Indirect Calorimetry: Clinical Implications in Critically Ill Patients

Sharla Tajchman, PharmD, BCPS, BCNSP
Critical Care / Nutrition Support Clinical Pharmacy Specialist
University of Texas MD Anderson Cancer Center
Objectives

- Discuss changes in energy expenditure in critically ill patients
- Discuss the potential impact of nutrition on patient outcomes in the intensive care unit
- Identify barriers to accurate determination of energy requirements
- Implement indirect calorimetry measurements into clinical practice in the ICU
How much do I feed this patient?
Alterations in Energy Expenditure
Metabolic Response to Stress

- ↑ metabolic rate (35 – 40 kcal / kg / day)
- ↑ use of protein for fuel
- ↑ glucose production in excess of need
- Inefficient use of fat for energy

Hypothalamus → Adrenal glands → Pancreas → Plasma

Plasma changes:
- ↑ ACTH
- ↑ Cortisol
- ↑ Adrenaline
- ↑ Glucagon

Metabolic changes:
- ↑ Adipocyte lipolysis
- ↑ Hepatic gluconeogenesis
- ↑ Muscle protein degradation
- ↑ Hepatic acute phase protein synthesis

Hypermetabolism

Pathophysiology

Sarcopenia Malnutrition

Catabolism Starvation

Changes in resting energy expenditure (REE)
Inadequate delivery of protein and calories

Increased morbidity
Increased mortality
Increased length of stay

Immobilization

Metabolic Response to Stress

![Graph showing metabolic response to different stressors like major burn, major trauma or surgery with critical illness, major surgery uncomplicated, starvation, and normal range.](image-url)
Factors that alter REE

- Age
- Gender
- Body composition
- Disease processes
- Genetics
- Hormonal status

- Burn
- Diet
- Fever / infection
- Nutrition status
- Medications
- Organ failure
- SIRS / Sepsis
- Severity of disease
- Surgery
- Trauma
- Wounds

Predictive Equations

- Ideal body weight: Mifflin – St. Jeor (Harris-Benedict)
- Penn State 2003: Swinamer
- Spontaneously breathing: Fusco
- Adjusted body weight: Liu
- Obesity
- 25 kcal / kg / day: Cunningham
- Penn State 1998
- Ireton – Jones 1997
- Actual body weight: Schofield
- Fick Method
- Mechanical ventilation
- Ireton – Jones 1992
# Predictive Equations in the ICU

<table>
<thead>
<tr>
<th>Equation</th>
<th>Findings</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fick Method</td>
<td>Overestimate</td>
<td>Not recommended</td>
</tr>
<tr>
<td></td>
<td>Imprecise</td>
<td></td>
</tr>
<tr>
<td>Harris-Benedict (HB) without added factors</td>
<td>Underestimate</td>
<td>Not recommended</td>
</tr>
<tr>
<td>HB with factors</td>
<td>Under AND overestimate</td>
<td>Not recommended</td>
</tr>
<tr>
<td></td>
<td>Imprecise</td>
<td></td>
</tr>
<tr>
<td>Swinamer</td>
<td>Inaccurate</td>
<td>Limited data - inconclusive</td>
</tr>
<tr>
<td>Ireton-Jones (1992)</td>
<td>Inaccurate</td>
<td>Limited data - inconclusive</td>
</tr>
<tr>
<td>Ireton-Jones (1997)</td>
<td>Inaccurate</td>
<td>Not recommended</td>
</tr>
<tr>
<td>Penn State (2003)</td>
<td>Accurate in BMI &lt; 30</td>
<td>Recommended in BMI &lt; 30</td>
</tr>
<tr>
<td></td>
<td>Inconclusive</td>
<td></td>
</tr>
</tbody>
</table>

Harris-Benedict Equation


- n = 26
  Mixed ICU
  Actual body weight used to calculate HB

- Measured REE (kcal / day)
  MREE / EREE (%)

- Patients (%)
  < 90 90 - 110 > 110

- R = 0.52
  p < 0.01
Harris-Benedict Equation

1919
Average
BMI ~21

2010
Average
BMI ~28

BMR = 66.47 + 6.23 * Wt (lb) + 12.67 * Ht (in) − 6.76 * age (yrs), Men
BMR = 655.1 + 4.34 * Wt (lb) + 4.69 * Ht (in) − 4.68 * age (yrs), Women
Clinical Impact of Nutrition in Critically Ill Patients

"Oh, he's worse than critical. He's downright insulting."
Nutrition in the ICU

- Incidence of malnutrition - 43% to 88%

- Average energy intake - 49% to 70% of requirements
  - Underfeeding
    - 79% and 61% of calorie and protein requirements, respectively
  - Overfeeding
    - Not frequently reported

- Barriers to nutrition delivery

Impact of Caloric Deficit

Mean energy deficit of 1,200 kcal / day of mechanical ventilation predicted death after day 14 in ICU

Correlation with:
- Total number of complications
- ICU length of stay (LOS)
- Length of mechanical ventilation

NO correlation with mortality

Impact of Caloric Deficit

**Total complications**

**Max. negative energy balance (kcal)**

- **NO** correlation with:
  - Length of mechanical ventilation
  - ICU LOS
  - Hospital LOS
  - Mortality

**Patients (no.)**

- **Complications**
  - Pressure ulcer
  - Surgery
  - ARF
  - ARDS
  - Sepsis

Clinical Measurement of Energy Expenditure
Indirect Calorimetry

O₂ + Substrate → CO₂ + H₂O + Energy

- Accuracy depends on:
  - Instrument
  - Testing conditions
  - Patient characteristics
  - User knowledge

Who should get IC?

