Brief Communication

Use of metabolic monitors in a multidisciplinary Intensive Care Unit: A prospective pilot study of 20 patients

Tanvir Samra, Neerja Banerjee[1], Arushi Gupta[2]

Abstract

Introduction: Caloric intake of critically ill patients are usually calculated using predictive equations. Recent advances in gas exchange measurements have the potential to estimate energy expenditure at the bedside and at different time periods. **Materials and Methods:** Energy needs of critically ill patients were estimated over a period of 3 months using simplistic formula of 25 kcal/kg/day estimated energy expenditure (EEE), Harris–Benedict equation (HBE) (Basal energy expenditure [BEE]) and M-COVX™ metabolic monitor resting energy expenditure (REE) on day 4 of Intensive Care Unit (ICU) admission. Calculations based on HBE were taken as standard, and percentage errors (PE) were calculated for each patient for values derived from simplistic formula and metabolic monitor. Adequacy of nutritional intake in ICU was also assessed. **Results:** Metabolic monitor could be used in only 20/70 patients. The mean age of patients was 40 years, 65% were males, and average body mass index was 23.69 kg/m^2. Intermittent intolerance to feeds was reported in 50%. Values of REE and EEE were greater than BEE in 70% of patients. A significant difference was reported in values of PE of ≤20% and ≥30%; P = 0.0003 and 0.0001, respectively estimated using REE and EEE. **Conclusions:** It is not feasible to use metabolic monitors in all patients. Variability in readings is large and further studies are needed to establish the validity of its measurements. Calculations using simplistic formulas are much closer to values obtained using HBE.

Keywords: Energy expenditure, gas exchange, measurement techniques, metabolic monitors, metabolism

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Introduction

Energy needs of critically ill patients are estimated using simplistic formulas (25–30 kcal/kg/day), predictive equations or indirect calorimeters.[1] Metabolic monitors like M-COVX™ (GE Healthcare/Datex-Ohmeda) measure pulmonary oxygen uptake (VO_2) and carbon dioxide production (VCO_2) and have thus been used in Intensive Care Units (ICUs) for measuring resting energy expenditure (REE), work of breathing and alveolar dead space.[2,3]

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Critically ill patients are in an unstable metabolic or hemodynamic state. The energy needs of these patients thus vary from one to another and in a single patient vary from 1-time to another.[4]

Calorie intake is calculated in our ICU using a simplistic formula of 25 kcal/kg/day. The aim of this pilot study was to evaluate the feasibility of M-COVX™ metabolic monitor for assessment of nutritional needs of critically ill patients admitted in our multidisciplinary ICU. Values of REE estimated by M-COVX™ were compared with those calculated using Harris–Benedict equation (HBE). Variability in the measurements, the clinical significance of the difference and adequacy of nutritional intake was assessed for each patient.

Materials and Methods

After approval from the Ethics Committee, a pilot study was conducted over a period of 3 months to assess the nutritional status of patients in the multidisciplinary ten bedded ICU of our hospital.

Inclusion criteria

- All patients on assisted or control mode of mechanical ventilation and stable hemodynamics
- Day 4 of ICU admission.

Energy requirements were calculated using HBE (Basal energy expenditure [BEE]), empirical formula of 25 kcal/kg (Estimated energy expenditure [EEE]) and simultaneously recorded from metabolic monitor REE.

Value of BEE was considered as a gold standard and all comparisons were made with it.[5]

Harris–Benedict formula:

- Males: BEE (kcal/day) =66 + (13.7 × weight in kg) + (5 × height in cm) − (6.8 × age in years)
- Females: BEE (kcal/day) =655 + (9.7 × weight in kg) + (1.8 × height in cm) − (4.7 × age in years).

