Specific nutritional care in children

Feeding the critically ill child

N. Mehta (US)
Feeding the critically ill child

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• I have no conflicts of interest
Nutrition therapy

How much? Energy and Protein requirement

Why? Nutrition and outcomes during critical illness

When? Early versus Late

Which route? Enteral or Parenteral
Nutrition therapy

How much?  Energy and Protein requirement

Why?  Nutrition and outcomes during critical illness

When?  Early versus Late

Which route?  Enteral or Parenteral
Disease-specific nutritional considerations

- ARDS/Acute Respiratory failure/Chronic respiratory failure
- Cardiac intensive care – post-cardiac surgery (CP Bypass)
- Post-operative state (major surgery) + ECMO
- Neurocritical care – TBI, seizures
- HSCT
- Burn injury
REE after PEDIATRIC CARDIAC SURGERY

EE after CPB for Fontan repair 24 Hrs Post-surgery


Li J et al. PCCM 2008;9(1)

EE and caloric intake on postoperative days 0, 1, 2, and 3 after Norwood procedure.
Resting Energy Expenditure in the PICU population

**Pediatric Severe TBI**

![Graph showing energy expenditure over time after TBI](Graph.png)

**REE > hematopoietic stem cell transplantation**

![Graph showing % predicted BMR over time from admission](Graph2.png)


The Goldilocks dilemma!!

Energy intake in the PICU

• At risk of Underfeeding (Hypermetabolic)
• At risk of Overfeeding (Hypometabolic)

Energy Imbalance
unintended consequence

Metabolic profile after stress/surgery – Energy target

Weekly ENERGY INTAKE – based on Equation Estimated Energy Expenditure

Energy Intake: Measured REE = 164% (90-250%)

Resting energy expenditure after Burn Injury

HYPERMETABOLISM
REE elevated for months > injury

**SCCM + ASPEN Nutrition Guidelines for the critically Ill Child**

<table>
<thead>
<tr>
<th>Q2A. What is the recommended energy requirement for critically ill children?</th>
</tr>
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<tbody>
<tr>
<td>R2A. Based on observational cohort studies, we suggest that measured energy expenditure by indirect calorimetry (IC) be used to determine energy requirements and guide prescription of the daily energy goal.</td>
</tr>
<tr>
<td>Quality of evidence: low</td>
</tr>
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<td>GRADE recommendation: weak</td>
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<tr>
<th>Q2B. How should energy requirement be determined in the absence of IC?</th>
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<tr>
<td>R2B. If IC measurement of resting energy expenditure (REE) is not feasible, we suggest that the Schofield or Food Agriculture Organization/World Health Organization/United Nations University equations may be used without the addition of stress factors to estimate energy expenditure. Multiple cohort studies have demonstrated that most published predictive equations are inaccurate and lead to unintended overfeeding or underfeeding. The Harris-Benedict equations and the RDAs, which are suggested by the Dietary Reference Intakes, should not be used to determine energy requirements in critically ill children.</td>
</tr>
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<td>Quality of evidence: very low</td>
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<td>GRADE recommendation: weak</td>
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<tr>
<th>Q2C. What is the target energy intake in critically ill children?</th>
</tr>
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<td>R2C. Based on observational cohort studies, we suggest achieving delivery of at least two thirds of the prescribed daily energy requirement by the end of the first week in the PICU. Cumulative energy deficits during the first week of critical illness may be associated with poor clinical and nutritional outcomes. Based on expert consensus, we suggest attentiveness to individualized energy requirements, timely initiation and attainment of energy targets, and energy balance to prevent unintended cumulative caloric deficit or excesses.</td>
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Persistence of muscle catabolism after severe burn injury

Negative Protein Balance

until 9 months after injury

Associated with erosion of LBM

Mean age was 7.6 +/- 1.5 years

TBSA burns: 65%

Protein Balance after thoracic surgery

Protein Synthesis: 5.8 \((3.8, 6.6)\) g/kg/d

Protein Breakdown: 6.6 \((4.5, 7.6)\) g/kg/d

Protein Balance after thoracic surgery

24h UUN method
Protein Balance = -0.48 (-0.65, -0.28) g/kg/d

Mean (urea and Ammonia) $^{15}$N end-product enrichment method
Protein Balance = -0.34 (-0.48, -0.29) g/kg/d

