Energy requirement in critically ill pediatrics

Are there times to proceed with caution?

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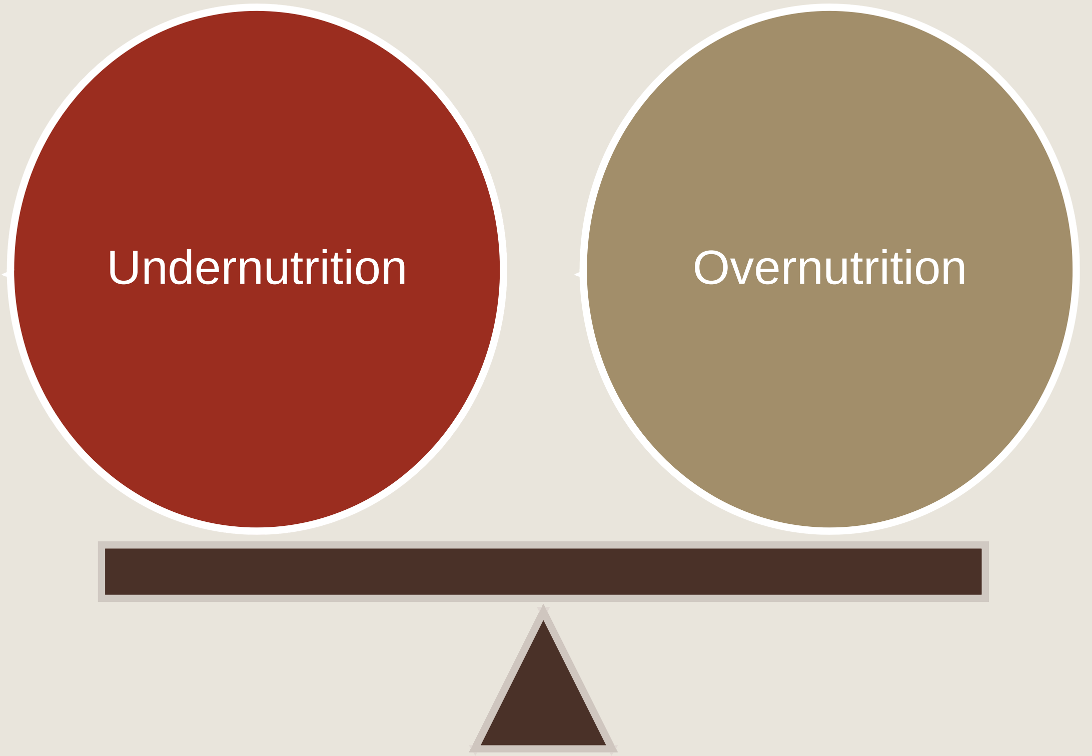
Pediatric Intensive Care Unit Event
Shiraz Autumn 2024

Why Nutrition is important?

Incidence of malnutrition and severe malnutrition: One third of hospitalized children



Masoud khosrshidi, et al. Prevalence of Malnutrition among Iranian Pediatric Patients before and After Hospitalization (2015 To 2017): A Multicenter Study. International journal of pediatrics

Causes of underfeeding or overfeeding

- Failure to recognize the Hypometabolic or hypermetabolic state
- Using standardized equations
- Inaccurate weight
- Failure to achieve nutritional goal

Mehta NM. Pediatric Critical Care Nutrition. McGraw-Hill Education. 2014; Mehta NM, *et al. J Parenter Enteral Nutr* 2009;33:336-44; Lee JH, *et al. Asia Pac J Clin Nutr* 2015

Risk of Underfeeding in Critically Ill Children

- ✓ Loss of critical lean body mass and subcutaneous fat
- ✓ Gastrointestinal dysfunction
- ✓ Poor wound healing
- ✓ Increased risk of infections with poor immune response
- ✓ Increased mechanical ventilation days
- ✓ Increased LOS
- ✓ Repeat hospital admissions
- ✓ Increased risk of developing multi-organ failure
- ✓ Increased mortality

Mehta NM, *et al. J Parenter Enteral Nutr* 2009;33:336-44.Lee JH, et al. *Asia Pac J Clin Nutr* 2015.

