Energy Expenditure and Nutritional Therapy in Critically ill Patients

Elisabeth De Waele, MD, PhD

SIZ Award 2016

Universitair Ziekenhuis Brussel
Vrije Universiteit Brussel

Preiser *et al. Critical Care* (2015) 19:35
DOI 10.1186/s13054-015-0737-8

CRITICAL CARE

REVIEW Open Access

Metabolic and nutritional support of critically ill patients: consensus and controversies

Jean-Charles Preiser[1*], Arthur RH van Zanten[2], Mette M Berger[3], Gianni Biolo[4], Michael P Casaer[5], Gordon S Doig[6], Richard D Griffiths[7], Daren K Heyland[8], Michael Hiesmayr[9], Gaetano Iapichino[10], Alessandro Laviano[11], Claude Pichard[12], Pierre Singer[13], Greet Van den Berghe[5], Jan Wernerman[14], Paul Wischmeyer[15] and Jean-Louis Vincent[1]

Consequences of inappropriate feeding

Underfeeding

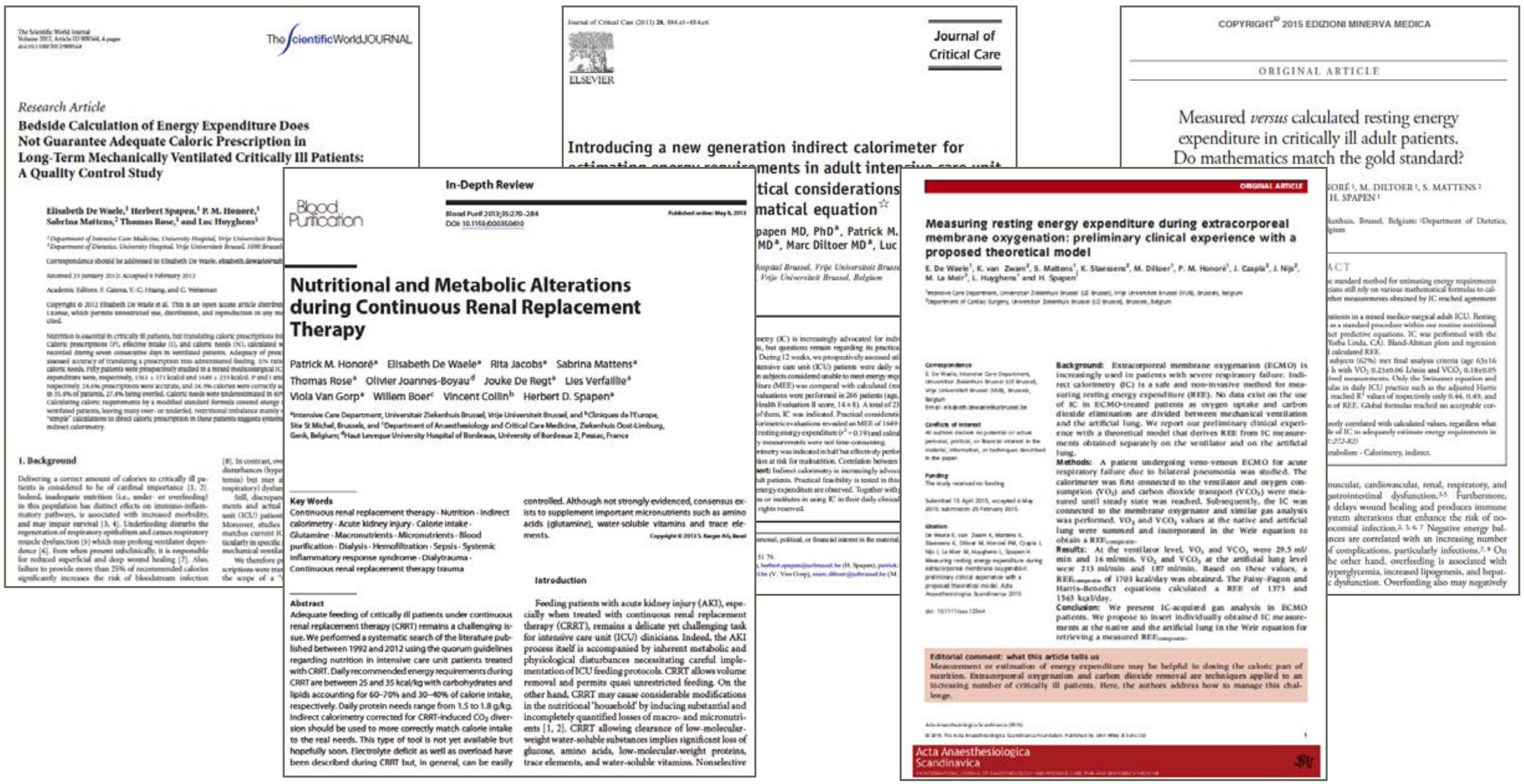
Observational studies have shown the association between negative energy balance and poor outcome