M-COVX™ (Engstrom carestation, Datex-Ohmeda Inc., Madison, WI, USA) metabolic module was used in our ICU. It consists of a gas analyzer and a spirometer unit and displays oxygen consumption (VO_2) and carbon dioxide production (VCO_2). Partial pressures of O_2 and CO_2 are measured by the rapid paramagnetic analyzer and infrared analyzer, respectively and inspired tidal volume is measured using a pneumotachograph. Modified weir equation (REE = $[VO_2\ (3.941) + VCO_2\ (1.11)]$ 1440 kcal/day) is used to calculate REE and respiratory quotient ($RQ = VCO_2/VO_2$).[6] Reliability of displayed value of REE was assessed after considering the concomitant readings of RQ whose normal values range from 0.69 to 0.98. All values of REE with an RQ outside the above mentioned range were discarded.

The value of REE was recorded from the metabolic monitor at 700 and 1900 h. The following precautions were taken at the time of measurement:

- Patients were not disturbed, and no major procedure was performed within 30 min of the test; e.g., tracheal suctioning, physiotherapy, postural changes, radiologic studies, and body washings
- Constant minute ventilation was assured for 30 min prior to test
- Total of three 1-min gas exchange measurements of REE and RQ were recorded and the mean value recorded
- Leaks in the ventilator circuit and around tracheal tube cuffs were checked
- Care was taken to ensure that there was no water vapor in the circuit.

Patients with agitation, chest tubes or bronchopleural fistula, cuff leaks, and increased oxygen requirements (FiO_2 >0.4), were excluded. Demographic parameters (age, sex, weight, height, and body mass index [BMI]) clinical diagnosis, Sequential Organ Failure Assessment (SOFA) score, vitals (heart rate, blood pressure, pulse oximetry [SPO_2], end tidal carbon dioxide concentrations, and temperature) biochemical variables (blood gas analysis, electrolyte values, serum albumin, hematology, and coagulation studies) were recorded.

Intermittent enteral feeds were administered at intervals of 3 h by the nurses through a nasogastric tube. The empirical formula of 25 kcal/kg was used for calculation of caloric intake, and the total intake was administered in six equally divided feeds with 6 h of rest at night. Formula feed [Appendix 1] with calorie density of 1 kcal/ml and carbohydrate to fat ratio of 60:40 was given to all patients (Ensure, Abbott Laboratories BV, Zwolle, The Netherlands, Division of Abbott Laboratories, USA). All checks and precautions were taken to avoid aspiration. Intolerance to feed was defined as an aspirate volume >200 ml or more than half the previous feed after administration of a prokinetic (injection metoclopramide 0.15 mg/kg BID) agent. Dextrose infusions (5%) at 1 ml/kg/h was administered to patients with intolerance to enteral feeding. Total caloric intake (enteral and parenteral) was recorded for each patient. Signs of intolerance such as abdominal distention, diarrhea, and absent bowel sounds were also recorded. Percentage error (PE) was calculated to compare the values of REE (recorded from metabolic monitor) and EEE (calculated using empirical formula) with the gold standard that is, BEE (HBE).

Formula used to calculate PE:

$$\frac{\text{Approximate value} - \text{exact value}}{\text{Exact value}} \times 100\%$$

PE of REE:

$PE_{REE} = (REE - BEE/BEE) \times 100$

PE of EEE:

$PE_{EEE} = (EEE - BEE/BEE) \times 100$

PE of more than 20% was considered clinically significant. Fischer's exact test was applied to compare the values in each group and calculate the level of significance. $P < 0.05$ was considered statistically significant.

Results

The metabolic monitor could be used in only 20 patients [Figure 1].

The demographic data is summarized in Table 1. The mean age of the patients was 40 years (range; 22–62 years) and 65% were males. Average BMI was 23.69 kg/m^2 (range; 15.22–29.1 kg/m^2); only one patient was malnourished; none was obese. About half of the patients had serum albumin levels <3 g% and 75% had < 3.5 g%. Median value of SOFA score was 6; approximately half of the patients had scores below it and half had above it.