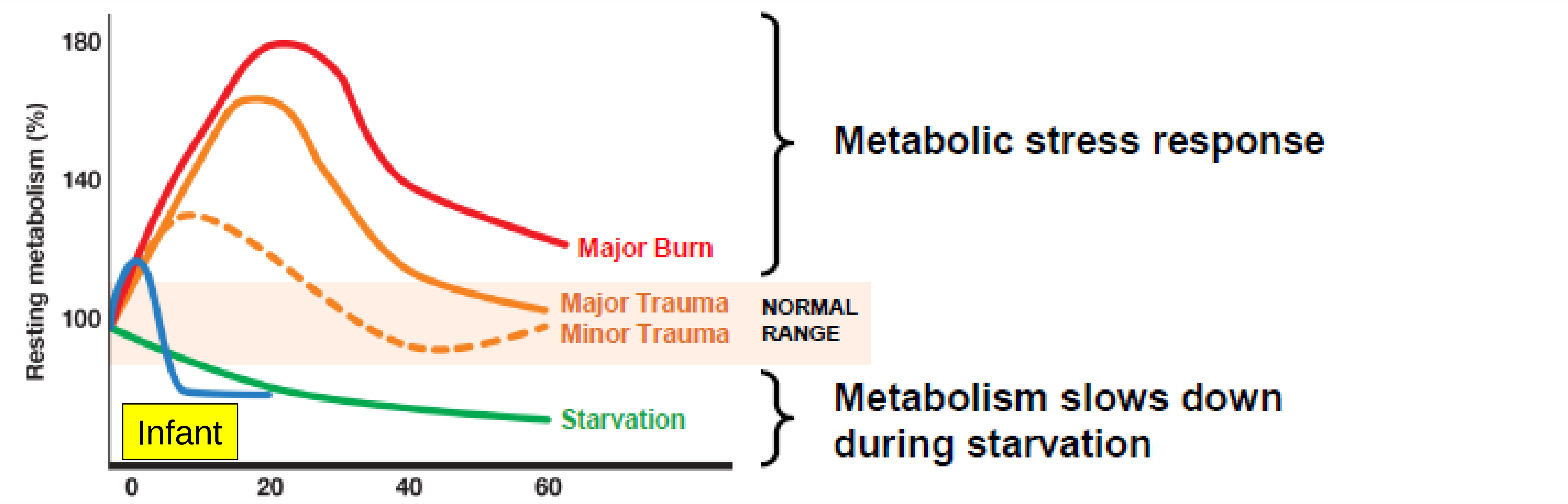
Risks of Overfeeding in Critical Illness

- ✓ Increase hospital length of stay
- ✓ Infections
- ✓ Lipogenesis
- ✓ Organ failure
- ✓ Prolong mechanical ventilation
- ✓ Hyperglycemia
- ✓ Hypertriglyceridemia
- ✓ Hepatic steatosis
- ✓ Azotemia
- ✓ Hypercapnia
- ✓ Increased mortality

Mehta NM, *et al. J Parenter Enteral Nutr* 2009;33:336-44.Lee JH, et al. *Asia Pac J Clin Nutr* 2015.

TOO MUCH, TOO LITTLE, OR JUST RIGHT?

Metabolic stress response



- Stress response in children is **less pronounced** than in adults.

Adequate protein and energy intake helps maintain protein balance and prevent lean body mass depletion in the PICU patient

Am J Clin Nutr 1977; 30:1301-1310; Mehta NM, Costello JM, Bechard LJ, *et al. J Parenter Enteral Nutr* . 2012;36:685-92; Goday PS, Mehta NM. Pediatric Critical Care Nutrition. McGraw-Hill Education. 2014.

The Acute phase of stress

Vital organ support, stress response, resulting in hypercatabolism.

