Nutrition Care of the Critically Ill Child

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Disclosures

• None
Objectives

• To discuss the role of nutrition support as it relates to outcomes during critical illness

• To review the metabolic aspects of critical illness that drive energy and protein requirements

• To review current evidence-based practices specific to nutrition delivery in the Pediatric Intensive Care Unit (PICU)
Nutrition Care in Critically Ill Children

• **Why?**
  • *Nutrition and patient related outcomes*

• **How much?**
  • Energy and protein prescriptions

• **Which route?**
  • Enteral vs. Parenteral

• **When?**
  • Early vs. Late
Nutrient **Delivery** Goals during Critical Illness

- Offset the burden of metabolic stress response
- Improve patient-related outcomes
- Optimal dose – Via the safest route – At the right time –
- Preserve lean body mass
- Avoid complications of EN and PN
Nutrition Goals and **Outcomes** in PICU

- **Loss of Lean Body Mass**
  - Muscle strength/function
  - Prolonged Ventilation

- **Micronutrient Imbalance**
  - Wound healing
  - Acquired infections
  - Impaired Development

- **CO2 Burden from Overfeeding**
  - Prolonged LOS

- **Immune Suppression**
- **Caloric Deficit**
Nutrition Status and Outcomes

**TABLE 2. Clinical Outcomes Risk in Critically Ill Children in PICUs**

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortalitya</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>1.53</td>
<td>1.24–1.89</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.44</td>
<td>0.94–2.19</td>
<td>0.09</td>
</tr>
<tr>
<td>Obese</td>
<td>1.55</td>
<td>0.87–2.76</td>
<td>0.14</td>
</tr>
<tr>
<td>Infections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>1.88</td>
<td>1.18–3.01</td>
<td>0.008</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.42</td>
<td>0.99–2.05</td>
<td>0.06</td>
</tr>
<tr>
<td>Obese</td>
<td>1.64</td>
<td>1.33–2.03</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

OR = odds ratio.
Generalized estimating equations model controlling for location, age, sex, study year, admission category, diagnosis category, PICU size, infections³, length of stay⁴, and illness severity. \(n=1,430\).
Referent category: normal weight.


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**Figure 2.** Cumulative percentage of subjects remaining hospitalized over the 60-d study period, according to nutritional status category, \(n=1,510\).
Body Composition in Children

MUAC and patient outcomes – duration of mechanical ventilation

n = 72
Median age: 21 months

Malnutrition:
41% Stunted
18% Wasted

Grippa RB et al. Nutrition 2017
BCH initiative – weights and heights

WOW = Weight on Wednesday

WHOA = Weight & Height on Admission = BMI
Nutrition Care in Critically Ill Children

• Why?
  • Nutrition and patient related outcomes

• How much?
  • Energy and protein prescriptions

• Which route?
  • Enteral vs. Parenteral

• When?
  • Early vs. Late
Metabolic Stress Response

Resting Energy Expenditure (REE) s/p Injury

Energy Requirement based on recent studies

Unintended Overfeeding

HYPOmetabolism

REE lower than normal

Long CL. Am J Clin Nutr 1977
Energy Intake in the PICU

- At risk of
  - Underfeeding
  - Overfeeding

- Longer LOS in the PICU at greatest risk

- Cumulative energy imbalances $\rightarrow$ unintended consequences

"Goldilocks dilemma"

## Consequences of Inaccurate Energy Expenditure Estimates

<table>
<thead>
<tr>
<th>Underfeeding</th>
<th>Overfeeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Delayed wound healing</td>
<td>- Hypertriglyceridemia</td>
</tr>
<tr>
<td>- Impaired O2 use</td>
<td>- Hyperglycemia</td>
</tr>
<tr>
<td>- Increased infection risk</td>
<td>- Hepatic steatosis</td>
</tr>
<tr>
<td>- Higher mortality rate</td>
<td>- Cholestasis</td>
</tr>
<tr>
<td>- Delayed mental &amp; psychomotor development</td>
<td>- Respiratory failure</td>
</tr>
<tr>
<td></td>
<td>- Uremia</td>
</tr>
</tbody>
</table>

