Indirect calorimetry: Is it necessary for everyone?

Or do you prefer to guess?
Is indirect calorimetry necessary?

Pierre Singer, MD
Institute for Nutrition Research
Critical Care Department
Rabin Medical Center
Tel Aviv University
Messages

• For the normal population: equations are just fine
• For disease: equations are inaccurate
• For obesity, critically ill patients, home parenteral nutrition patient: useful tool
• Day to day variability
• Calculation of energy balance.
• It is a monitoring tool, not a treatment...
Harris - Benedict Equations

Subjects - 239
136 male       103 female

Weights        Heights        Ages
40 - 100 kg    140-210 cm    20-70 yrs

Measurement Conditions
no skeletal activity for 30 minutes
traveled to the center
indirect calorimetry

Harris JA and Benedict FG. Biometric Studies of Basal Metabolism in Man Carnegie Institution of Washington, publication no. 270, 1919.
Variability of the Harris Benedict Equations

Original published version:
Men:
EE = 66.4730 + 13.7516 (W) + 5.0033 (H) - 6.7550 (A)
Women:
EE = 655.0955 + 9.5634 (W) + 1.8496 (H) - 4.6756 (A)

Rounding off variation:
Men: EE = 66 + 13.8 (W) + 5 (H) - 6.8 (A)
Women: EE = 655 + 9.6 (W) + 1.8 (H) - 4.7 (A)

Van Way, CW  *JPEN*, 1992
RMR Differs from One Individual to the Next Due to Numerous Variables (Genetics, Muscle Mass, Hormones, Medications, Dietary Intake, Exercises and Activities, etc…)

Subjects of Same Height and Weight

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<td>1263</td>
<td>1523</td>
<td>1778</td>
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</table>

Measurement vs Estimation:
Indirect Calorimetry vs HarrisBenedict (standard+corrected), alternative Formulae

REE (M) = 14 x kg + 5 x cm – 7 x years
REE (F) = 10 x kg + 1.8 x cm – 5 x years

N=70 ventilated ICU patients (from 132 !!!)

Faisy et al. AJCN 2003; 78: 241
Struggle with the weight

Actual weight
Ideal weight
Adjusted weight
Indirect calorimetry
Estimation of caloric requirements

• Measurement: calorimetry
• Estimation:
  Adjusted weight (AW):
  patient weight - IBW(*0.25) + ideal body weight
  AW*25kcal/24h
How much calories to your ICU patient?

Your guess is as good as mine
Optimal amount of calories for critically ill patients: Depends on how you slice the cake!

Daren K. Heyland, MD, MSc; Naomi Cahill, RD, PhD (candidate); Andrew G. Day, MSc

Do all the patients just look the same?
Nutritional gain versus financial gain: the role of metabolic carts in the surgical ICU
Davis, et al J Trauma 2006; 61:1436

59 patients, 106 measurements: H B/ REE

<table>
<thead>
<tr>
<th></th>
<th>All patients</th>
<th>Trauma</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBx1.5</td>
<td>2,339 ± 497</td>
<td>2,389 ± 503</td>
<td>1,966 ± 440</td>
</tr>
<tr>
<td>30cal/kg</td>
<td>2,276 ± 447</td>
<td>2,357 ± 517</td>
<td>2,027 ± 408</td>
</tr>
<tr>
<td>REE</td>
<td>2,217 ± 540</td>
<td>2,281 ± 548</td>
<td>1,965 ± 440</td>
</tr>
<tr>
<td>RQ</td>
<td>0.77 ± 0.06</td>
<td>0.77 ± 0.06</td>
<td>0.78 ± 0.07</td>
</tr>
<tr>
<td>P value</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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</tbody>
</table>
Are patients fed appropriately in ICU?

McClave S, JPEN 1998; 22:375

% Metabolism (Measured/Harris-Benedict EE x 100)

Level of energy expended (indirect calorimetry) vs delivered in 213 ICU patients on mechanical ventilation receiving full artificial feeding.
5. How much parenteral nutrition should critically ill patients receive?