- Clinical condition that significantly alters REE
- Failure to respond to nutrition support
  - Wound dehiscence, loss of lean body mass
- Individualization of nutrition support in critically ill patients
  - Long-term patients with multiple insults

Excluded Patients

- FiO2 requirements > 60%
- PEEP > 12 cm H2O
- VDR or oscillator for mechanical ventilation
- Leak in ventilator system
- Endotracheal or tracheal cuff leak
- Chest tube with air leak
- Bronchopleural fistula
- Hemodialysis

Duration of IC Study

- 5-minute REE (kcal/day)
- 30-minute REE (kcal/day)

Controlled MV
Assisted MV
Spontaneous

Measured REE

- Differs from total energy expenditure
- No adjustments needed
  - Sedation, analgesia, nutrition, fever
- Target daily caloric intake to maintain weight
  - Exceptions
    - Obesity

Respiratory Quotient

\[ RQ = \frac{VCO_2}{VO_2} \]

- **Physiological range**
  - Hypoventilation
  - Hyperventilation
  - Underfeeding
  - Overfeeding
  - Alkalosis
  - Acidosis
  - Ketosis
  - Mixed-fuel

Respiratory Quotient

- Under ideal IC study conditions:
  - Assess substrate utilization for fuel

- Do not alter nutrition support based on RQ value alone
  - Summation of substrate utilization

- Values should be within physiological range
  - Reinforces validity of study results
Clinical Application of Measured Energy Expenditure

"WHAT'S FOR DESSERT?"
Interpretation of Steady State

REE 2134 kcal / day
RQ 0.72

43 year old male
Lymphoma
Wt 96 kg
BMI 28 kg/m²
Interpretation of Steady State

- **REE** (kcal / day)
  - 2293 kcal / day
- **RQ value**
  - 0.69

- **56 year old male**
- **AML**
- **Wt 92 kg**
- **BMI 30 kg/m²**

REE 2293 kcal / day
RQ 0.69
Interpretation of Steady State

78 year old female
Esophageal adenocarcinoma
Wt 37 kg
BMI 18 kg/m²

REE 874 kcal / day
RQ 0.93

Study interruption
Study restart
Minor agitation
Benefit of Urine Urea Nitrogen

Indirect calorimetry only provides 24-hour caloric requirements. A UUN can help determine protein requirements.

Clinical Application

- Hypocaloric, high protein feeding in obesity
  - Adipose tissue is metabolically inactive
  - Provide 50% MEE as non-protein calories
  - Provide 2 – 2.5 g protein / kg ideal body weight / day

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Non-protein calories</th>
<th>Protein</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dickerson, et al.</td>
<td>13</td>
<td>50% of MEE</td>
<td>2.13 g/kg/day</td>
<td>No lipids administered</td>
</tr>
<tr>
<td>Burge, et al.</td>
<td>23</td>
<td>Control (n = 7) 100% MEE</td>
<td>2.18 g/kg/day</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hypocaloric (n = 16) 50% MEE</td>
<td>2 g/kg/day</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient</th>
<th>Wt</th>
<th>Complications</th>
<th>MEE / RQ</th>
<th>UUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 year old male Appendiceal adenocarcinoma Surgery – CRS with IPHC</td>
<td>132 kg 207% IBW</td>
<td>POD #10 ICU admission, intubation, septic shock, emergent return to OR</td>
<td>POD #3 2468 kcal / day</td>
<td>POD #9 - 5 g N / day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>POD #17 OR for abdominal closure</td>
<td>POD #15 3229 kcal / day</td>
<td>POD #14 - 8 g N / day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multiple pelvic abscesses</td>
<td>POD #24 2781 kcal / day</td>
<td>POD #27 + 2 g N / day</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POD #35 2201 kcal / day</td>
<td>POD #41 + 1 g N / day</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>POD #53 2370 kcal / day</td>
<td></td>
</tr>
</tbody>
</table>
Cost Considerations

Cost of one IC study = One day of TPN = $300

Cost of one hospital-acquired pressure ulcer = $43,000¹

Cost of one day of mechanical ventilation = $4,000 to $6,000²

¹ Centers for Medicare & Medicaid Services. Medicare Program; Changes to the Hospital Inpatient Prospective Payment Systems and Fiscal Year 2008 Rates; Final Rule. Federal Register. 2007;72(162):47130-4817571.
Summary

- Metabolic alterations due to stress response in critically ill patients are unpredictable.
- Inappropriate nutrition can have detrimental outcomes in the ICU.
- IC can provide an accurate measure of caloric requirements in metabolically complex patients.
- Appropriate interpretation of IC results is necessary for implementation of nutrition.
Questions?

I think it's stress!!
Indirect Calorimetry: Clinical Implications in Critically Ill Patients

Sharla Tajchman, PharmD, BCPS, BCNSP
Critical Care / Nutrition Support Clinical Pharmacy Specialist
University of Texas MD Anderson Cancer Center