Overfeeding

Provision of macronutrients in excess of metabolic demand is deleterious.

Aim

- To optimize nutritional therapy
- To improve bedside techniques



1. Quality control study

Universitair Ziekenhuis Brussel

Vrije Universiteit Brussel

Methods

- Prospective non-interventional design
- Adult critically ill patients
- Intubation and mechanical ventilation for 7 days
- n=50

De Waele, ScientificWorldJournal. 2012

Protocol

- Prescription/Need
- Intake/Need
- Intake/Prescription

Physicians' note

Harris Benedict Formula

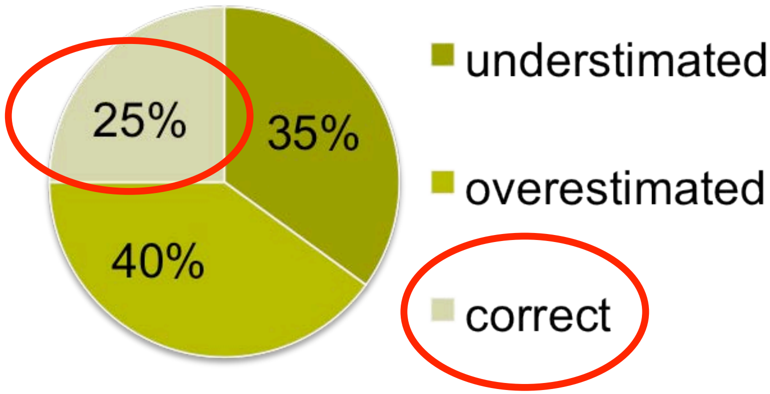
Medical record

Observation days	**350**
Mechanical ventilation	7 days
Number of patients	50

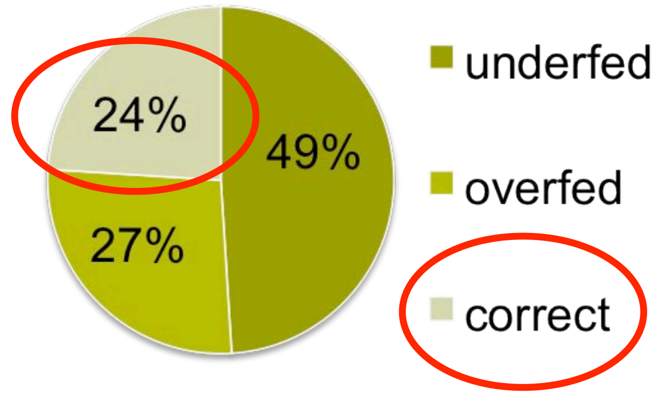
De Waele, ScientificWorldJournal. 2012

Results: Adequacy

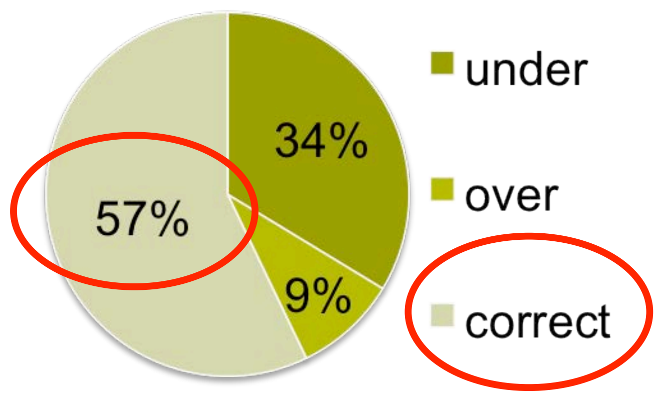
Prescriptions



Intake



Translation



De Waele, ScientificWorldJournal. 2012

2. Feasibility of Indirect Calorimetry to determine Energy Expenditure

Optimal nutrition = use of Indirect Calorimetry

Research

Open Access

Optimal nutrition during the period of mechanical ventilation decreases mortality in critically ill, long-term acute female patients: a prospective observational cohort study

Rob JM Strack van Schijndel[1], Peter JM Weijs[2], Rixt H Koopmans[1], Hans P Sauerwein[3], Albertus Beishuizen[1] and Armand RJ Girbes[1]

→ Energy determined by indirect calorimetry

→ Protein at least 1.2 g/kg/d

Strack van Schijndel, Crit Care, 2009

Indirect Calorimetry

Principle:

- Oxygen consumption
- Carbon dioxide production

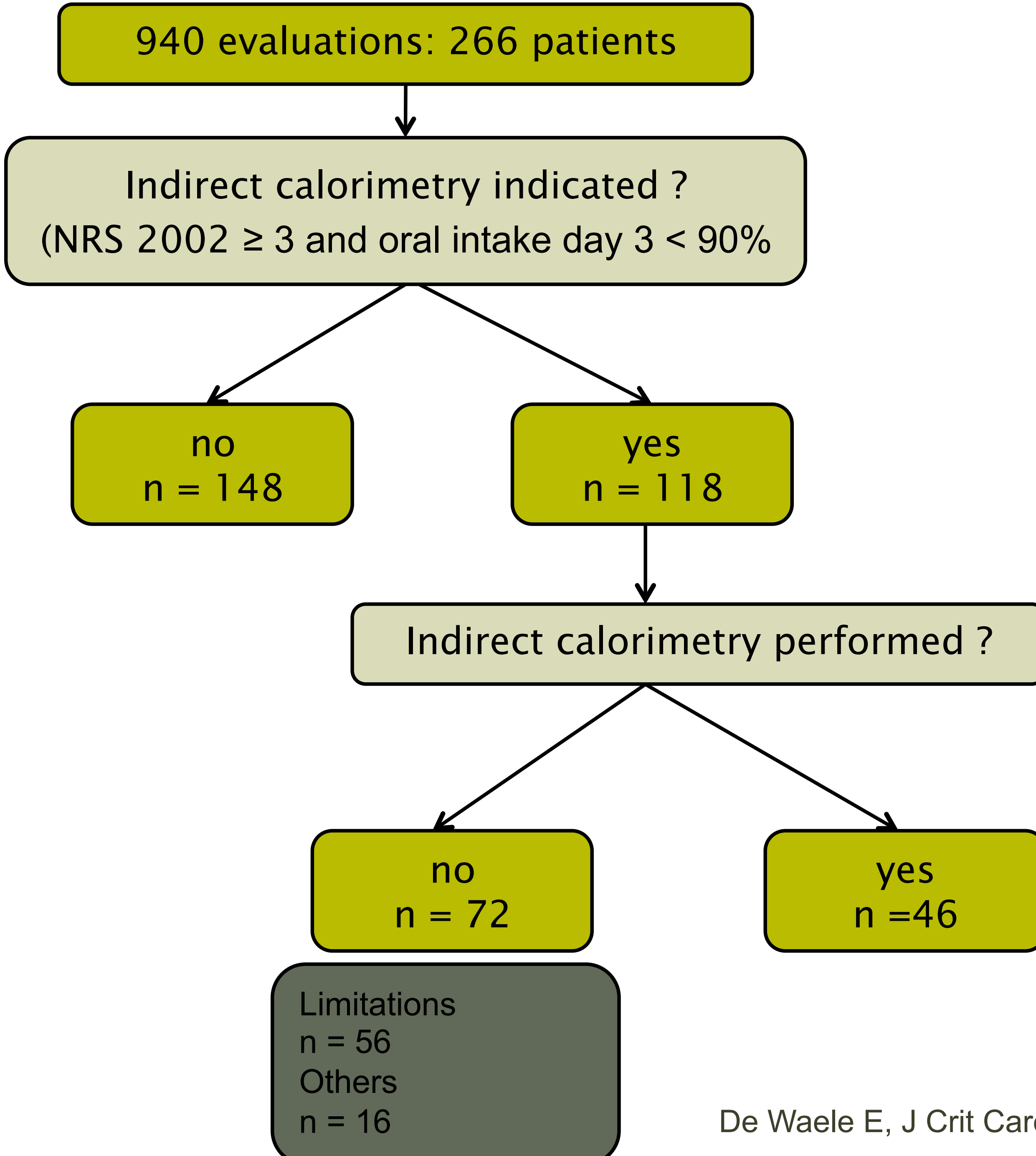
→Metabolism

Abbreviated Weir Equation:

REE = [3.9 (VO2) + 1.1 (VCO2)] 1.44

VO2 = oxygen uptake (ml/min)
VCO2 = carbon dioxide output (ml/min)

Respiratory quotient (RQ) = VCO2/VO2



De Waele E, J Crit Care, 2013

3. Correlation between IC measured and equation-generated Energy Expenditure

Universitair Ziekenhuis Brussel

Vrije Universiteit Brussel

Energy Expenditure - Calculated

	Formula
Harris Benedict 1919	♂: 66.4730 + (13.7516 x W) + (5.0033 x H)-(6.7550 x A) ♀: 655.0955 + (9.5634 x W) +(1.8496 x H)-(4.6756 x A)
Harris Benedict 1984	♂: 88.362 + (13.397 x W) + (4.799 x H)-(5.677 x A) ♀: 447.593 + (9.247 x W) +(3.098 x H)-(4.33 x A)
Faisy-Fagon	(8 x W) + (14 x H) + (32 x Vm) + (94 x T)-4834
Ireton-Jones 1992	1925-(10 x A) + (5 x W) + (281 if ♂) + (292 if trauma present) + (851 if burns present)
Ireton-Jones 1997	1784-(11 x A) + (5 x W) + (244 if ♂) + (239 if trauma present) + (840 if burns present)
Penn State 1998	(1.1 x value of HBE) + (140 x Tmax) + (32 x V_E)-5340
Penn State 2003	(0.85 x value of HBE) + (175 x Tmax) + (33 x V_E)-6433
Penn State 2003b	Mifflin (0.96) + Tmax (167) + Ve (31)-6212 Mifflin: Men: 10(W) + 6.25(H)-5(A) +5
Penn State 2010	Mifflin (0.71) + VE (64) + Tmax (85)-3085 Women: 10(W) + 6.25(H)-5(A)-16
Swinamer	(945 x BSA) – (6.4 x A) + (108x T) + (24.2 x RR) + (817 x V_T)-4349
American College of Chest Physicians (ACCP) recommendation	25 × W – if BMI 16-25 kg/m² use usual body W – if BMI > 25 kg/m² use ideal body W – if BMI < 16 kg/m² use existing body W for the first 7-10days. then use IBW
ESICM '98 statement	Caloric target = caloric need × corrected IBW Formula for calculating IBW ♂: 50 + [0.91x (H-152.4)] ♀: 45.5 + [0.91x (H-152.4)]

