mysafety insight

Metabolic Monitoring

Clinical Information Leaflet

mindray
healthcare within reach

Appropriate Nutrition Support Matters

Nutrition can impact clinical outcomes

The importance of nutrition therapy in the care of critically ill patients is increasingly acknowledged. Over-nutrition and under-nutrition may be associated with infection, duration of mechanical ventilation, length of stay in ICU as well as in the hospital, and mortality [1,2,3]. In addition, undernutrition can lead to loss of muscle strength and pressure sores, while overfeeding can result in hyperglycemia, hyperlipidemia, hypercapnia, and exacerbation of respiratory failure (Figure 1) [4].

Therefore, delivering careful nutrition support is seen as a proactive therapeutic strategy that may reduce disease severity, diminish complications, decrease the length of stay in the ICU, and favourably improve patient outcomes [5]. Evidence has shown that the right nutritional intervention has a positive clinical impact that can be objectively measured [6,7,8].

As the first step, an accurate assessment of patient energy demand is key to prevent overfeeding and underfeeding.

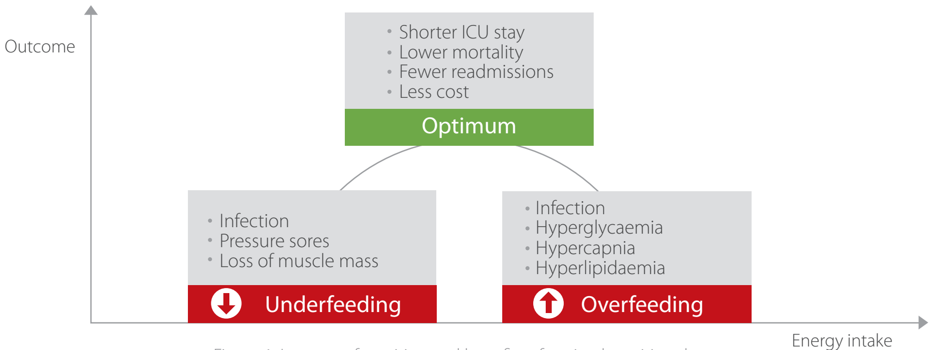


Figure 1. Impacts of nutrition and benefits of optimal nutrition therapy

The Assessment of Nutrition Demands is Challenging

Determining exact energy demands of critically ill patients can be difficult. Many factors, such as the acuity of illness and treatment plans, can affect the patient's metabolism which affects their energy expenditure (EE).

Components of daily energy expenditure

The 24-hour total energy expenditure (TEE) of a patient is composed of basal metabolic rate (BMR, approximately 60-75% of total energy expenditure in healthy people and may account for 75-100% of total energy expenditure in the critically ill), thermic effect of food (TEF, approximately 10% of total energy expenditure), physical activity (Figure 2), and possible disease process (including healing) [9,10,11,12].

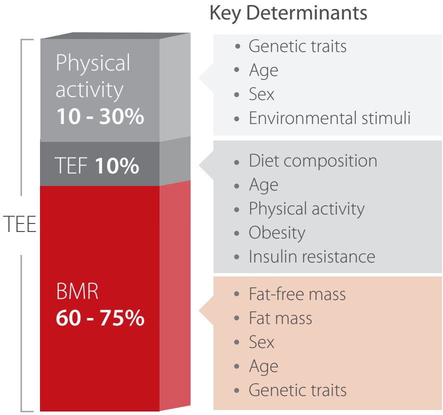


Figure 2. Components of total daily energy expenditure [13]

In clinical practice, resting energy expenditure (REE) is often interchangeable with BMR. While BMR is a minimum number of calories required for basic functions at rest, REE is the number of calories that the body burns while it is at rest. Although there is a small difference between BMR and REE, REE could be an accurate estimate of the BMR [14]. The amount of lean body mass is the most important determinant of REE, but other factors (age, gender, temperature, thyroid function, systemic inflammation, disease process, clinical intervention) also affect REE.

REE is a reference for nutrition demands

The 24-hour total energy expenditure of a healthy individual or a patient is an important reference for nutritional therapy. It is usually determined by measuring the REE via indirect calorimetry or by estimation with the help of formulas like Harris-Benedict equation [15]. Other components of TEE, such as thermic effect of food and energy expended during physical activity, are estimated afterwards. In the ICU setting, TEE of a patient is generally only 0–7% higher than REE (not markedly different), due to low physical activity and low thermic effect of food [16].

More than 200 equations have been developed to predict REE for critically ill patients. These equations like Harris-Benedict equation, are calculated generally based on weight, height, age and sex. However, conditions such as particularly sepsis, trauma and burns, can cause a clinically relevant increase in REE (Figure 3) [17]. Though some of the equations involve additional factors taken into consideration if the patient is ventilated, or has multiple trauma, burns, or obesity, they have been demonstrated in many studies to have a low level of accuracy for critically ill patients, leading to large errors in the estimation of energy requirements [18,19].