# Whole Body Protein Turnover

<table>
<thead>
<tr>
<th>Subject groups</th>
<th>Method</th>
<th>Protein synthesis</th>
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<th>Protein balance</th>
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<tr>
<td>Critically ill</td>
<td>Phen +Tyr tracer</td>
<td>8.37 (0.62)</td>
<td>9.31 (0.62)</td>
<td>-0.94</td>
</tr>
<tr>
<td>Surgery</td>
<td>$^{15}$N Glycine EP</td>
<td>5.44 (0.63)</td>
<td>6.15 (1.13)</td>
<td>-0.71</td>
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<td>Sepsis</td>
<td>$^{15}$N Glycine EP</td>
<td>9.06 (2.06)</td>
<td>9.37 (2.31)</td>
<td>-0.31</td>
</tr>
<tr>
<td>Healthy</td>
<td>$^{15}$N Glycine EP</td>
<td>2.94 (0.36)</td>
<td>1.25 (0.44)</td>
<td>+1.7</td>
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Whole Body Protein Turnover

Compared to healthy children
PICU population is characterized by:

- Increased PS and PB
- PB > PS
- Negative Protein Balance

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**Pediatric International Nutrition Study**

**Protein** by age group over first 7 days in PICU, median (IQR)

<table>
<thead>
<tr>
<th>Parameter/age group</th>
<th>0-1 year</th>
<th>1-4 years</th>
<th>4-8 years</th>
<th>8-12 years</th>
<th>12-18 years</th>
</tr>
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<tr>
<td>Prescribed protein (g/kg)</td>
<td>2.09 (0.68)</td>
<td>1.91 (0.71)</td>
<td>1.50 (0.86)</td>
<td>1.50 (0.53)</td>
<td>1.28 (0.51)</td>
</tr>
<tr>
<td>Delivered protein intake (g/kg)</td>
<td>0.96 (1.72)</td>
<td>0.92 (1.73)</td>
<td>0.51 (1.27)</td>
<td>0.40 (1.03)</td>
<td>0.28 (1.04)</td>
</tr>
<tr>
<td>% Protein adequacy</td>
<td>46.1 (79)</td>
<td>53.3 (99)</td>
<td>34.6 (93)</td>
<td>27.8 (74)</td>
<td>22.8 (82)</td>
</tr>
</tbody>
</table>

The median **calorie to nitrogen ratio**
> 210 each day, and
>150 over the 7 day period for all age groups.

N= 1715
(65% with ICU stay > 7d)

Mech ventilated > 48h

Median age: 2y

90 PICUs, 16 countries
SCCM + ASPEN Nutrition Guidelines for the critically Ill Child

Q3A. What is the minimum recommended protein requirement for critically ill children?

R3A. Based on evidence from RCTs and supported by observational cohort studies, we recommend a minimum protein intake of 1.5 g/kg/d. Protein intake higher than this threshold has been shown to prevent cumulative negative protein balance in RCTs. In critically ill infants and young children, the optimal protein intake required to attain a positive protein balance may be much higher than this minimum threshold. Negative protein balance may result in loss of lean muscle mass, which has been associated with poor outcomes in critically ill patients. Based on a large observational study, higher protein intake may be associated with lower 60-d mortality in mechanically ventilated children.

| Quality of evidence: moderate | GRADE recommendation: strong |

Q3B. What is the optimal protein delivery strategy in the PICU?

R3B. Based on results of randomized trials, we suggest provision of protein early in the course of critical illness to attain protein delivery goals and promote positive nitrogen balance. Delivery of a higher proportion of the protein goal has been associated with positive clinical outcomes in observational studies.

| Quality of evidence: moderate | GRADE recommendation: weak |

Do not recommend RDA values

**Enteral** vs. Parenteral

SCCM + ASPEN  Nutrition Guidelines for the critically Ill Child

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Do not recommend RDA values

Enteral vs. Parenteral

THE OPTIMAL PROTEIN DOSE ASSOCIATED WITH IMPROVED CLINICAL OUTCOMES IS NOT KNOWN.
Nutrition therapy

How much? Energy and Protein requirement

Why? Nutrition and outcomes during critical illness

When? Early versus Late

Which route? Enteral or Parenteral
Optimal \textit{Protein + Energy = postoperative anabolism}

Pediatric cardiac surgery, Post-operative Days (3 - 10)

A minimum intake of \textbf{55 kcal/kg/day and 1.0 g protein/kg/day} associated with anabolism.