Change in energy production, loss of control of energy substrate utilization by their availability.

Endogenous production of energy provides the majority of energy requirements (up to 75%), irrespective of the exogenous provided amount of energy.

Energy imbalance, which is associated with poor outcome.

Goday PS, Mehta NM. Pediatric Critical Care Nutrition. McGraw-Hill Education. 2014.

Nutrition support cannot reverse or prevent this response

However

Failure to provide optimal nutrition during this stage may exacerbate nutritional deficiencies and result in malnutrition, which may affect clinical outcomes.

Energy Requirement

In a healthy child

Resting energy expenditure (REE, BMR)
60%
Substrate turnover
Respiration
Cardiac output
Body temperature

\+

Thermic effect of food (TEF)
10%
Digest, absorb, metabolize, and store the remaining food, and some are burned off as heat.

\+

Physical activity
30%
The most variable and, after BMR, the second largest component of daily energy expenditure.

\+

Growth
Normal growth or catch up growth.

=

TEE

In acute phase of illness

REE
Clinical status

\+

Continuous feeding, abnormal digestion, absorbtion, metabolism and storage

\+

No physical activity

\+

No growth

=

TEE

REE = TEE

Factors affecting REE

Effects on REE	Factors	
↑	• Burns • Hyperventilation • Hyperthermia • Hyperthyroidism, pheochromocytoma • Inflammation (interleukins, interferons, tumor necrosis factors etc.) • Metabolic acidosis	• Morbid obesity • Overfeeding • Physical agitation • Sepsis • Stress (epinephrine, cortisol, glucagon etc.)
↓	• Coma/deep sleep • General anesthesia • Heavy sedation • Hypothermia • Hypothyroidism • Hypoventilation	• Gluconeogenesis • Metabolic alkalosis • Paralysis • Sarcopenia, cachexia • Starvation/underfeeding/ketosis

Hardin TC, Melnik G (eds): Nutritional assessment and support – a primer. 2nd ed. Baltimore:Williams and Wilkins, 1994; 32.

Energy requirements in the acute, stable and recovery phases of critical illness

Energy requirements in phases of critical illness

Acute phase:

- **Generally, in acute phase, It is recommended to use REE, without stress factors.**

- **Stress factors must be used selectively with caution, might result in unintended overfeeding.**

Vigilantly monitor for potential signs of overfeeding:

- Hyperglycemia, hypertriglyceridemia, increased Co2 production, increased arm circumference, and rapid or excessive weight gain

Veldscholte, K., Joosten, K., & Jotterand Chaparro, C. (2020). Energy expenditure in critically ill children. *Pediatric Medicine, 3*. doi:10.21037/pm-20-62

Energy requirements in the acute and stable phases of critical illness

Recovery phase:

- The **recovery** phase starts when the patient is **mobilized** and the stress response is **resolving** and normalized.
- **Last up to several months**.
- Body shifts further from **catabolism to anabolism** with **protein synthesis** exceeding protein breakdown, which results in tissue repair and **(catch-up) growth.**
- Energy requirements may rise considerably, **even exceeding normal energy requirements of healthy children.**

Recent guidelines state that, after the acute phase, energy intake should account for **energy debt, physical activity, rehabilitation and growt**h.

Veldscholte, K., Joosten, K., & Jotterand Chaparro, C. (2020). Energy expenditure in critically ill children. *Pediatric Medicine, 3*. doi:10.21037/pm-20-62

Energy requirements in the acute and stable phases of critical illness

Prescribing nutrition in different phases of disease

Phase	Enteral nutrition	Parenteral nutrition	Energy target
Acute phase	Increase EN in stepwise manner	No PN	Do not exceed 100% REE
Stable phase	Increase EN further, if possible	Start PN >1 week after PICU admission, if energy targets are not met	Increase of %REE depending on age and disease
Recovery phase	Increase EN further, if possible	Continue PN if necessary to achieve energy targets	Up to 200% REE (and occasionally up to 400% REE). Target for (catch-up) growth

EN, enteral nutrition; PN, parenteral nutrition; REE, resting energy expenditure.