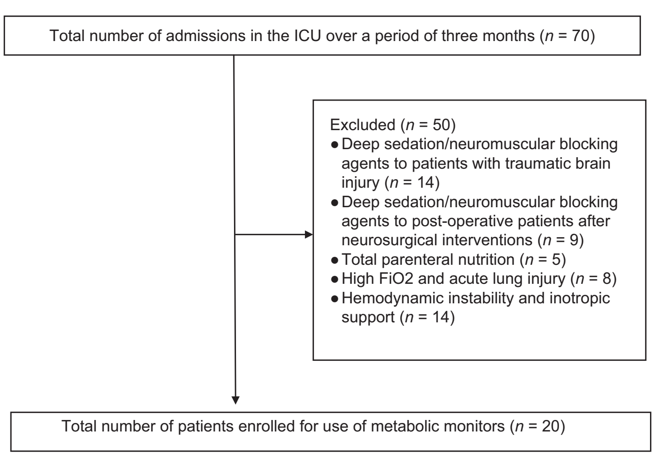

Figure 1: Flowchart of patient enrollment

Enteral feeding was initiated in 30% (21/70) of patients on the 1st day of ICU admission. It was established in 75% (53/70) of the patients by day 3. Intermittent episodes of intolerance were reported in 50% of the patients. Parenteral supplementation using 5% dextrose and/or intralipid infusions was needed in 7 patients.

Estimations of energy expenditure and nutritional intake of patients are summarized in Tables 2 and 3.

Table 1: Demographic data of the 20 patients included in the study

Diagnosis	Age/sex	BMI	Serum albumin	SOFA score
Gastric outlet obstruction	50/male	24.6	2	2
Polytrauma	36/male	24.6	3	2
CVA	40/female	20.8	3	4
GBS	22/male	20.76	3.6	2
GBS	28/male	24.9	3.2	2
GBS	28/male	24.9	3.1	4
DBE	30/male	29.1	1.5	5
Glioma	40/male	21.22	3.6	5
Meningioma	35/female	27.3	3.5	5
SDH	28/male	24.2	3.5	6
SDH	36/male	24.2	3.5	6
Ca esophagus	60/female	15.22	1.8	7
COPD	62/female	24.9	2.6	7
Pneumonia	40/female	24.6	2	8
Pancretitis	50/male	26.2	2.3	8
Viral (H1N1) pneumonia	25/male	22	2.3	8
Pneumonia	50/male	24.6	2	8
COPD	62/female	24.9	2.6	10
Obstructive jaundice	50/male	26.23	2.6	10
DIC	30/female	18.7	2.6	15

BMI: Body mass index; CVA: Cerebrovascular accident; GBS: Gullian-Barre syndrome; DBE: Diffuse brain edema; SDH: Subdural hematoma; COPD: Chronic obstructive pulmonary disease; DIC: Disseminated intravascular coagulation; SOFA: Sequential Organ Failure Assessment

Table 2: Nutritional assessment based on three different approaches and total intake in 24 h (day 4 of ICU stay)

BEE	REE/RQ	EEE	Energy (oral)	Energy (parenteral)	Total energy
1790	1939.5/0.78	2125	500	800	1300
1218	1337.3/0.76	1500	1000	-	1000
1473	1455/0.79	1500	600	500	1100
1543	2301/0.99	1500	800	200	1000
1225	1710/0.82	1125	800	400	1200
1804	2266/0.92	2000	800	300	1100
1596	1502/0.86	1750	1200	-*	1200
1178	1412/0.8	1100	1000	-*	1000
1688	1690/0.92	2000	500	-*	500
1626	973/0.78	1625	500	-*	500
1357	1345/0.67	1750	500	-*	500
1562	1921/0.7	1750	500	700	1200
1562	2000/0.8	1750	800	200	1000
1218	1542/0.7	1500	1200	-	1200
1629	1415/0.8	1500	1200	-	1200
1588	1359/0.9	1500	1200	-	1200
1804	2222/0.7	2000	1700	-	1700
1804	1922/0.88	2000	1650	-	1650
1226	1275/0.8	1500	1000	-	1000
1790	2308/0.72	2125	1400	-	1400

BEE: Basal energy expenditure; REE:/RQ→EEE; REE: Resting energy expenditure; EEE: Estimated energy expenditure; RQ: Respiratory quotient; ICU: Intensive Care Unit, (-): 0 value

Nutritional intake

- 70% (14/20) had calorie intake >75%
- 15% (3/20) had an intake of 60–65%
- 15% had intake of 30–40%
- Four patients had an intake >90% of estimated.