Corrected IBW	
If BMI < 18.5	(IBW + actual body W) /2
If BMI 18.5 – 27	IBW
If BMI > 27	IBW x 1.2

Caloric need (kcal/kg/day)	♀	♂
A ≤ 60 years	30	36
A > 60 years	24	30

♂: male; ♀: female; W: weight (kg); H: height (cm); A: age (years); Vm: minute ventilation (L/min); T: body temperature (°C); BSA: body surface area (m²); HBE: Harris Benedict equation; T_{max}: maximum body temperature in the past 24 h (°C); RR: respiratory rate (breaths/min); IBW: ideal body weight (kg); BMI: body mass index (kg/m²); V_E: minute volume (L/min); V_T: tidal volume (L).

Equations for calculating resting energy expenditure (kcal/day)

Degree of correlation between measured and calculated REE

Equation	R^2	Intercept	slope
Harris Benedict 1919	0.43	670,72	0,5403
Harris Benedict 1984	0.44	681,25	0,5420
Ireton-Jones 1992	0.30	1271,66	0,3791
Ireton-Jones 1997	0.28	1073,25	0,3587
Penn-State 1998	0.49	786,78	0,7628
Penn-State 2003	0.47	839,44	0,6377
Faisy-Fagon	0.49	1150,81	0,5358
Swinamer	0.51	1024,30	0,5856
ACCP recommendations	0.24	1171,05	0,2894
ESICM ’98 statement	0.41	658,32	0,9168

R^2 = correlation coefficient

De Waele E, Minerva Anestesiol. 2015

Correlation study

- Poor correlation between IC measurements and equation-derived energy calculations
- In the post-acute phase of critical illness we obtained a mean REE of 21 kcal/kg/day
- Clinical: Nutritional targets may be missed when using calculations

De Waele E, Minerva Anestesiol. 2015

4. Nutrition of patients under continuous renal replacement therapy

Universitair Ziekenhuis Brussel

Vrije Universiteit Brussel

Renal Replacement Therapy
Loss of nutritional substrates
Activation of protein catabolism
Increase in lipid peroxidation (bioincompatibility)

Maynar Moliner, Blood Purif. 2012

Methods

- Systematic review literature 1992-2012
- Nutrition in critically ill patients treated with CRRT
- QUORUM guidelines
- Provide recommendations for daily nutrition management in CRRT practice

Honoré, De Waele E, Blood Purif 2013

Recommendations (summary)

Energy	Indirect calorimetry 25–35 kcal/kg body weight/day	60–70% carbohydrates 30–40% lipids
Protein	1.5–1.8 g/kg body weight/day	
Electrolytes		
K	serum level >4 mEq/l	i.v. supplements K-rich replacement fluid K-rich substitution fluid
P		i.v. supplements substitution fluid enteral supplements
Mg		i.v. bolus 2–4 g/day
Glucose		strict glycemia control
Amino acid	+0.2–2.5 g/kg body weight/day glutamine (alanyl-glutamine dipeptide) 0.3–0.6 g/kg body weight/day	
Lipids		close triglyceride monitoring
Vitamins		
Water-soluble	vitamin B_1: 100 mg/day vitamin B_2: 2 mg/day vitamin B_3: 20 mg/day vitamin B_5: 10 mg/day vitamin B_6: 100 mg/day	vitamin B_7 (biotin): 200 mg/day vitamin B_9 (folic acid): 1 mg/day vitamin B_{12}: 4 µg/day vitamin C: 250 mg/day
Fat-soluble	vitamin E: 10 IU/day vitamin K: 4 mg/week	vitamin A: reduce supplementation
Trace elements	selenium: +100 µg/day zinc: 50 mg/day copper: 5 mg/day	triple dose of i.v. trace elements-containing solutions
Body temperature	>37°C	