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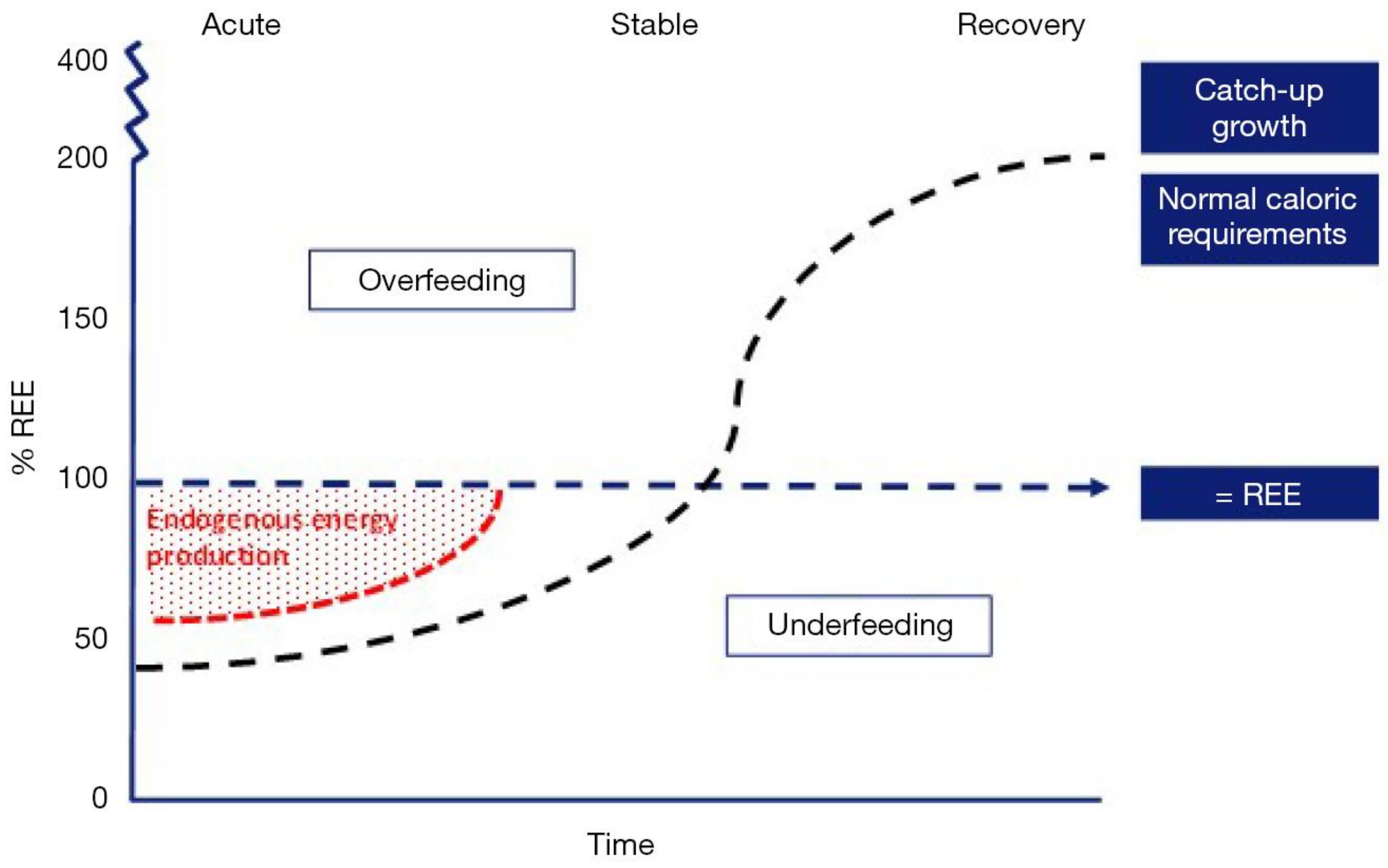