Condition	REE Change
Fever (per 1℃)	10 to 15%
Sepsis	20 to 60%
Trauma	20 to 50%
Burn	50~85%
Mechanical Ventilation	-25~-35%
Agitation	50~100%

Figure 3. Influencing factors of REE for critically ill patients

Compared with predictive equations, indirect calorimetry (IC) is able to provide a more individualised assessment of REE. Indirect calorimetry is the science related to metabolic process analysis, providing the measurement of energy expenditure and respiratory quotient. It has been proposed as the gold standard to determine energy needs for critically ill patients and recommended by the European Society for Parenteral and Enteral Nutrition (ESPEN) and the American Society for Parenteral and Enteral Nutrition (ASPEN) in their guidelines [5,20,21,22].

What is indirect calorimetry

The principle of indirect calorimetry derives from the fact that human body burns its available fuels (carbohydrates, fat, and protein) utilising oxygen and producing carbon dioxide, water, nitrogen and heat (Figure 4) [23,24]. Under steady-state conditions, respiratory gas exchange is in equilibrium with gas exchange within the mitochondria, thus indirectly measuring oxidative phosphorylation. Therefore, respiratory gas exchange can be estimated as a surrogate for substrates consumed and produced during metabolism as well as the heat generated.

Substrate	Gas volume equivalent of 1g of substrate (L)			Caloric value (kJ/g)
	O_2	CO_2	RQ	
Carbohydrate	0.829	0.829	1.0	16
Fat	2.016	1.427	0.707	37
Protein	0.966	0.782	0.809	17

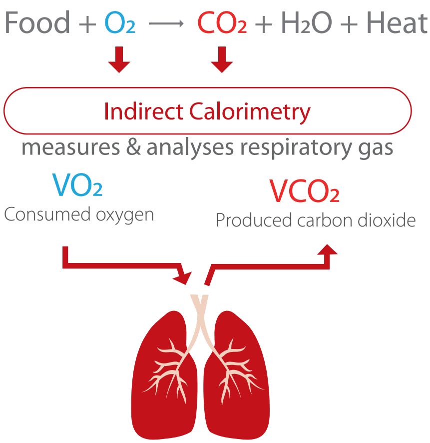


Figure 4. Simplified principle of metabolic process and indirect calorimetry technique

With the help of indirect calorimetry, the patient' s resting energy expenditure can be calculated through measuring continuous oxygen consumption (VO_2) and carbon dioxide production (VCO_2), where the Weir formula is the most commonly used (Figure 5) [25,26]. Since the contribution of protein oxidation to the total energy expenditure is small, the nitrogen generated from protein oxidation is usually estimated or ignored without causing an obvious error in the estimated energy expenditure [27].

$$\mathbf{EE} = (3.94 \times MVO_2 + 1.106 \times MVCO_2) \times 1.44 - 2.17 \times UN$$

$$\mathbf{RQ} = MVCO_2 / MVO_2$$

$$\mathbf{MVO_2} = MVinsp \times FiO_2 - MVexp \times FeO_2$$

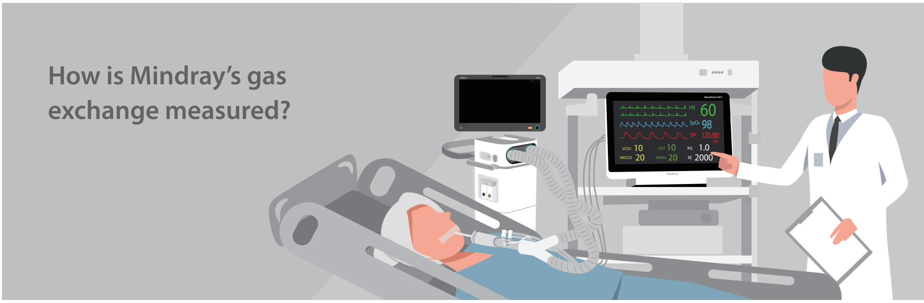
$$\mathbf{MVCO_2} = MVexp \times FeCO_2 - MVinsp \times FiCO_2$$

EE: kCal/day; **$MVCO_2$, MVO_2:** mL/min
UN: estimated urinary nitrogen excretion, 13g/24h

Figure 5. Equations to calculate EE and RQ

Indirect calorimetry provides two pieces of information: a measure of 24-hour energy expenditure or caloric requirements as reflected by the Energy Expenditure (EE) and a measure of substrate utilisation as reflected in the Respiratory Quotient (RQ) (Figure 5). The value of EE can help doctors determine nutrition prescription, while a variation of RQ in response to the feeding regimen can be used to validate those decisions.