Recommendation: During acute illness, the aim should be to provide energy as close as possible to the measured energy expenditure in order to decrease negative energy balance. (Grade B). In the absence of indirect calorimetry, ICU patients should receive 25 kcal/kg/day increasing to target over the next 2-3 days (Grade C).

8. Under what conditions should PN be added to EN?

In patients who tolerate EN and can be fed approximately to the target values no additional PN should be given (A).

In patients who cannot be fed sufficiently enterally the deficit should be supplemented parenterally (C). In patients intolerant to EN, careful parenteral nutrition may be proposed at a level equal to but not exceeding the nutritional needs of the patient (C). Overfeeding should be avoided.

C1. The target goal of EN (defined by energy requirements) should be determined and clearly identified at the time of initiation of nutrition support therapy. (Grade: C) Energy requirements may be calculated by predictive equations or measured by indirect calorimetry. Predictive equations should be used with caution, as they provide a less accurate measure of energy requirements than indirect calorimetry in the individual patient. In the obese patient, the predictive equations are even more problematic without availability of indirect calorimetry. (Grade: E)

C3. If unable to meet energy requirements (100% of target goal calories) after 7-10 days by the enteral route alone, consider initiating supplemental PN. (Grade: E) Initiating supplemental PN prior to this 7-10 day period in the patient already receiving EN does not improve outcomes and may be detrimental to the patient. (Grade: C)
Table 1. Prediction Equations for Resting Energy Expenditure (kcal/d)*

American College of Chest Physicians equation\textsuperscript{27}

\[ 25 \times \text{weight} \]

If BMI 16–25 kg/m\textsuperscript{2} use usual body weight
If BMI > 25 kg/m\textsuperscript{2} use ideal body weight
If BMI < 16 kg/m\textsuperscript{2} use existing body weight for the first 7–10 d, then use ideal body weight

Harris-Benedict equation\textsuperscript{59}

Men: \[ 66.4730 + (13.7516 \times \text{weight}) + (5.0033 \times \text{height}) - (6.7550 \times \text{age}) \]

Women: \[ 655.0955 + (9.5634 \times \text{weight}) + (1.8496 \times \text{height}) - (4.6756 \times \text{age}) \]

Ireton-Jones 1992 equation\textsuperscript{60}

\[ 1,925 - (10 \times \text{age}) + (5 \times \text{weight}) + (281 \text{ if male}) + (292 \text{ if trauma present}) + (851 \text{ if burns present}) \]

Ireton-Jones 1997 equation\textsuperscript{61}

\[ (5 \times \text{weight}) - (11 \times \text{age}) + (244 \text{ if male}) + (239 \text{ if trauma present}) + (840 \text{ if burns present}) + 1,784 \]

Penn State 1998 equation\textsuperscript{56}

\[ (1.1 \times \text{value from Harris-Benedict equation}) + (140 \times T_{\text{max}}) + (32 \times V_{E}) - 5,340 \]

Penn State 2003 equation\textsuperscript{56}

\[ (0.85 \times \text{value from Harris-Benedict equation}) + (175 \times T_{\text{max}}) + (33 \times V_{E}) - 6,433 \]

Swinamer 1990 equation\textsuperscript{62}

\[ (945 \times \text{body surface area}) - (6.4 \times \text{age}) + (108 \times \text{temperature}) + (24.2 \times \text{respiratory rate}) + (817 \times V_{T}) - 4,349 \]
Baseline Nutrition Assessment

Methods Used to Calculate Energy Requirements

- Harris Benedict Equation
- Schofield Equation with no adjustment for stress and activity
- Schofield Equation with adjustment for stress and/or activity
- Mifflin-St. Jeor Equation
- Ireton-Jones Equation
- <20 Kcal/Kg
- 20-24 Kcals/Kg
- 25-29 Kcals/Kg
- 30-35 Kcals/Kg
- Provide 1500-2000 Kcal as standard
- Other, please specify

IC was not suggested
Predictive Equations for Energy Needs for the Critically Ill

Renee N Walker MSc RD LD CNSD and Roschelle A Heuberger PhD RD
Analysis of estimation methods for resting metabolic rate in critically ill adults
Frankenfield et al  JPEN 2009; 33:27

- 202 ventilated patients
- HB weight adjusted: 18% accuracy (the worse)
- Mifflin 25%
- Mifflin x 1.25 49%
- ACCP 35%
- Faisy 53%
- Penn State 64% : most precise and unbiaised
Measurement Versus Estimation of RMR

- Measurement of RMR and TEE has always been the “gold-standard” of determining the energy expenditure of any individual.