Acute
Stable
Recovery
400
200
150
100
50
0
% REE
Catch-up growth
Normal caloric requirements
Overfeeding
= REE
Endogenous energy production
Underfeeding
Time

Energy requirement

Energy requirements

Measure

Estimate

Estimate caloric requirements

Common predictive equations to predict energy expenditure in PICU

Name	Gender	Equation
Schofield		
White (kJ/d)		17 x A[mo] + (48 x W) + (292 x body temp °C) - 9677
FAO/WHO/UNU		
Harris-Benedict† (kcal/d)	M	66.4730 + (5.0033 x H) + (13.7516 x W) - (6.7550 x A)
	F	655.0955 + (1.8496 x H) + (9.5634 x W) - (4.6756 x A)

Goday PS, Mehta NM. Pediatric Critical Care Nutrition. McGraw-Hill Education. 2014; Sion-Sarid R, *et al. Nutrition* 2013;29:1094-1099

Schofield equation to estimate BMR (kcal/day) of PICU patient

Age	Gender	Equation	
		W	WH
<3 years	M	59.48W - 30.33	0.167W + 1517.4H - 617.6
	F	58.29W - 31.05	16.252W + 1023.2H - 413.5
3–10 years	M	22.7W + 505	19.59W + 130.3H + 414.9
	F	20.3W + 486	16.97W + 161.8H + 371.2
10–18 years	M	17.7W+ 659	16.25W + 137.2H + 515.5
	F	13.4W+ 696	8.365W + 465H + 200

In critically ill children, use of actual weight (whether child is underweight or overweight) is recommended.

Schofield WN. *Hum Nutr: Clin Nutr* 1985 39C;5-41; Koletzko B, *et al. J Pediatr Gastroenterol Nutr* 2005;41 Suppl 2:S5-11; Corkins MR (ed). Pediatric nutrition support handbook. 2011. American Society for Parenteral and Enteral Nutrition; Goday PS, Mehta NM. Pediatric Critical Care Nutrition. McGraw-Hill Education. 2014

FAO/WHO/UNU equations to estimate REE (kcal/day)

Name	Gender	Equation
<3 years	M	60.9W - 54
	F	61W - 51
3–10 years	M	22.7W + 495
	F	22.5W + 499
10–18 years	M	17.5W + 651
	F	12.2W + 746

Goday PS, Mehta NM. Pediatric Critical Care Nutrition. McGraw-Hill Education. 2014

Predictive equations: Which to use?

It is recommended to use Schofield equation, without stress factors

- **Regular** reassessment is necessary to ensure that appropriate nutrition is provided.
- Use the **same** equation for serial assessments.

WHO Energy and protein requirements Geneva 1985; Schofield WN. *Hum Nutr Clin Nutr* 1985;39 Suppl 1:5-41; Briassoulis G, *et al. Crit Care Med* 2000;28:1166-1172; White MS, *et al. Crit Care Med* 2000;28:2307-2312; Mehta, NM *et al. Pediatr Crit Care Med: J Soc Crit Care Med World Fed Pediatr Intensive Crit Care Soc* 2011;12(4):398-405.

Energy expenditure requirements (EER)

Preterm infants: 120 kcal/kg per day (150 to 160 mL/kg per day of preterm formula (0.8 kcal/mL) or fortified human milk

0 through 2 months – 100 to 110 kcal/kg per day

3 through 5 months – 85 to 95 kcal/kg per day

6 through 8 months – 80 to 85 kcal/kg per day

9 through 11 months – 80 kcal/kg per day

12 through 24 months – 80 to 83 kcal/kg per day

1.Food and Agriculture Organization of the United Nations. Human energy requirements: Report of a Joint FAO/WHO/UNU Expert Consultation. 2004. Available at: https://www.fao.org/3/y5686e/y5686e00.htm (Accessed on May 16, 2016).
2.National Academy of Medicine. Dietary Reference Intakes for Energy. 2023. Available at: https://nap.nationalacademies.org/catalog/26818/dietary-reference-intakes-for-energy (Accessed on October 23, 2023).