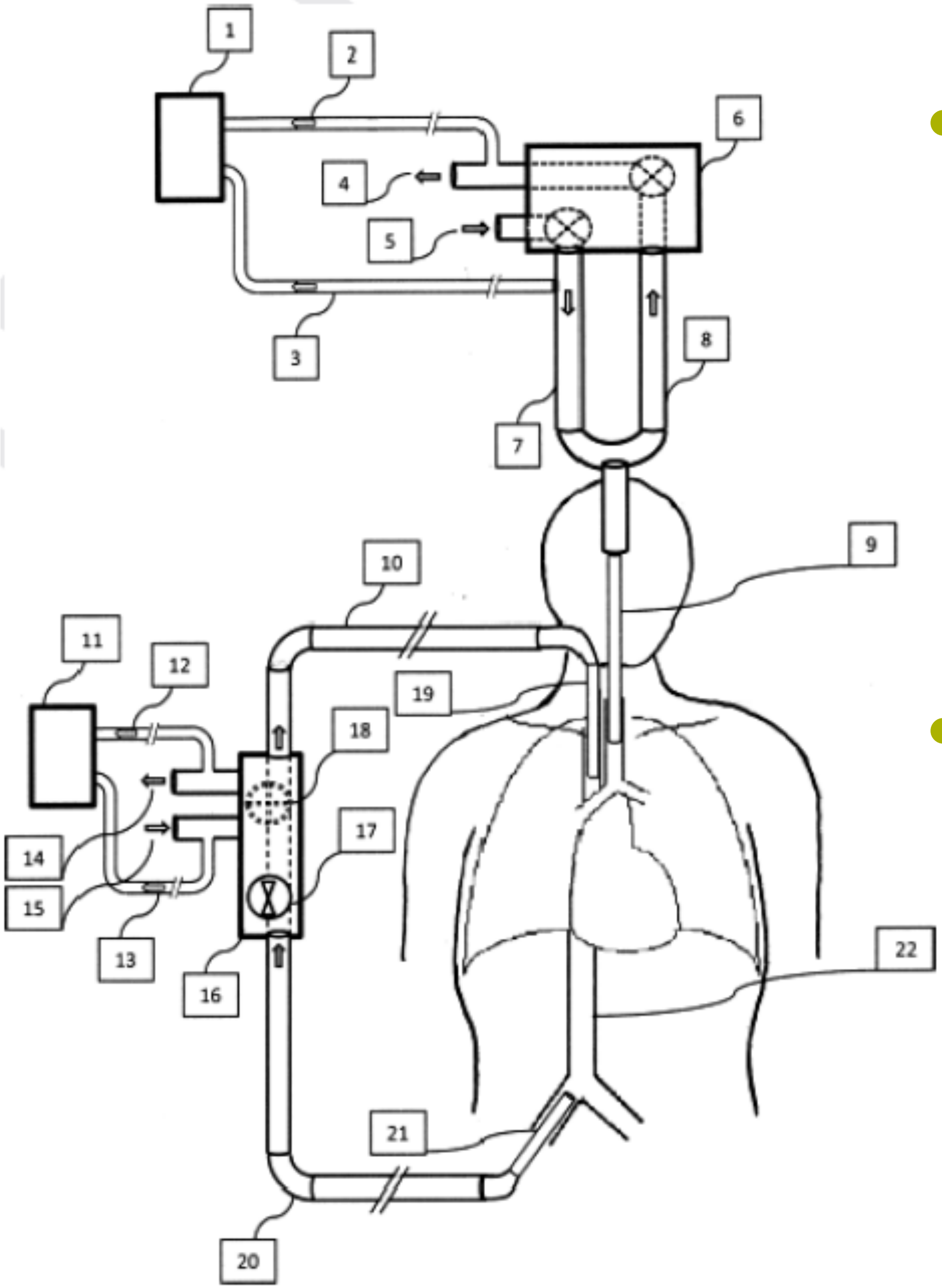
Honoré, De Waele E, Blood Purif 2013

5. Indirect Calorimetry during Extra-Corporeal Membrane Oxygenation

Nutrition implications and challenges of the transplant patient undergoing extracorporeal membrane oxygenation therapy.