Individualised Metabolic Monitoring Solutions



Mindray bedside patient monitors utilise indirect calorimetry technology, offering the possibility to calculate metabolic parameters for ventilated patients. It is achieved by sharing gas samples from the patient's mechanical ventilator circuit with the patient monitor's modular analysers. The gas exchange measurement is captured through a gas analyser (gas sampling and analysing module) together with a respiratory mechanics analyser (RM module). The gas analyser can be either a sidestream EtCO_2 with O_2 measurement module or the anaesthesia-gas (AG) with O_2 measurement module, using a paramagnetic O_2 sensor and the infrared CO_2 analyser. The respiratory mechanics module can provide a full set of respiratory mechanics parameters, including flow volume.

Parameters and interpretation

Volumetric parameters	
VCO_2 (ml)	CO_2 production for one breath
VO_2 (ml)	O_2 consumption for one breath
$MVCO_2$ (ml/min)	CO_2 minute production
MVO_2 (ml/min)	O_2 minute consumption

CO_2 production: Amount of expired CO_2 minus the amount of inspired CO_2

O_2 consumption: Amount of inspired O_2 minus the amount of expired O_2

Metabolic parameters	
RQ	Respiratory quotient
Substance	**RQ**
Carbohydrates	1
Proteins	0.8-0.9
Fats	0.7
Malic acid	1.3
EE(kCal/day)	Energy expenditure

- **Energy expenditure (EE):** It represents the resting energy expenditure measured under resting conditions, helping doctors determine the energy needs of critically ill patients.

- **Respiratory quotient (RQ):** It is the ratio between carbon dioxide produced and oxygen consumed by the body, illustrating the substrate utilisation by the patient during resting state.

Typically, the range of RQ is between 0.7 and 1.0. A ratio of 0.7 is indicative of sole use of lipids, whereas a ratio of 1.0 indicates the exclusive use of carbohydrates. Energy-mixed substrates from fat, protein, and carbohydrates normally yield an RQ of 0.85. Underfeeding, which promotes the use of endogenous fat stores, should cause decreases in the RQ, whereas overfeeding, which results in lipogenesis, should cause increases in the RQ (Figure 6). Marked increases in VCO_2 (with subsequent increases in RQ) in response to overfeeding may cause respiratory compromise in patients with limited pulmonary reserve. Thus, variation in the RQ in response to the feeding regimen may indicate inappropriate feeding and serve as a marker for patient intolerance [28].

RQ Interpretation Chart

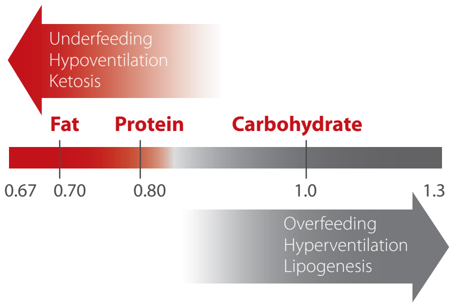


Figure 6. Influencing factors of REE for critically ill patients

Clinical value and practice recommendations

Clinical value

- Management of a patient's metabolic status
- Nutritional assessment
- Treatment decision aid (ventilation, oxygenation and nutrition)
- Support for the weaning process

Recommendations to improve measurements [29]

- Collecting data in a quiet and thermoneutral environment
- Ensuring that the patient is resting in supine position >30 min before the study
- Ensuring that the rate and composition of continuously infused nutrients is stable at least 12 hours before the study
- Patients receiving intermittent feedings should be studied about 1 hour after the feeding if thermogenesis is to be included in the REE, or 4 hours after the feeding if thermogenesis is to be excluded in the REE

Factors that can affect results [29]

- Mechanical ventilation with FiO_2>60%
- Mechanical ventilation with PEEP>12 cm H_2O
- FiO_2 changes during the measurement
- Sampling system leakage
- Hyper/hypoventilation which alters the body's CO_2 stores
- Moisture in the system which can affect the O_2 analyser

Mindray's metabolic monitoring technology provides the highest standards to determine energy expenditure in critically ill patients continuously. The modular design allows fast set-up at the bedside, and its integration enables convenient access to both hemodynamic and respiratory parameters within one glance at the patient monitor screen.

References:

1. Dvir, D., Cohen, J. & Singer, P., 2006. Computerized energy balance and complications in critically ill patients: An observational study. Clinical Nutrition, 25(1), pp.37–44.

2. Villet, S. et al., 2005. Negative impact of hypocaloric feeding and energy balance on clinical outcome in ICU patients. Clinical Nutrition, 24(4), pp.502–509.

3. Braunschweig, C.A. et al., 2015. Intensive Nutrition in Acute Lung Injury. Journal of Parenteral and Enteral Nutrition, 39(1), pp.13–20.