Measure energy needs

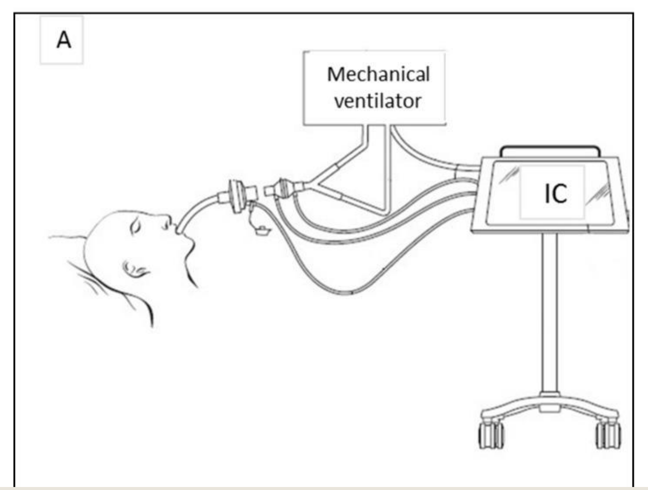
1. Indirect calorimetry
2. Tracer Methodology (DLW)

Indirect calorimetry (IC)

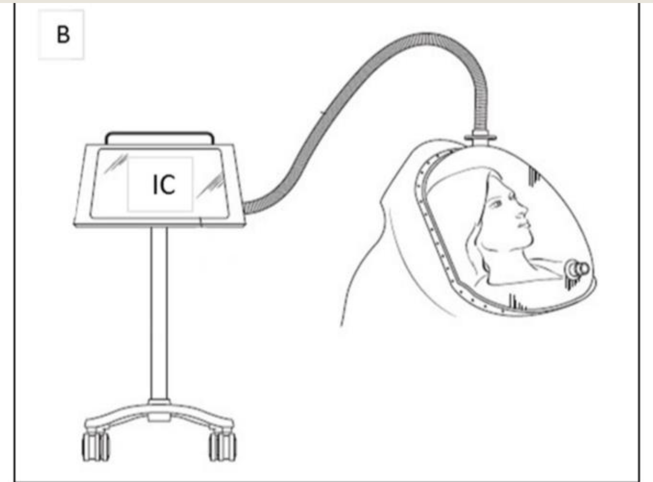
- **A gold standard** to measure resting energy expenditure

IC allows measuring REE in both:

- Mechanically ventilated patients
- Spontaneously breathing patients



- Despite the known faults of predictive equations and recent A.S.P.E.N. recommendations, **IC is not commonly used** in the PICU. **This is due to many factors, including:**
- Cost
- Lack of expertise
- Technical limitations in certain populations
- (eg, patients with high ventilatory needs)



Delsoglio M, Achamrah N, Berger MM, Pichard C. Indirect Calorimetry in Clinical Practice. J Clin Med. 2019 Sep 5;8(9):1387. doi: 10.3390/jcm8091

Indirect calorimetry (IC)

- Human energy stems from chemical energy, which is released from nutrients through the oxidation of food substrates.

- Carbon-based nutrients (ie, fuels) are converted into carbon dioxide (CO2), water (H2O), and heat in the presence of oxygen (O2).

$$\text{Substrate} + O_2 \xrightarrow{oxidation} CO_2 + H_2O + \text{Heat}$$

- Indirect calorimetry (IC) measure REE, by measuring oxygen consumption (VO_2) and carbon dioxide production (VCO_2).

Weir equation MREE= VO2 (3.941) + VCO2 (1.11) x1440

Delsoglio M, Achamrah N, Berger MM, Pichard C. Indirect Calorimetry in Clinical Practice. J Clin Med. 2019 Sep 5;8(9):1387. doi: 10.3390/jcm8091387. PMID: 31491883; PMCID: PMC6780066.