Energy – *How much?*

### Resting Energy Expenditure:

**WHO and Schofield**

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>WHO</th>
<th>Schofield</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 years</td>
<td>Male</td>
<td>60.9 x Wt - 64</td>
<td>0.17 x Wt + 15.17 x Ht - 617.6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>61 x Wt - 51</td>
<td>16.25 x Wt + 10.232 x Ht - 413.5</td>
</tr>
<tr>
<td>3-10 years</td>
<td>Male</td>
<td>22.7 x Wt + 495</td>
<td>19.6 x Wt + 1.303 x Ht + 414.9</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>22.5 x Wt + 499</td>
<td>16.97 x Wt + 1.618 x Ht + 371.2</td>
</tr>
<tr>
<td>10-18 years</td>
<td>Male</td>
<td>17.5 x Wt + 681</td>
<td>16.25 x Wt + 1.372 x Ht + 515.5</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12.2 x Wt + 746</td>
<td>8.365 x Wt + 4.65 x Ht + 200</td>
</tr>
</tbody>
</table>

### Stress Factors

**Use as a guide – indirect calorimetry is gold standard when available**

**Multiply REE by Stress Factor according to illness**

<table>
<thead>
<tr>
<th>Illness</th>
<th>Factor (REE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Surgery</td>
<td>1.05-1.5</td>
</tr>
<tr>
<td>Fever</td>
<td>12 % per degree &gt;37°C</td>
</tr>
<tr>
<td>Sepsis</td>
<td>1.2-1.6</td>
</tr>
<tr>
<td>Starvation</td>
<td>0.7-0.85</td>
</tr>
<tr>
<td>Growth Failure</td>
<td>1.5-2</td>
</tr>
<tr>
<td>Burns</td>
<td>1.5-2.5</td>
</tr>
<tr>
<td>Cardiac Failure</td>
<td>1.15-1.25</td>
</tr>
<tr>
<td>Trauma</td>
<td>1.1-1.8</td>
</tr>
<tr>
<td>Weight Maintenance*</td>
<td>1.3</td>
</tr>
<tr>
<td>Closed Head Injury</td>
<td>1.3</td>
</tr>
<tr>
<td>Growth*</td>
<td>1.5</td>
</tr>
</tbody>
</table>

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*Harvard Medical School*
Predictive Equations Are Often *Inaccurate*

<table>
<thead>
<tr>
<th>Methods</th>
<th>Percent of patients within 10% mREE</th>
<th>Range: pREE/mREE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mREE</td>
<td>37</td>
<td>55%–200%</td>
</tr>
<tr>
<td>Mayo</td>
<td>40</td>
<td>65%–200%</td>
</tr>
<tr>
<td>Talbot</td>
<td>36</td>
<td>38%–213%</td>
</tr>
<tr>
<td>Schofield</td>
<td>27</td>
<td>69%–774%</td>
</tr>
<tr>
<td>Harris-Benedict (a)</td>
<td>36</td>
<td>49%–220%</td>
</tr>
<tr>
<td>Harris-Benedict (i)</td>
<td>31</td>
<td>60%–404%</td>
</tr>
<tr>
<td>WHO</td>
<td>4$§$</td>
<td>74%–428%</td>
</tr>
</tbody>
</table>

Hardy CM et al NCP 2002
Inaccurate Estimates = Energy Imbalance

Median age: 2 years
Median PICU LOS: 44 days
n=29

HYPERmetabolic: 17%
HYPOmetabolic: 55%

Energy – How much?

• Indirect Calorimetry = gold standard
  • VO2 = oxygen consumption
  • VCO2 = CO2 production
  • Weir Equation: REE (kcal/d) = [VO2(3.94)+VCO2(1.11)] x 1440 min

• Used to determine energy requirements and guide prescription of the daily energy goal
Suggested Criteria for Indirect Calorimetry

Underweight (body mass index [BMI] <5th percentile for age), at risk of overweight (BMI >85th percentile for age), or overweight (BMI >95th percentile for age)
Greater than 10% weight gain or loss during medical-surgical intensive care unit stay
Failure to consistently meet prescribed caloric goals
Failure to wean or escalation in respiratory support
Need for muscle relaxants for >7 days
Neurologic trauma (traumatic, hypoxic, and/or ischemic) with evidence of dysautonomia
Oncologic diagnoses (including stem cell or bone marrow transplantation)
Need for mechanical ventilatory support >7 days
Suspicion of severe hypermetabolism (status epilepticus, hyperthermia, systemic inflammatory response syndrome, dysautonomic storms) or hypometabolism (hypothermia, hypothyroidism, pentobarbital or midazolam coma)
Intensive care unit length of stay >4 weeks
Energy – what is recommended?

