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Indirect Calorimetry in an Obese Critically Ill Patient

Emily Haller, RD

Abstract

Use of predictive equations to determine energy requirements in critically ill obese patients can result in under- or overfeeding due to differences in body composition and severity of metabolic stress. In this case study, a morbidly obese woman presents from an outside hospital with community-acquired pneumonia and acute respiratory distress syndrome. The accuracy of the predictive equations used to estimate her energy needs is questioned because her body mass index (BMI) is greater than 60 and she is fluid overloaded. Indirect calorimetry (IC) documents a higher measured resting expenditure than original predicted energy needs. IC can provide more accurate assessments if patients meet specific parameters and they achieve a steady state (period of "metabolic equilibrium") during the study.

Introduction

The obesity epidemic in the United States is reflected in intensive care units (ICUs) across the nation, with epidemiologic studies suggesting that one third of the patients in an ICU are obese (1). Obesity is associated with increased morbidity and mortality as well as disorders in respiratory, cardiovascular, and metabolic functions, all of which create challenges in caring for an obese patient in the ICU. For the nutrition support registered dietitian (RD) or registered dietitian nutritionist (RDN), the challenge with these patients is accurate estimation of energy needs. A specific concern is that the accuracy of predicting energy requirements from published equations decreases as BMI increases (2).

Frankenfield and associates (3) recently compared multiple commonly used equations with IC measurements to validate their use in underweight and morbidly obese critically ill patients. For the morbidly obese group, the Penn State equation was the most accurate equation and the only one determined to be valid, predicting the resting metabolic rate to within 10% in 76% of cases. Both the standard and the modified Penn State equation were tested and validated. Interestingly, researchers noted that the modified version, which is used in adults older than 60 years, did not provide an advantage in overall accuracy in the morbidly obese compared to the standard version (3).

Another common clinical concern is the prevalence of malnutrition in the acute-care

Table 1. Nutrition Assessment on Day of Admission

Height: 162.6 cm Admission Weight: 186.4 kg   Dry Weight: 170 kg   Ideal Body Weight (IBW): 54.5 kg Body Mass Index: 64.3 (per 170 kg)
Estimated Nutrition Goals (per A.S.P.E.N./SCCM Guidelines [4]): Energy: 1,850 to 2,400 kcal (11 to 14 kcal/kg, per 170 kg) Protein: 110 to 135 g (2 to 2.5 g/kg, per IBW)
Nutrition Diagnosis: Inadequate protein-energy intake related to increased nutrient needs, patient's clinical status as evidenced by patient nil per os status x 3 days.
Enteral Access: Nasogastric tube
Diet order: Nil per os
Skin: 2+ bilateral lower extremity chronic lymphedema, wound from left breast incision and drainage

setting, which is associated with poor clinical outcomes and places a financial hardship on the health care system. Provision of adequate energy is essential to prevent malnutrition, which makes accurate estimation or measurement of energy needs in the critically ill obese patient even more important.

Case Presentation

A 40-year-old woman is admitted from an outlying hospital with hemodynamic instability and profound hypoxemia. Her medical history includes iron deficiency anemia, diabetes mellitus, chronic lower extremity lymphedema, morbid obesity, and carcinoid syndrome status following left lung lobectomy. She had originally presented to the outlying hospital 1 month ago with a 1-day history of shortness of breath, fever, and malaise. She had been discharged with home vancomycin after undergoing irrigation and debridement of a left breast abscess. At baseline, she was receiving 3 L home oxygen.

She returns to that hospital emergency department with a Pao_2 of 59 mm Hg (normal, 80 to 100 mm Hg). She is intubated and placed on the ventilator for septic shock. She shows no improvement with biphasic intermittent positive airway pressure, pressure control ventilation (PCV), or high-frequency oscillatory ventilation. Her diagnosis is consistent with community-acquired pneumonia and acute respiratory distress syndrome.

When transferred, she is receiving norepinephrine 0.15 mcg/kg/min (16 mg/250 mL) and vasopressin 0.04 units/min (50 units/50 mL) for hemodynamic instability and cisatracurium for neuromuscular paralysis, with a goal mean arterial pressure (MAP) of greater than 65 mm Hg. She is admitted to the surgical ICU for an extracorporeal membrane oxygenation (ECMO) evaluation.