- Because of the complexity, expense, and size of instrumentation historically required to measure RMR, estimations of RMR based on statistical population averages have been utilized as the most practical alternative.

- Predictive formulae used to estimate RMR are DERIVED from averaged values of measured RMR on individual subjects.

- Predictive formulae are VALIDATED against averaged values of measured RMR on individual subjects.
Nutritional requirements of surgical and critically ill patients: do we really know what we need?
Reid C Proc Nutr Soc 2004; 63:467
Clin Nutr 2007; 26:649

– 43% develop malnutrition
– Indirect calorimetry is the gold standard
– Predictive equations are inaccurate compared to measured requirements obtained by IC
– Underfeeding < 90%
– Overfeeding >150% of MEE
236 kg and 40°C fever
Which weight to use?
What is the REE?
Linear: RMR = 647 + wt (11)
Allometric: RMR = 202 \times wt^{0.4722}

BMI > 45

Equation method
- Linear (Frankenfield)
- Allometric (Livingston)
Table 1. Differences and percent changes in body size and metabolic rate in healthy and critically ill people grouped by BMI

<table>
<thead>
<tr>
<th>Variable</th>
<th>Healthy BMI group</th>
<th>Critically ill BMI group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>mean ± SD</td>
<td>percent of nonobese group</td>
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<tr>
<td>Age, years</td>
<td></td>
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<tr>
<td>1</td>
<td>40±16</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>41±13</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>39±8</td>
<td>NA</td>
</tr>
<tr>
<td>Height, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>170±10</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>170±11</td>
<td>NA</td>
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<td>3</td>
<td>169±11</td>
<td>NA</td>
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<td>Weight, kg</td>
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<td>69±12</td>
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<td>BMI</td>
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<td>24.0±2.8</td>
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<tr>
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<td>33.9±3.2</td>
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<td>RMR, kcal/day</td>
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<td>2</td>
<td>1801±391</td>
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<td>3</td>
<td>2386±521</td>
<td>1.63</td>
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<td>RMR, % Mifflin</td>
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<tr>
<td>1</td>
<td>1.01±0.08</td>
<td>1.00</td>
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<tr>
<td>2</td>
<td>1.03±0.13</td>
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<td>3</td>
<td>1.04±0.09</td>
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<td>RMR, kcal/wt</td>
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<tr>
<td>1</td>
<td>21±2</td>
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<td>2</td>
<td>18±3</td>
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<tr>
<td>3</td>
<td>16±2</td>
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<td>RMR, kcal/IBW</td>
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<td>1</td>
<td>21±2</td>
<td>1.00</td>
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<td>2</td>
<td>28±5</td>
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<td>25±4</td>
<td>1.12</td>
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<td>Equation</td>
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</tr>
<tr>
<td></td>
<td>±10%(^1)</td>
<td>&lt;10%(^2)</td>
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<tr>
<td>ACCP(_{wt})</td>
<td>0.48</td>
<td>0.20</td>
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<tr>
<td>ACCP(_{MAW})</td>
<td>-</td>
<td>-</td>
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<tr>
<td>ACCP(_{IBW})</td>
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<td>Faisy</td>
<td>0.51</td>
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<td>Penn state</td>
<td>0.74</td>
<td>0.14</td>
</tr>
<tr>
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<td>Greenberg and Jeejeebhoy, 1979 [56]</td>
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<td>Dickerson et al., 1986 [19]</td>
<td>Prospective</td>
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<td>Burge et al., 1994 [54]</td>
<td>Prospective Double-blind</td>
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<td>Choban et al., 1997 [53]</td>
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<td>Liu et al., 2000 [57]</td>
<td>Retrospective</td>
<td>18</td>
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<tr>
<td>Group 1: &lt;60 years of age</td>
<td>Retrospective</td>
<td>12</td>
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<tr>
<td>Group 2: &gt;60 years of age</td>
<td>Retrospective</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

Alb, Albumin; CBW, current body weight; IBW, ideal body weight; ICU, intensive care unit; Kcal, kilocalories; N, number of patients per group; NB, nitrogen balance; TIBC, total iron-binding capacity.