4. Hiesmayr, M., 2012. Nutrition risk assessment in the ICU. Current Opinion in Clinical Nutrition and Metabolic Care, 15(2), pp.174–180.

5. Mcclave, S.A. et al., 2009. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). JPEN. Journal of parenteral and enteral nutrition, 33(3), pp.277–316.

6. Stratton, R.J. et al., 2005. Enteral nutritional support in prevention and treatment of pressure ulcers: A systematic review and meta-analysis. Ageing Research Reviews, 4(3), pp.422–450.

7. Lawson, R.M. et al., 2003. The effect of unselected post-operative nutritional supplementation on nutritional status and clinical outcome of orthopaedic patients. Clinical Nutrition, 22 (1), pp.39–46.

8. Banks, M. et al., 2010. Malnutrition and pressure ulcer risk in adults in Australian health care facilities. Nutrition, 26(9), pp.896–901.

9. Geissler et al., 2017. Human nutrition / edited by Catherine Geissler, Hilary Powers. Thirteenth.,

10. Walker, R.N. & Heuberger, R.A., 2009. Predictive equations for energy needs for the critically ill. Respiratory care, 54(4), pp.509–521.

11. Du et al., 2014. The Thermic Effect of Food is Reduced in Older Adults. , 46(5), pp.365–369.

12. Demling, R.H., 2009. Nutrition, anabolism, and the wound healing process: an overview. Eplasty, 9, p.e9.

13. Lam, Y.Y. & Ravussin, E., 2016. Analysis of energy metabolism in humans: A review of methodologies. Molecular Metabolism, 5(11), pp.1057–1071.

14. Cuerda, C. et al., 2007. How accurate are predictive formulas calculating energy expenditure in adolescent patients with anorexia nervosa? Clinical Nutrition, 26(1), pp.100–106.

15. Harris, J.A. & Benedict, F.G., 1918. A Biometric Study of Human Basal Metabolism. Proceedings of the National Academy of Sciences of the United States of America, 4(12), pp.370–373.

16. Kreymann, G., Adolph, M. & Mueller, M.J., 2009. Energy expenditure and energy intake – Guidelines on Parenteral Nutrition, Chapter 3. GMS German Medical Science, 7, p.Doc25.

17. Chioléro, R., Revelly, J.-P. & Tappy, L., 1997. Energy metabolism in sepsis and injury. Nutrition, 13(9), pp.45–51.

18. Gupta, R. et al., 2017. Indirect calorimetry: From bench to bedside. Indian Journal of Endocrinology and Metabolism, 21 (4), pp.594–599.

19. Zusman, O. et al., 2019. Predictive equations versus measured energy expenditure by indirect calorimetry: A retrospective validation. Clinical Nutrition, 38(3), pp.1206–1210.

20. SINGER, P., & COHEN, J. D., 2003. Clinical Applications of Indirect Calorimetry in the Intensive Care Setting. Intensive Care Medicine, pp.912–919.

21. Schoeller, D.A., 2007. Making Indirect Calorimetry a Gold Standard for Predicting Energy Requirements for Institutionalized Patients. Journal of the American Dietetic Association, 107(3), pp.390–392.

22. Singer, P. et al., 2019. ESPEN guideline on clinical nutrition in the intensive care unit. Clinical Nutrition, 38(1), pp.48–79.

23. Macdonald, I., 1991. Energy metabolism, indirect calorimetry, and nutrition: By Bursztein, Elwyn, Askanazi and Kinney Williams & Wilkins 1989. Clinical Nutrition, 10(3), p.177.

24. Bender, D.A., 2014. Introduction to Nutrition and Metabolism, Fifth Edition, Bosa Roca: CRC Press LLC.

25. Bursztein S. et al., 1989. A mathematical analysis of indirect calorimetry measurements in acutely ill patients. American Journal of Clinical Nutrition, 50, pp.227–230.

26. Weir, J.B.D.B., 1949. New methods for calculating metabolic rate with special reference to protein metabolism. The Journal of physiology, 109(1-2), pp.1–9.

27. Brandi, L.S. et al., 1992. Energy expenditure and gas exchange measurements in postoperative patients: Thermodilution versus indirect calorimetry. Critical Care Medicine, 20 (9), pp.1273–1283.

28. McClave, S.A. et al., 2003. Clinical use of the respiratory quotient obtained from indirect calorimetry. Journal of Parenteral and Enteral Nutrition, 27(1), pp.21–26.

29. Merritt R. et al, 2005. The A.S.P.E.N Nutrition Support Practice Manual 2nd Edition, pp.277-278.

healthcare within reach

MINDRAY SOCIAL MEDIA CHANNELS

LinkedIn @Mindray

@Mindray Global

Wechat

www.mindray.com

P/N: ENG-Metabolic Monitoring Clinical Information Leaflet-210285X8P-20200707

mindray
healthcare within reach