\textit{Acta Paediatr. 2011 Jul;100(7):977-82.}
Nutrient intake in ARDS

Adequate vs. Inadequate protein group

Mortality: 14.3% vs. 60.2%, (P = 0.002)

Vent-Free Days:
12.0 [3–19] vs. 0 [0–4], (P = .005)

PIM2 score: 9.2 (4.0–21.7) vs. 6.4 (3.3–14.1) NS

OI (Day 2): 13.7 (7.4–25.4) vs. 17.6 (11.2–24.8) NS

Predictors of ICU mortality: (Multivariable model)
PIM2, OI and Protein adequacy

107 patients with ARDS (AECC); median OI:14
Singapore
Mortality: 54%

Protein intake - Mechanically ventilated children, N = 1245

Protein prescription
1.9 g/kg/day (median)

Protein delivery
0.66 g/kg/day
38% of required
1 g/kg/day deficit

<table>
<thead>
<tr>
<th>Variables</th>
<th>Multivariable model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β coefficient ± SE</td>
</tr>
<tr>
<td>Time to EN initiation</td>
<td>-8.06 ± 0.89</td>
</tr>
<tr>
<td>Route of EN (PP)</td>
<td>1.94 ± 0.10</td>
</tr>
<tr>
<td>EN interruption (duration)</td>
<td>-1.14 ± 0.24</td>
</tr>
<tr>
<td>Dedicated ICU Dietitian</td>
<td>6.53 ± 2.80</td>
</tr>
</tbody>
</table>

Nutritional outcomes in infants with Congenital Diaphragmatic Hernia

N = 201, infants with CDH

Predictors of growth at 12 months

Patch repair

Protein intake in ICU

Minimum Protein intake of 2.3 g/kg/day was associated with optimal growth

Severely burned children (n=33) significantly lower lean body mass significantly lower peak torque as well total work performance using the extensors of the thigh.

Muscle function testing

Isokinetic Dynamometer

Peak torque
Total work

Nutrition therapy

How much? Energy and Protein requirement

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When? Early versus Late

Which route? Enteral or Parenteral
PEPaNIC Trial

Early vs. Late PN in critically ill children

PN started within 24 hours if EN did not reach 80% of goal calories vs.

PN started on Day 8

PEPaNIC Trial

Early vs. Late PN in critically ill children

<table>
<thead>
<tr>
<th>Center</th>
<th>First day</th>
<th>Subsequent stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leuven, Belgium</td>
<td>First 10 kg: 100 kcal/kg&lt;br&gt;10-20 kg: + 50 kcal/kg&lt;br&gt;&gt;20 kg: + 20 kcal/kg</td>
<td>(adjusted downward when fluid restriction required)</td>
</tr>
<tr>
<td>Rotterdam, The Netherlands</td>
<td>EN: basal metabolic rate by Schofield-weight&lt;sup&gt;2&lt;/sup&gt;&lt;br&gt;PN: ESPGHAN&lt;sup&gt;3&lt;/sup&gt;</td>
<td>EN: Recommended Dietary Allowances&lt;sup&gt;4&lt;/sup&gt;&lt;br&gt;PN: ESPGHAN&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Edmonton, Canada</td>
<td>Resting energy expenditure by indirect calorimetry&lt;br&gt;If indirect calorimetry impossible: 65% of basal metabolic rate (FAO-WHO)&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Adjusted daily by the diettian based on clinical information</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Center</th>
<th>On admission</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Subsequent Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leuven, Belgium</td>
<td>Mixture of glucose 30% and Vaminolact&lt;sup&gt;®&lt;/sup&gt; (Fresenius)</td>
<td>Addition of lipids (SMOFlipid&lt;sup&gt;®&lt;/sup&gt; Fresenius)</td>
<td>All replaced by mixture of glucose 50% and SMOFlipid&lt;sup&gt;®&lt;/sup&gt; with Vaminolact&lt;sup&gt;®&lt;/sup&gt; or Vamin 18&lt;sup&gt;®&lt;/sup&gt;</td>
<td>Glucose 50% and SMOFlipid&lt;sup&gt;®&lt;/sup&gt; with Vaminolact&lt;sup&gt;®&lt;/sup&gt; or Vamin 18&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td>Rotterdam, The Netherlands</td>
<td>Continuous glucose infusion with glucose intake 4-6 mg/kg/min (&lt;30 kg) or 2-4 mg/kg/min (&gt;30 kg)</td>
<td>Pharmacy-made PN: mixture of glucose, Primene&lt;sup&gt;®&lt;/sup&gt; (Baxter) and Intraplant&lt;sup&gt;®&lt;/sup&gt; (Baxter, 50% of final dose). Children &gt;30 kg Olim&lt;sup&gt;®&lt;/sup&gt; (Baxter, N5 or N4 depending on central or peripheral line)</td>
<td>Increase of lipids to 100% Pharmacy-made PN: mixture of glucose, Primene&lt;sup&gt;®&lt;/sup&gt; (Baxter) and Intraplant&lt;sup&gt;®&lt;/sup&gt; (Baxter, 100% of final dose). Children &gt;30 kg Olim&lt;sup&gt;®&lt;/sup&gt; (Baxter, N5 or N4 depending on central or peripheral line)</td>
<td>Increase of lipids to 100% Mixture amino acids, concentrated glucose and 20% IV lipids</td>
</tr>
<tr>
<td>Edmonton, Canada</td>
<td>Continuous glucose infusion with glucose intake 3-4 mg/kg/min</td>
<td>Addition of 20% IV lipids (50% of final dose)</td>
<td>Increase of lipids to 100% Mixture amino acids, concentrated glucose and 20% IV lipids</td>
<td></td>
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Figure 2. Daily Caloric and Macronutrient Intake.
Figure 2. Daily Caloric and Macronutrient Intake.
PEPaNIC Trial