*P = 0.06.

*Patients received enteral nutritional support. Remaining studies were conducted with patients receiving parenteral nutrition.

Reprinted from Dickerson [58*], with permission from the American Society for Parenteral and Enteral Nutrition (ASPEN). ASPEN does not endorse the use of this material in any form other than its entirety.
Metabolic support of the obese intensive care unit patient: a current perspective
Ava M. Port and Caroline Apovian

Is hypocaloric feeding appropriate?

- NO
  - Is indirect calorimetry available to measure REE?
    - YES
      - Estimate total daily energy needs (TEE) by multiplying measured REE with an appropriate stress factor (1.0-2.0), depending on type and severity of injury.
    - NO
      - Select a prediction equation to estimate total daily energy needs (TEE)
        - Is patient intubated, with minute ventilation (Ve) and Tmax available?
          - YES
            - Penn state Equation (using HBE)
          - NO
            - Harris-Benedict with adjusted weight (25%) and stress factor (1.1) OR 21 kCal/kg actual weight

REE, resting energy expenditure; HBE, Harris-Benedict equation; Tmax, maximum temperature in a 24 h period.
Indirect Calorimetry
# CRITICAL CARE: Energy Requirements

<table>
<thead>
<tr>
<th>Reference</th>
<th>Patients</th>
<th>Mean Kcal/kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zauner A et al, Int Care Med 2006; 32: 428</td>
<td>MedICU</td>
<td>24.8</td>
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<tr>
<td>Zauner C et al, AJCN 2001; 74: 265</td>
<td>ICU</td>
<td>23</td>
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<tr>
<td>Reid CL. Clin Nutr 2007; 26: 649</td>
<td>ICU</td>
<td>27.4</td>
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<td>Schneeweiss B et al, Metabolism 1992; 41: 125</td>
<td>Infection</td>
<td>27.8</td>
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<tr>
<td>Carlsson M et al, Clin Nutr 1984; 3: 103</td>
<td>Trauma/Inf Resp Fail</td>
<td>30.5</td>
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<tr>
<td>Wolfe RR et al, Ann Surg 1983; 197: 163</td>
<td>Burn</td>
<td>31-34.1</td>
</tr>
</tbody>
</table>

Range for EE: 22.3-34.1 Kcal/kg/day
Resting Energy Expenditure

Cohorts (%) vs. Resting Energy Expenditure (kcal/kg BW/day)
Factors That Can Affect RMR

- Age
- Gender
- Body Composition
- Genetics
- Dietary Regimen
- Disease
- Severity of Disease
- Point of Time in Overall Disease Process
- Fever / Infection
- Hormonal Status
- Pharmaceuticals
## Parameters changing VO2 and REE

<table>
<thead>
<tr>
<th>Increased</th>
<th>By</th>
<th>Decreased</th>
<th>By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>13%/oC</td>
<td>Hypothermia</td>
<td>13%/oC</td>
</tr>
<tr>
<td>Shivering</td>
<td>100%</td>
<td>Curare</td>
<td>60%</td>
</tr>
<tr>
<td>Visit of relatives</td>
<td>40-60%</td>
<td>Analgesia</td>
<td>50%</td>
</tr>
<tr>
<td>Work of breathing</td>
<td>25%</td>
<td>Adapted Ventilation</td>
<td>20-30%</td>
</tr>
<tr>
<td>Nutrition</td>
<td>9%</td>
<td>Starvation</td>
<td>10%</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>30%</td>
<td>Beta blocker</td>
<td>25%</td>
</tr>
</tbody>
</table>
Metabolic Response to Trauma

Resting metabolism after injury (Long et al, Am J Clin Nutr 1977)
Energy intake should be targeted
TRAUMA and ICU

Majority young patients
No medical history
Do not take medication
Day to day variability of resting energy expenditure (REE) in multiple trauma patients