The values of REE obtained from metabolic monitors were greater than BEE calculated using HBE in 70% (14/20) of patients.

Percentage error value of resting energy expenditure

- ≤20% PE in 55% (11/20) of patients
- 20–30% PE in 30% (6/20) ≥30% PE in 15% of (3/20) patients
- The value of EEE was greater than BEE in 70% (14/20) of patients.

Percentage error values of estimated energy expenditure

- ≤20% in 80% of patients (16/20)
- 20–30% PE in 20% patients
- No patient had a difference of >30% [Table 4].

Table 3: Calorie intake and PE

Caloric intake expressed as percentage (total energy intake/BEE)×100	PE_{REE}	PE_{EEE}
75	8.3	18.7
80	9.7	23.15
75	−1.2	1.8
65	49	−2
98	39	−8
60	25	10
75	−5	9.6
85	19.8	−6
30	0.1	18
30	−40	−0.06
36	−0.8	28.9
77	22.9	12
64	28	12
98	26.6	23
74	−13	−8
75	−14.4	−5.5
94	23	10.8
90	6.5	10.8
81	4	22.3
78	28.9	18.7

REE: Resting energy expenditure; EEE: Estimated energy expenditure; PE: Percentage error; BEE: Basal energy expenditure

Table 4: Comparison of values of PE for REE and EEE

	PE_{REE}	PE_{EEE}	*P*
Group I (PE ≤20%)	55	80	0.0003
Group II (PE 20-30%)	30	20	0.14
Group III (PE ≥30%)	15	0	0.0001

All values are in percentage. REE: Resting energy expenditure; EEE: Estimated energy expenditure; PE: Percentage error

Discussion

Routine use of metabolic monitors for nutritional assessment is labor intensive.[7] In our study, a dedicated clinician was involved in data collection and nutritional assessment. An intensivist has multiple tasks to perform, e.g., admission/discharge of patients, intubation/extubation, hemodynamic stabilization, ventilator management, etc., and thus it may not be feasible for the clinician to make appropriate use of the metabolic monitor in the ICU. Criteria to be fulfilled prior to data collection are very stringent and lead to erroneous results if not followed precisely. Values cannot be recorded unless a constant minute ventilation is attained. In a multidisciplinary ICU, it is technically very difficult to ensure that the patient is not disturbed for 30 min prior to the test. Only 28% of the patients admitted in our ICU fulfilled the criteria for inclusion in this study.

We considered the value computed by HBE as the gold standard. PE_{REE} and PE_{EEE} were then calculated as described above. We recorded a significant difference ($P = 0.0003$) in the values belonging to group I when comparing PE_{REE} and PE_{EEE}. But error ≤20% (group I) was not considered to cause any significant change clinically. This difference is statistically significant but may not have any clinical relevance. No significant difference was noted in the values belonging to group II (20–30% error). A significant difference ($P = 0.0003$) was present in the values in group III (≥30% error). But only 15% of patients included for assessment belonged to this group. Thus, in this pilot study the PE obtained using REE were larger than that obtained using EEE and the difference was statistically significant (group III). This questions the reliability of the use of metabolic monitors for nutritional assessment and favors the use of simplistic formula of 25 ml/kg/day.

Canadian Clinical Practice Guidelines published in 2013[8] clearly state that there is insufficient evidence to put forward a recommendation for the use of indirect calorimetry over predictive equations for determining energy needs in critically ill patients. Brandi *et al*.[9] reported several sources of error and technical difficulties in applying indirect calorimetry in critical care settings. However, metabolic monitors may prove beneficial for assessment of energy needs in patients with poor response to nutritional supplementation, patients with single- or multiple-organ dysfunction, patients with prolonged ICU stay and artificial nutritional support. Some more indications enumerated in the American Association for Respiratory Care Clinical Practice guidelines[2] are as follows: Patients with neurological trauma, chronic obstructive pulmonary disease, acute pancreatitis, multiple trauma, amputations, severe sepsis, obesity, and severely hyper metabolic or hypo metabolic patients.