Chest radiography reveals gross consolidation on the right side, and a bronchoscopy documents mucopurulent exudate with erythema of the right mainstem bronchi. The patient is started on broad-spectrum antibiotic therapy and oseltamivir. She is not placed on EMCO, but a plan for weaning her off of vasopressors and the ventilator is put in place. She is initially placed on PCV with peak inspiratory pressure (PIP) of 42 cm H_2O, and positive end-expiratory pressure (PEEP) of 24 cm H_2O, which is gradually reduced to a PIP of 40 cm H_2O and PEEP of 16 cm H_2O. Ventilatory support is continually weaned based on oxygenation of arterial blood gases. By keeping the right side of the bed raised, the medical team gradually can reduce the patient's Fio_2 over a course of 8 hours from 100% to 80%. Over the next 2 weeks, the patient's respiratory status gradually improves, and she is extubated on hospital day 16. Initially after extubation, she is on bilateral positive airway pressure (BiPaP) to recruit her alveoli and keep them open. BiPaP is subsequently weaned to use only at night, and on the day of discharge, her oxygen requirement is 4 L via nasal cannula, close to her baseline of 3 L, with use of BiPaP at night for obstructive sleep apnea.

During her ICU stay, the patient initially receives a furosemide drip and metolazone 10 mg twice daily, with a goal of net negative 1 L every 8 hours. She responds to diuresis and is eventually weaned to intermittent furosemide therapy as tolerated. She tolerates the diuresis hemodynamically and her electrolytes are supplemented as needed.

Table 2. Ideal Patient Parameters for Indirect Calorimetry

• Mechanical ventilation with Fio_2 ≤60
• Positive end-expiratory pressure (PEEP) <12 cm H_2O
• Supine position or at rest in recliner for 30 minutes
• Quiet, thermoneutral environment
• Patient displaying usual patterns of voluntary muscle activity
• Avoid: – Administration of analgesics or sedatives within 30 minutes of study initiation – Intermittent hemodialysis or peritoneal dialysis within 4 hours of study initiation – Painful procedures within 1 hour of study initiation – General anesthesia within 6 to 8 hours of study initiation – Changes in ventilator settings within 90 minutes of study initiation – Routine patient care activities during the study
• Stable nutrient delivery for 12 hours before initiation of study on continuous feeding regimen if thermogenesis is to be included in the resting energy expenditure measurement

Data from Wooley JA, Sax HC. Indirect calorimetry: applications to practice. *Nutr Clin Pract.* 2003; 18:434–439.

Assessment and Nutrition Support

A nutrition assessment is completed on the patient's first day of admission. Her anthropometric and nutrition parameters are shown in Table 1.

Enteral nutrition (EN) is started on hospital day 2, once the patient is off of the norepinephrine and vasopressin and is hemodynamically stable, with a goal MAP of greater than 65 mm Hg. The RD selects a 1.5-kcal/mL formula and starts administration at 20 mL/hr, advancing by 10 mL every 8 hours until reaching the goal rate of 55 mL/hr on hospital day 3. This

(Continued on next page)

Table 3. Indirect Calorimetry Measurement

Resting energy expenditure	3,145 kcal/day
Respiratory quotient	0.82
Steady state	Yes
Positive end-expiratory pressure	10 cm H_2O
Fio_2	39

Table 4. Evaluation of Steady State

	Oxygen Consumption (mL/min)	Carbon Dioxide Elimination (mL/min)	Respiratory Quotient	Resting Energy Expenditure (kcal/day)
Mean	450	370	0.82	2,145
Standard deviation	15.34	22.9	0.03	118
Coefficient of variation (%) (Goal is <10%)	3.4	6	4	3.8

regimen provides 1,320 mL formula, 1,980 kcal, 82 g protein, and 1,005 mL free water per 24 hours. A liquid protein modular is used to help meet the patient's protein needs. Each packet of the modular provides 72 kcal and 15 g protein. A total of three packets per day is prescribed to provide an additional 216 kcal and 45 g protein per 24 hours. The EN formula and protein modular provide a total 2,196 kcal and 127 g protein per 24 hours.

During the first week of admission, the patient remains intubated and sedated and receives a daily average of 1,595 kcal and 95 g protein from EN and liquid protein modular, meeting 72% of the prescribed energy goal and 74% of the prescribed protein goal. She does not receive goal EN during the first week because her feedings are held for multiple tests and procedures. When the RD reassesses the patient on hospital day 8, they add a fourth packet of the protein modular to the nutrition prescription to assist in the delivery of adequate protein. The patient's nutrition regimen of EN formula at 55 mL/hr x 24 hours plus one packet of protein modular every 6 hours provides 2,268 kcal and 142 g protein per day. During the second week of admission, she receives a daily average of 2,135 kcal and 120 g protein from EN and liquid protein modular, meeting 94% of the energy goal and 84% of the protein goal.