• IC remains the gold standard

• If IC not feasible, Schofield or WHO equations should be used without addition of stress factors

• Target?
  • Delivery of >60% of the prescribed energy goal by the end of the first week of PICU admission
Protein – *How much?*

- **2005 RDA**

<table>
<thead>
<tr>
<th>Category</th>
<th>Age</th>
<th>Protein g/kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants</td>
<td>0-6 mo</td>
<td>1.52 AI*</td>
</tr>
<tr>
<td></td>
<td>7-12 mo</td>
<td>1.2</td>
</tr>
<tr>
<td>Children</td>
<td>1-3 y</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>4-13 y</td>
<td>0.95</td>
</tr>
<tr>
<td>Adolescent</td>
<td>14-18 y</td>
<td>0.85</td>
</tr>
<tr>
<td>Adult</td>
<td>&gt;18 y</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Not recommended during critical illness

- **Protein requirements for critical illness**
  - Updated evidence suggests a minimum: 1.5 gm protein/kg/d
  - Infants and patients with severe catabolic conditions likely require more

Protein – positive nitrogen balance

1.5 gm/kg/d

>54 kcal/kg/d

(J Pediatr 2012;161:333-9)
Protein – outcomes

n=1245 PICU pts (1-18 yrs)

Mechanically ventilated

Association between higher enteral protein adequacy and a lower 60-day mortality

Median values of protein intake adequacy in survivors vs. non-survivors

Mehta NM et al. AJCN 2015
Prevention of Muscle Mass Depletion

The optimal protein dose associated with improved patient outcomes is still not known.
Nutrition Care in Critically Ill Children

• Why?
  • Nutrition and patient related outcomes

• How much?
  • Energy and protein prescriptions

• Which route?
  • Enteral vs. Parenteral

• When?
  • Early vs. Late
Nutrition Support; EN vs. PN

EXPERT STATEMENT

Nutritional support for children during critical illness: European Society of Pediatric and Neonatal Intensive Care (ESPNIC) metabolism, endocrine and nutrition section position statement and clinical recommendations


GUIDELINES

Surviving sepsis campaign international guidelines for the management of septic shock and sepsis-associated organ dysfunction in children

Enteral Nutrition (EN) – current recommendations

• **EN** = preferred mode of nutrition support

• **Early EN** recommended → associated with improved patient outcomes
  • 24-48 hours of PICU admission
  • Maintain GI mucosal integrity & motility

• **Gastric route** preferred
  • Post-pyloric route should be considered if gastric route poorly tolerated and/or at increased risk of aspiration

• Support use of **Enteral Algorithm** to advance feeds

### Early EN – clinical outcomes - Mortality

<table>
<thead>
<tr>
<th>Percentage Nutrition Delivered</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mehta et al., CCM 2012</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 33.3%</td>
<td>----</td>
</tr>
<tr>
<td>33.3-66.7%</td>
<td>0.27</td>
</tr>
<tr>
<td>&gt;66.7%</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Mikhailov et al., JPEN 2014</strong></td>
<td></td>
</tr>
<tr>
<td>No nutrition</td>
<td>----</td>
</tr>
<tr>
<td>&lt;25%</td>
<td>0.79</td>
</tr>
<tr>
<td>25-100%</td>
<td>0.33</td>
</tr>
<tr>
<td>&gt;100%</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Early EN – clinical outcomes - Mortality

Nutrition timing and outcomes in critical illness

n = 1844 mechanically ventilated patients (77 PICUs)
Median age: 1.64 years

Bechard, LJ, et al. AJCN 2021
Common **Barriers** to Optimal EN *Delivery* in the PICU

- Hemodynamic instability
- Mode of ventilation
- Fluid availability
- Feeding tube management
- Feeding intolerance
Factors That May Influence Intolerance

• Sedatives and anesthesia agents
  • Motility

• Mechanical ventilation (invasive and non-invasive)

• Surgery
  • Post-operative ileus

• Delayed initiation
Avoidable vs. Unavoidable Interruptions

EN Interruptions = 1483 Hours (total)

Mehta, N. et al. JPEN 2010
EN Intolerance

• No unifying definition exists, instead a constellation of s/s have been used to describe problem
  • Increased gastric residual volume (GRV)
  • Increased abdominal girth
  • Diarrhea
  • Vomiting

• Patients with s/s of intolerance are less likely to achieve goal feeds and more likely to need PN
BCH PICU EN Algorithm – EN Intolerance

Assess for intolerance every four hours after EN initiation

EN INTOLERANCE will be suspected if patient meets 2 or more of the following signs/symptoms after EN initiation:

- New onset vomiting – 2 or more episodes/24 hrs
- Subjective abdominal discomfort
- Abdominal distension - 2 consecutive increases in AG in 24 hrs
- New onset diarrhea- 3 or more episodes of loose stool in 24 hrs
- Gastric residual volume >3mL/kg or >250 mL if patient >50kg

GRV only checked with gastric feeds

GRV may be refed up to 3mL/kg or 250mL (>50 kg) unless contraindicated

Absent bowel sounds are not an indicator of feeding intolerance
BCH PICU Nutrition Algorithm

2. SELECT ENTERAL or PARENTERAL NUTRITION

Is the patient able to meet nutrition goals orally?