**Figure 2.** Daily Caloric and Macronutrient Intake.

- **Enteral**
  - Early PN
  - Late PN

- **Parenteral**
  - Early PN
  - Late PN

- **Total**

Patients in ICU:

- (50%) (26%)

No. at Risk:

- Late PN: 717, 348, 159, 103, 63
- Early PN: 723, 399, 216, 139, 93

PEPaNIC Trial

Early vs. Late PN in critically ill children

PN started within 24 hours if EN did not reach 80% of goal calories

vs.

PN started on Day 8

Very early vs. late/No PN

Overfeeding vs. appropriate feeding?

Late PN group

7.8% lower rate of new infection (airway, blood stream); OR 0.48 (CI, 0.35 to 0.66)

Shorter PICU stay (2.7 days)

Higher likelihood of discharge alive; HR 1.23 (CI, 1.11 to 1.37)
PEPaNIC Trial

Provision of amino acids early could explain the worse clinical outcomes seen with early supplemental PN.

.........early administration of PN that contains zero (or less) amino acids could reduce infections and enhance recovery of critical illness in children.

PN use in the ICU

• 487 (28%) received PN during the first week

• Time to PN initiation: median 3 days (IQR 2.0)

• At the time of initiation of PN,
  • 77% of subjects were fasting,
  • 21% received ≤50% of prescribed energy from EN, and
  • 2% received >50% of prescribed energy from EN

N= 1715
(65% with ICU stay > 7d)
Mech ventilated > 48h
Median age: 2y
90 PICUs, 16 countries
Avoid unnecessary PN administration in the early days
Avoid overfeeding
? Provide IV micronutrients,

Advance EN as tolerated (stepwise algorithm)

PEPaNIC Trial

EN INTERRUPTIONS (TOTAL-1483 HOURS)

- Feed intolerance (13 patients): 12/25 (48%) avoidable
- Extubation/Intubation (14 patients): 17/21 (81%) avoidable
- Feeding tube issues (7 patients): 9/12 (75%) avoidable
- Other reasons (6 patients): 8/10 (80%) avoidable
- Radiology procedures (9 patients): 2/10 (20%) avoidable
- Bedside procedures (6 patients): 2/7 (29%) avoidable
- OR procedures (3 patients): 1/3 (33%) avoidable

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?
      - YES
        - Proceed to STEP 3
      - NO
        - Review daily rounds checklist
          - NO
            - Is patient malnourished + anticipate NPO ≥5 days OR NOT malnourished + anticipate NPO ≥7 days OR Newborn ≤30 days + anticipate NPO ≥8 days?
              - YES
                - Initiate Parenteral Nutrition
                  - In consultation with Clinical Nutrition Service & RD
              - NO
                - Exit algorithm
PICU Nutrition Algorithm
Boston Children’s Hospital - 2006

2. SELECT ENTERAL or PARENTERAL NUTRITION

Is the patient able to meet nutrition goals orally?

YES

NO

Exit algorithm

Initiate Specialized Nutrition Support (SNS)

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

YES

NO

Proceed to STEP 3

If NOT malnourished;
PN only if unable to reach 50% goal via EN by Day 7

Initiate Parenteral Nutrition
In consultation with Clinical Nutrition Service & RD

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

NO
Time to reach Enteral Nutrition goal
Impact of a nutrition delivery algorithm in the PICU

![Graph showing improvement in time to reach enteral nutrition goal](image)

*Log rank (Mantel-Cox) test, p value < 0.0001
Hazard ratio = 0.29, CI 0.16 to 0.52

PRAGMATIC APPROACH

• Identify the vulnerable at-risk patients

• ***Individualized Energy and PROTEIN prescription

• Early EN initiation < 24-48 hrs after admission
  (after Hemodynamic stability – resuscitation)

• Cautious protocol/guidelines for advancing EN

• Monitor for intolerance (?GRV) .....stop if any concerns….restart

• Nutrition as part of discussions on daily rounds – nutrition goals

• No role for early PN within the first few days (micronutrients)

• No MAGIC ‘fits-all’ therapies for a heterogeneous population….yet

• Follow-up to document meaningful outcomes
THANK YOU

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