>
<td>1.2</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>CHO g/L</td>
<td>169</td>
<td>203</td>
<td>133</td>
<td>138</td>
<td>150</td>
</tr>
<tr>
<td>Protein g/L</td>
<td>55</td>
<td>62</td>
<td>83</td>
<td>62</td>
<td>78</td>
</tr>
<tr>
<td>Fat g/L</td>
<td>39</td>
<td>49</td>
<td>75</td>
<td>28</td>
<td>43</td>
</tr>
<tr>
<td>Osm</td>
<td>450</td>
<td>525</td>
<td>875</td>
<td>380</td>
<td>630</td>
</tr>
<tr>
<td>Special</td>
<td>Contains fiber</td>
<td>concentrated</td>
<td>Low carb</td>
<td>High protein, fiber</td>
<td>Immune enhancing, semi-elemental</td>
</tr>
</tbody>
</table>
## Picking tube feeds

<table>
<thead>
<tr>
<th></th>
<th>Nepro</th>
<th>Peptinex</th>
<th>Crucial</th>
<th>Vivonex</th>
<th>Prosource</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kcal/ml</strong></td>
<td>1.8</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td><strong>CHO g/L</strong></td>
<td>166</td>
<td>206</td>
<td>135</td>
<td>175</td>
<td>0</td>
</tr>
<tr>
<td><strong>Protein g/L</strong></td>
<td>81</td>
<td>76</td>
<td>94</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td><strong>Fat g/L</strong></td>
<td>96</td>
<td>42</td>
<td>67</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Osm</strong></td>
<td>600</td>
<td>550</td>
<td>490</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td><strong>Special</strong></td>
<td>Reduced electrolytes</td>
<td>Calorically dense, semi elemental</td>
<td>High protein, semi elemental</td>
<td>100% AA free</td>
<td></td>
</tr>
</tbody>
</table>
TPN

- Developed in 1968 by a surgical resident, Dr. Stanley Dudrick.
- Advantages...don’t have to stop for surgical procedures, definite delivery of caloric needs.
- All studies show the TPN is INFERIOR to enteric nutrition.
- Associated with increased morbidity such as higher infections, longer ICU stays, and prolonged ventilation.
Prospective randomized trial

Patients undergoing elective GI or urologic surgery

Given TPN or D10W + lytes POD#1 till taking PO of for 2 weeks time

24/150 TPN and 28/150 D10W unable to eat for 2 weeks.

In TPN group had increased morbidity and mortality
TPN Complications

- TPN administration is independently associated with late ARDS Plurad et al. *Injury* 12/08
Combining Enteral and Parenteral

- Concern that EN alone doesn’t provide caloric needs
- Suggest that if goal caloric intake cannot be obtained by Day 3 → add TPN
- Concluded that can meet 100% of nutritional goals but couldn’t prove any survival benefit
Dhaliwal et al. *Intensive Care Med* 2004

- Literature review
- 11 studies
- No difference in mortality, slight increase in infections in TPN+EN, less calories given to EN alone

Concluded: in critically ill patients who are not malnourished and have an intact GI tract, starting TPN with EN provides no benefit, some detriment and was at a much higher cost.
Special Situations

• Open Abdomen – Collier et al. *J Parenter Enteral Nutr* 2007
  ○ Enteral feeding within 3 days of laparotomy undergo earlier definitive abd closure and less fistulae

• Hemodynamically unstable – Rokyta et al. *Intensive Care Med* 2004
  ○ Splanchnic blood flow increases in response to intestinal delivery of nutrients during some degree of hemodynamic compromise

• Pancreatitis – Petrov et al. *Dig Surg* 2006
  ○ Prospective randomized enteric vs. TPN nutrition in severe pancreatitis showed decreased infection rates and lower mortality in those fed enterally.
Special Situations Cont.

- **Respiratory Failure**
  - PaCO2 directly relates to VCO2 (CO2 production). If your are over feeding and creating an increase in VCO2 the PaCO2 increases as well and may worsen Resp. failure.

- **Obesity**
  - In mild to moderately stressed severely obese (BMI > 40), can provide a hypocaloric feeding as long as achieve + nitrogen balance.

- **Liver Failure**
  - If encephalopathic should decrease protein and AA, need to give zinc and vitamins A,D,E and K.

- **Renal Failure**
  - Restrict Nitrogen, watch electrolytes and use concentrated formulas.
Refeeding Syndrome

- Rare in the surgical population
- Dangerously low level of phosphorus
- Reintroduction of glucose can lead to irreversible cardiac damage
- Must measure and replace the phos, potassium, and magnesium in these patients to avoid refeeding syndrome