The patient remains on the ventilator, but her clinical status improves sufficiently to provide favorable parameters (Table 2) for an IC measurement. At this facility, the RD and respiratory therapist (RT) collaborate to identify and assess mechanically vented patients who are candidates for an IC study as well as discuss and interpret the study's results. On hospital day 15, the RT completes a 20-minute IC study in which a 5-minute steady state is reached (Table 3) and results are validated (Table 4). The patient's measured resting energy expenditure (REE) of 3,145 kcal/day is higher than both her original predicted energy needs and what her current enteral regimen is providing. A comparison of her measured REE to the daily average of 2,135 kcal she is receiving shows that she is meeting only 67% of her needs during her second week of hospitalization. Despite being underfed, which is not ideal, her clinical status improves and she is extubated on hospital day 16. She continues to receive EN, and a swallow study is performed on hospital day 17. She is approved for a regular diet. Tube feedings continue and a calorie count is started to assess her ability to consume adequate oral intake. Results show that she is able to consume adequate energy intake, and her feeding tube is removed. The patient is discharged on a regular diet.

Discussion

Several factors were taken into consideration when interpreting results of the patient's IC study. The first consideration was whether the respiratory quotient (RQ) was within the human biological range of 0.67 to 1.3. RQ is the ratio of the volume of carbon dioxide produced (V_{CO_2}) to the volume of oxygen consumed (V_{O_2}). This measurement is useful for validating an IC study by ensuring that the value falls within the physiologic range. When values are outside of this range, the IC study should not be considered valid and the REE should not be used (5,6).

Another factor is whether the patient achieves a steady state. Steady state represents a period of "metabolic equilibrium" and is generally defined as a 5-minute interval where the coefficient of variation for the REE (V_{O_2} and V_{CO_2}) and the RQ are less than 10% (5,7). The calculations used to determine the coefficient of variation are shown in Table 5.

The patient's IC study measured an RQ of 0.82, which is within the physiologic range (0.67 to 1.3) and helps to confirm the test's validity. This patient reaches a steady state, which also helps confirm the reliability of the IC study, as the coefficients of variation are all less than 10%. Her measured REE of 3,145 kcal is greater than her predicted energy needs (Table 6). Hospital day 15 is the first day the patient meets favorable parameters to conduct an IC study (Table 2) with improved respiratory status. She is extubated the following day, so no change is made to her enteral feeding regimen. Had the patient not been extubated, her daily energy goal could have been increased to feed closer to her measured REE.

Predictive equations for the obese population remain unclear because energy expenditure can vary substantially, depending on differences in body composition and severity of metabolic stress (5,6,8). Accordingly, this patient was a good candidate for IC. In addition, she had chronic lymphedema and had received

Table 5. Determining the Coefficient of Variation (CV)

- CV for Resting Energy Expenditure = (Standard Deviation ÷ Mean) × 100
- CV for Respiratory Quotient = (Standard Deviation ÷ Mean) × 100
- CV for Oxygen Consumption (VO_2) = (Standard Deviation ÷ Mean) × 100
- CV for Carbon Dioxide Elimination (VCO_2) = (Standard Deviation ÷ Mean) × 100

both intravenous fluids and blood transfusions before hospital transfer, all of which affect body weight, making predictive equations even more unreliable. When compared to the patient's measured REE, all of these predictive equations underestimated the patient's energy needs (Table 6). IC, which is considered the reference standard, provided a more accurate approach to assessing energy requirements in this obese, fluid-overloaded, critically ill patient. Predictive equations are not as reliable in this patient population and may lead to under- and overfeeding, both of which are associated with negative outcomes. Underfeeding can lead to or worsen malnutrition, and energy deficit has been associated with increased complications, including infections (9,10). Overfeeding can contribute to hyper-glycemia, hepatic steatosis, respiratory failure, prolonged ventilation, and increased mortality (11,12).

IC provides the most accurate measure of total energy expenditure in the obese critically ill patient. Although the goal is for patients to achieve energy balance from nutrition support and IC is the most accurate method of determining REE, currently no randomized, controlled trials have assessed whether using IC can help a patient meet energy needs or improve outcomes. Further research is needed to assess whether the measurement of REE improves a patient's clinical outcome.

Summary

Predictive equations often provide inaccurate results in critically ill obese patients. In the acute care setting, IC offers an opportunity to tailor nutrition support therapy to meet each patient's individualized and changing needs throughout his or her hospital course.

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Table 6. Predictive Energy Equations for the Patient*

Predicted Equation	Estimated Energy Requirements	Difference from Indirect Calorimetry	% Difference from Indirect Calorimetry
11 to 14 kcal/kg	1,850 to 2,400 kcal	-1,295 to -745 kcal	58% to 76%
Mifflin-St Jeor	2,356 kcal	-789 kcal	74%
Penn State	2,665 kcal	-480 kcal	84%

*The patient's actual dry body weight of 170 kg was used for the following calculations.

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