R Anbar¹, M Theilla², I Kagan², S Lev², L Lupinsky², M Gruney², P Singer²

¹Nutrition Unit Rabin Medical Center, ²General Intensive Care Department and Institute for Nutrition Research, Rabin Medical Center, Beilinson Hospital, Petah Tikva, Israel
Methods

• A retrospective study
• 50 critically ill ventilated multiple trauma patients who were admitted in our ICU and having more than 3 different REE measurements were included.
• Parameters collected using bedside information system (iMD software) included: demographic data, APACHE II scores, Harris Benedict (HB) predictive equation and REE measurements.
Methods

• Resting energy expenditure (REE) and respiratory quotient (RQ) were obtained by indirect calorimetry measurements (Deltatrac II, Datex-Ohmeda, Finland).

• Statistical analysis of the REE compared the daily measurements between each other using an ANOVA analysis of variance.
# Characteristics of patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Sex</td>
<td>38M, 12F</td>
</tr>
<tr>
<td>Age (years)</td>
<td>44 ± 18.9</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>26 ± 4.8</td>
</tr>
<tr>
<td>APACHE II</td>
<td>19 ± 6.3</td>
</tr>
<tr>
<td>Mean REE (Kcal/d)</td>
<td>2030 ± 597</td>
</tr>
<tr>
<td>Harris Benedict formula (Kcal/d)</td>
<td></td>
</tr>
</tbody>
</table>
Results

• 304 REE measurements were obtained and all of them were higher than the estimated by HB equation.

• There was a significant difference between the REE measurements during the 14 days of observation (p<0.05).

• The highest REE reached 48% increase from HB at day 6 and 51% at days 12-13. REE was the lowest during the first 2 days after admission.
Day to day variability of REE (as % HB) in 51 trauma ventilated patients
Controversies in the determination of energy requirements

- Will a patient have a better outcome if he is fed to energy requirements?
- How do different levels of feeding affect outcome?
- Does feeding have to be tailored to individual requirements or would a standard regimen be sufficient?
- Do prescriptions for energy need to reflect MEE on a day-to-day basis?
Added values of measuring energy expenditure

• 1. Determination of energy balance

• 2. Targeting energy delivery

• 3. Following clinical conditions
Energy Balance

IN

Out
Computerized energy balance and complications in critically ill patients.

Dvir, Cohen & Singer, Clin Nutr, 2006;25:37

Fig 1. Daily mean energy balance (in kcal) in relation with time in days
Impact of hypocaloric feeding on ICU outcome


Mechanical ventilation for 11 ± 8 days, ICU stay 15 ± 9 days.

30-days mortality 38%.
Impact of hypocaloric feeding on ICU outcome


[Box plot image showing the relationship between cumulated energy balance and complications. The p-value is 0.004.]
Correlation between the total complications in the 50 ICU patients and maximum negative energy balance (= measured energy expenditure - energy intake)

Computerized energy balance and complications in critically ill patients.

Dvir, Cohen & Singer, Clin Nutr, 2006;25:37
MAX NEGATIVE ENERGY BALANCE

PATIENTS %

<4000kcal

>4000kcal

PRESSURE SORE

SURGERY

RF

ARDS

SEPSIS

COMPLICATIONS

0

10

20

30

40

50

60

70

80

90

100
„the true life for EN support in critically ill patients“

ITN > 7  sept. shock: n=19; ARF: n = 11; ARDS: n = 4; coma: n =

mean energy deficit
<1200 kcal/d
>1200 kcal/d

Faisy C et al., Br J Nutr 2009
Targeting energy delivery.
ICU patients receiving PN should receive a formulation to cover their needs  

Grade C

Provide energy as close as possible to the measured energy expenditure to decrease negative energy balance.  

Grade B
Impact of a computerized information system on quality of nutritional support in the ICU

Energy delivery > 30 kcal/kg

% of days

Before
After CIS
Non nutritional energy

< 30% BSA
> 30% BSA

*
Considering energy deficit in the intensive care unit
Pierre Singer\textsuperscript{a}, Claude Pichard\textsuperscript{b}, Claudia P. Heidegger\textsuperscript{b} and Jan Wernerman\textsuperscript{c}

Commentary
Toward protein-energy goal-oriented therapy?
Pierre Singer

Curr Opinion Clin Nutr Metab Care 2009; Epud ahead of publication
Crit Care 2009; 13: 158
What are the goals? True life...
The Unresolved Questions of Nutritional Support in the ICU: Now or Later, More or Less, Enteral or Parenteral?