- Provision of adequate nutrition support challenging
- Clinical guidelines are available for the nutrition support of neonates
- No guidelines for the adult population
- Guidelines for nutrition support therapy in the adult critically ill provide best guidance.

Ulerich, Nutr. Clin Pract. 2014

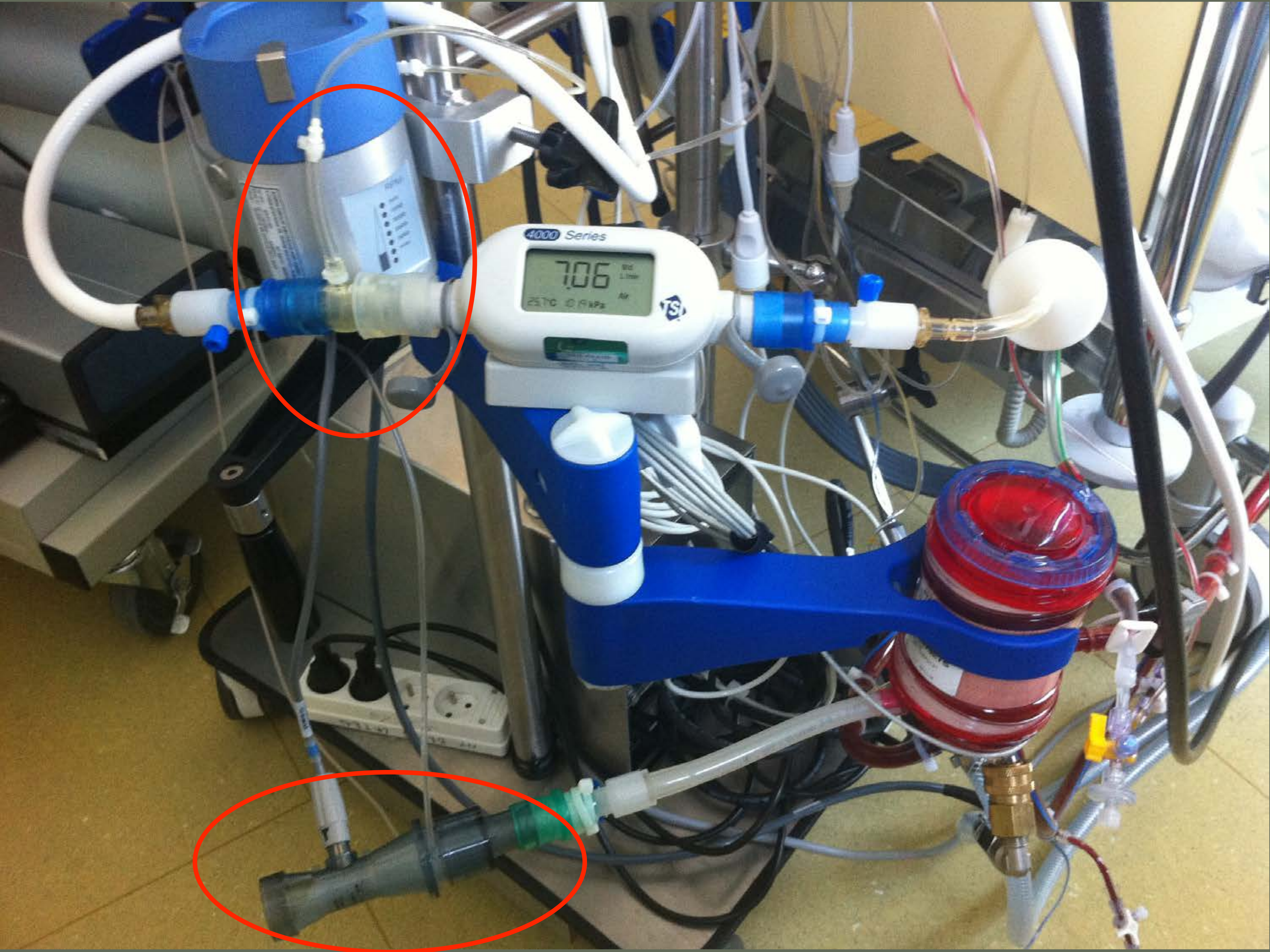


- 30 minutes indirect calorimeter connected to the ventilator
- 30 minutes indirect calorimeter connected to the oxygenator

De Waele, Acta Anaesthesiol Scand. 2015


1000 ml
MOOG


4000 Series


4000 Series
7.06
Air
TSI

Calculation case

- $Weir$: heat output total kg.cal. = (3.9 x L O_2 used + 1.1 x L CO_2 produced)
- $Weir_{abbr}$ REE kcal = {(3.94 x VO_2) + (1.1 x VCO_2)} x 1440
- $Weir_{ECMO}$: REE = {(3.94 x $VO_{2\ total}$) + (1.11 x $VCO_{2\ total}$)} x 1440

  $Weir_{ECMO}$: REE = {(3.94 x 0.243 L/min) + (1.11 x 0.203 L/min)} x 1440 min/24h

  REE = (0.957 + 0.225) x 1440 = 1.182 L/min x 1440 min/24h = 1703 kcal/day

  $VO_{2\ total} = VO_{2\ native\ lung} + VO_{2\ ECMO}$

  $VO_{2\ total}$ = 29.5 ml/min + 213 ml/min = 243 ml/min

  $VCO_{2\ total} = VCO_{2\ native\ lung} + VCO_{2\ ECMO}$

  $VCO_{2\ total}$ = 16 ml/min + 187 ml/min = 203 ml/min