- YES: Exit algorithm
- NO: Initiate Specialized Nutrition Support (SNS)
  - Is the patient able to be fed enterally? Refer to EN contraindications (Appendix 1)
    - YES: Proceed to STEP 3
    - NO: Initiate Parenteral Nutrition in consultation with Clinical Nutrition Service & RD
      - Is patient malnourished + anticipate NPO ≥ 5 days OR
        NOT malnourished + anticipate NPO ≥ 7 days? OR
        Newborn ≤ 30 days + anticipate NPO ≥ 3 days?
          - YES: Review daily rounds checklist
Boston Children's Hospital
PICU Algorithm

Does the patient meet 2 or more signs/symptoms (s/s) of EN intolerance?

YES

Maintain at current rate for 1 hour

NO

Advance Feeds (q 4hrs)
- 1mL/kg/hr q 4hrs
- 25mL/hr q 4hrs maximum
*120 mL/hr max rate for post-pyloric feeds

Does the patient still meet 2 or more s/s of EN intolerance?

YES

Continue to assess for EN intolerance q4h and advance until patient reaches individualized goal
* If patient on PN and advancing EN discuss with RD weaning of PN

NO

If patient fails to advance from initial EN rate--> consider delivering trophics (0.5 mL/kg/h or 20mL/h) in discussion w/ RD and clinical team

NO

Consider returning to previously tolerated rate OR stop feeds for 4 hr

After 1 hr, reassess for s/s of intolerance

After 4 hr, reassess for s/s of intolerance

Does the patient still meet 2 or more s/s of EN intolerance?

YES

STOP EN & Consult Clinical Team and RD
2. SELECT ENTERAL or PARENTERAL NUTRITION

Is the patient able to meet nutrition goals orally?

- YES: Exit algorithm
- NO: Initiate Specialized Nutrition Support (SNS)

   Is the patient able to be fed enterally?
   Refer to EN contraindications (Appendix 1)

   - YES: Proceed to STEP 3
   - NO: Review daily rounds checklist

   Is patient malnourished + anticipate NPO ≥ 5 days
   OR
   NOT malnourished + anticipate NPO ≥ 7 days?
   OR
   Newborn ≤ 30 days + anticipate NPO ≥ 3 days?

   - YES: Initiate Parenteral Nutrition
     In consultation with Clinical Nutrition Service & RD
   - NO: Proceed to STEP 3
Parenteral Nutrition (PN) – current recommendations

• Consider PN when EN is not feasible or contraindicated

• PN initiation within 24h of PICU admission is not recommended

• Role of supplemental remains unclear
  • Consider after the 1st week of PICU admission if unable to advance on enteral feeds
  • Neonates
  • Malnourished patients

Micronutrients

• Increased risk of nutrient deficiencies
  • Altered nutrient utilization and demand combined with inconsistent/inadequate nutrient delivery

• Lack of supporting evidence for supplementation as a targeted therapy
  • Selenium, Glutamine, Arginine, Vitamin C, Vitamin D

• Ensure delivery of adequate micronutrients to meet DRIs for age

Marino, LV et al, Clinical Nutrition 2020
PICU specific conditions

• Critically ill obese
  • 1.5 g protein/kg/d using ideal body weight
  • Permissive underfeeding NOT recommended

• ECMO patient
  • Both hypermetabolism and hypometabolism
  • Significant protein catabolism
  • EN is safe

• Burn injury
  • Significant degree of muscle protein catabolism >6 months after injury
Areas of future research – pediatric critical care nutrition

• Validated PICU screening
  • NUTRIC score – adults

• Validated body composition assessment measures
  • Muscle ultrasound; muscle thickness as a surrogate for LBM

• RCT showing the impact of IC-guided macronutrient delivery on clinical outcomes

• Protein dosing studies
Nutrition Therapy in Critically Ill Children

**WHY?**
- Optimal nutrient delivery $\rightarrow$ improved clinical outcomes during critical illness

**HOW MUCH?**
- Determining **accurate** energy and protein prescriptions is the 1\textsuperscript{st} step
- **Individual** considerations and reassessment are crucial
- Indirect Calorimetry should be utilized if available

**WHICH ROUTE?**
- EN is preferred with use of a stepwise feeding algorithm
- Nutrition support should be **individualized** and early PN is discouraged
THANK YOU!

Questions?