P. Singer, J. Cohen

Aktuel Ernahrungsmed 2012; 37: 1–2
The tight calorie control study (TICACOS): a prospective, randomized, controlled pilot study of nutritional support in critically ill patients.
• Study group:
  • EN: 34  PN: 3
  • EN + PN: 19

• Control group:
  • EN: 48  PN: 1
  • EN + PN: 7
Study
Total energy delivery: 2096 Kcal/Day
Energy delivered by EN: 1552 Kcal/Day
Energy delivered by PN: 479 Kcal/Day

Control
Total energy delivery: 1480 Kcal/Day
Energy delivered by EN: 1261 Kcal/Day
Energy delivered by PN: 139 Kcal/Day

n=56

* P<0.05
Cumulative energy balance kcal/14 days

<table>
<thead>
<tr>
<th>Study</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2087</td>
<td>-3486</td>
</tr>
</tbody>
</table>

P < 0.01
# Clinical outcomes

<table>
<thead>
<tr>
<th></th>
<th>Study n=56</th>
<th>Control n=56</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU Mortality</td>
<td>12 (21.4%)</td>
<td>15 (26.8%)</td>
<td>0.508</td>
</tr>
<tr>
<td>Length of ventilation (days)</td>
<td>17.4±14.5</td>
<td>12.0±8.0</td>
<td>0.015</td>
</tr>
<tr>
<td>ICU Length of stay (days)</td>
<td>18.6±14.4</td>
<td>13.3±7.9</td>
<td>0.017</td>
</tr>
<tr>
<td>Length of hospitalization (days)</td>
<td>36.7±22.8</td>
<td>34.6±28.2</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Hospital survival

Survival Functions

ITT

Per protocol

Cum Survival

Days

Study

Control
Belgium:
Prof. Pierre F Lattere, Brussels
Dr. De Waele, Brussels

Spain:
Dr. Sergio Ruiz, Gran Canaria
Dr. Manuel Cervera, Valencia
Dr. Francisco Fernández, Málaga
Dr. Carmen Sánchez, Murcia
Dr. Juan Carlos Montejo, Madrid

Brazil:
Dr. Diener, Rio de Janeiro
Dr. da Rocha, Iorianópolis, SC

Greece:
Dr. Milly Bitzani, Thessaloniki

Israel:
Prof. Pierre Singer

TICACOS International
Optimization of energy provision with supplemental parenteral nutrition (SPN) improves the clinical outcome of critically ill patients: PRCT

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C.P. Heidegger, S. Graf, R. Thibault, P. Darmon, M. Berger, C. Pichard

Intensive Care Division, Clinical Nutrition, Geneva University Hospital
Intensive Care Service, Lausanne University Hospital
Switzerland

C. Heidegger et al. As presented at ESPEN 2011
SPN Study (Supplemental PN)
Overnutrition vs Undernutrition

Outcome:
- Reduced life span
- Mortality
- Reduced length of stay

Energy:
- Consumption
- Intake

Optimum:
- Weakness
- Impaired mobility
- Difficult weaning
- Pneumonia
- Pressure sore
- Impaired wound healing

Hyperglycemia:
- Getting fat
- Fever
- Difficult weaning
- Infection
Computerized monitoring and indirect calorimetry
Delivery of too many, or too few calories is harmful to the ICU patient.

**Energy deficit:**
- Impairment of:
  - Immune response
  - Defense against oxidative injury
  - Cardiac and respiratory muscle

**Energy excess:**
- $\uparrow$ Gluc, FFAs, insulin resistance
- Oxidative stress, inflammation
- Tissue injury, organ dysfunction
- Impaired immune response
Conclusions:

• For normal population: equations are acceptable
• For patients, there is a large innaccuracy
• Day to day vairability]
• Energy balance may be important in the outcome.
• If possible you should measure