- $VO_{2\ ECMO} = (Fi_{O2\ ECMO} \times VI_{ECMO}) - (Fe_{O2\ ECMO} \times VE_{ECMO})$

  $VO_{2\ ECMO}$ = (0.950 x 3.5 L/min) – (0.889 x 3.5 L/min)

  = 3.325 L/min – 3.112 L/min = 0.213 L/min = 213 ml/min

- $VCO_{2\ ECMO} = (Fe_{CO2\ ECMO} \times VE_{ECMO}) - (Fi_{CO2\ ECMO} \times VE_{ECMO})$

  $VCO_{2\ ECMO}$ = (0.0539 x 3.5 L/min) – (0.00053 x 3.5L/min)

  = 0.189 L/min – 0.00186 L/min = 0.187 L/min = 187 ml/min

- $VCO_{2\ native\ lung} = (Fe_{CO2} \times VE_{native\ lung}) - (Fi_{CO2} \times VE_{native\ lung})$

  $VCO_{2\ native\ lung}$ = (0.00429 x 4.22 L/min) – (0.00051 x 4.22 L/min)

  = 0.0181 L/min – 0.00215 L/min = 0.0160 L/min = 16 ml/min

Conclusions

Conclusions (1)

- Nutritional therapy quality was low in our ICU
- Indirect calorimetry is feasible in daily clinical practice and indicated in half of ICU patients
- Equations used to estimate Energy Expenditure correlate very weakly with IC-EE

Conclusions (2)

- Nutritional treatment recommendations for patients undergoing Renal Replacement Therapy
- Indirect Calorimetry is made feasible in patients on Extra Corporeal Membrane Oxygenation

Energy Expenditure and Nutritional Therapy in Critically ill Patients

Thank you

Universitair Ziekenhuis Brussel

Vrije Universiteit Brussel