Indirect calorimetry (IC)

- Apart from REE, other parameters can be derived from IC, such as **substrate (carbohydrates, fat, and protein) utilization.**

- Indeed, the ratio between VCO_2 and VO_2 (VCO2/VO2) defines the respiratory quotient (RQ) that corresponds to the substrate use.

RQ (respiratory quotient)=VCO2/VO2 ratio

The RQ may help evaluate substrate utilization and/or nutritional support, and determine overfeeding and underfeeding

Delsoglio M, Achamrah N, Berger MM, Pichard C. Indirect Calorimetry in Clinical Practice. J Clin Med. 2019 Sep 5;8(9):1387. doi: 10.3390/jcm8091387. PMID: 31491883; PMCID: PMC6780066.

The use of the RQ

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RQ value constant, specific for each substrate, Oxidation of:

Fat= 0.7

Protein= 0.83

Carbohydrate= 1.0

RQ >1 may represent overfeeding= Lipogenesis

RQ < 0.6 may represent underfeeding= Ketosis

The **RQ** can be used to determine **under- and overfeeding** and to monitor the **tolerance** of nutritional support.

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Measurements of REE and RQ

after

the acute phase of disease may be helpful to guide nutritional therapy and to increase nutritional intake in relation to REE until (catch-up) growth and tissue repair are achieved.

Criteria for selecting patient for IC in PICU

- Underweight (BMI<5th P for age), Overweight (BMI>85th P for age)
- >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)
- Oncologic diagnosis (including stem cell or bone marrow transplantation)
- Need for mechanical ventilatory support >7 days
- Suspicion of severe: Hypermetabolism and Hypometabolism
- Intensive care unit length of stay >4 weeks

Delsoglio M, Achamrah N, Berger MM, Pichard C. Indirect Calorimetry in Clinical Practice. J Clin Med. 2019 Sep 5;8(9):1387. doi: 10.3390/jcm8091387. PMID: 31491883; PMCID: PMC6780066.

Factors limiting the reliability and feasibility of IC measurement

- **Weight < 15 kg**

- Agitation, fever, sedatives, and vasoactive adjustments during measurement
- Air leakages in respiratory circuit
- Dialysis or continuous renal replacement therapy
- ECMO
- Mechanical ventilation with PEEP > 10
- Mechanical ventilation with FiO_2 > 80%
- Noninvasive ventilation
- Other gases than O_2, CO_2, and N_2: helium
- Supplemental oxygen in spontaneous breathing patients

Energy requirement in obese child

- Diet and caloric restriction has **no** place when feeding a critically ill obese pediatric patient; however, overfeeding should be **avoided**.
- Critically ill obese pediatric patients are at risk of **overfeeding**.
- BMR yield **higher** requirements due to larger body weight and the wide variability in body composition among obese patients.
- Substituting an **adjusted** body weight leads to **underestimated** resting metabolic rate, and **adding** stress correction factors leads to overfeeding.
- Calculating energy needs based on **actual weight**, without **adjusting** for the degree of metabolic **stress**, is recommended to avoid overfeeding.
- Measurement of REE in obese by **IC** remains the **most accurate** way to **estimate** energy needs.

Take home message

- In critically ill children, clinicians have the complex role of prescribing an optimal energy intake, avoiding both **underfeeding and overfeeding**.
- **During the acute phase**, energy intake should be increased progressively according to the tolerance of the patients and **not exceed REE**, predicted by **Schofield** equation.
- **Recovery time,** energy intake may be increased considering **the energy debt, physical activity, rehabilitation and growth.**
- **Recovery time: 200%-400% of REE**.
- In **some** patients, measurement of REE using a validated calorimeter may be needed.
- In addition to measured REE, the **RQ** might be a helpful tool as well.
- The presence of a **nutrition team** including a dedicated dietitian is recommended to guide energy intake and nutritional support.

Thank you for your attention