BEE of critically ill patients is calculated using HBE. In critically ill septic patients or patients with multiple injuries, it is further multiplied with different stress and activity factors. The HBEs has been found to overestimate energy expenditure by 6–15% when compared with measurements done using indirect calorimetry.[10] Intake of 25 kcal/kg is adequate for most patients with normal BMI. In most patients, this value approximates the one calculated from HBE. The poor agreement has been documented by Chioléro *et al*.[11] between predictive equations and measured values derived from metabolic monitors. Results of our study are similar to these findings. Meyer *et al*.[12] concluded that the measurements using M-COVX metabolic monitor were not in the clinically acceptable range in nonsedated patients and different ventilation modes.

One of the limitations of our study is that we did not assess patients for nutritional status in our ICU. A very rough estimate can be made from the value of BMI, which was less than normal in only one patient (15.22 kg/m^2) with a diagnosis of Ca esophagus. Chakravarty *et al*.[13] reported malnutrition in two-fifth of the patients admitted in their ICU and thus emphasized on the urgent need to develop a comprehensive nutritional care program. They used Subjective Global Nutritional Assessment score to screen their patients.

Our study was an observational pilot study with a limited number of patients. We did not categorize the patients on the basis of the severity of illness, sex, BMI, etc., which could have a confounding effect on the measurements. We took three readings each at 700 and 1900 h but only on day 4 of ICU admission. There are day to day variabilities, and thus data collection should be done every day.

Hypoalbuminemia was present in three-fourth of our patients (50% had serum albumin levels <3 g%; 75% had <3.5 g%). But it is not a marker of nutritional status. It is used as a marker of systemic inflammatory response and has prognostic importance.

Underfeeding (<50% of daily energy requirement) has been reported in 38% of critically ill patients in a previous study.[14] The most common cause of interruptions in tube feedings was the performance of ICU tests and invasive procedures and feed intolerance.

Energy expenditure can be measured directly by putting a person in a calorimeter and measuring the amount of heat produced by the body mass.

This is expensive and very impractical in the clinical setting. Most valid metabolic cart is Deltatrac TM (Datex-Ohmeda Division, Instrumentarium Corp, Teollisuuskatu 29, Helsinki, FIN 00031, Finland).[15] It has undergone a number of independent laboratory and clinical validations. But it is expensive, requires high technical expertise and is time consuming. New compact modular metabolic monitors such as E-COVX™ (formerly M-COVX™, GE Healthcare/Datex-Ohmeda) are less expensive, simpler, smaller, and automatically calibrated. Kaiyala[16] has concluded that mathematical relationships between whole body oxygen uptake, carbon dioxide release, and metabolic heat production may are complex and thus unpredictable and thus assumptions made by practitioners of respirometric indirect calorimeters may be wrong.

We have successfully used Deltatrac II in a previous study conducted at our institute to compare two different regimes of enteral feeding-continuous vs. intermittent in patients with head injuries.[17] The metabolic monitor was also advantageous in diagnosing and managing a child with hypometabolism.[18] In this pilot study, we aimed to assess the feasibility and accuracy of the metabolic monitor as a tool to assess nutritional requirements of patients admitted in a multidisciplinary ICU.

We conclude that technical advances in measurement of gas exchange in ICU's have enabled the use of metabolic monitors for estimation of energy expenditure, assessment of pulmonary physiology, oxygen utilization, success of weaning, and measurement of metabolic stress. In order to fully utilize its potential it is essential to train a few intensivists in the measurement techniques and interpretation of data with these modules so that its limitations can be acknowledged and relevant information obtained. A team approach can also be used in the ICU with the involvement of a physician, nutritionist, and respiratory therapist in analyzing the results of the metabolic monitor and then modifying nutritional support. But first and foremost is the performance of further studies to establish the reliability and validity of results obtained with these modules. The impact of metabolic monitors on clinical outcomes such as mortality, ICU length of stay, duration of mechanical ventilation also needs to be established.

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Conflicts of interest

There are no conflicts of interest.

References

1. Kan MN, Chang HH, Sheu WF, Cheng CH, Lee BJ, Huang YC. Estimation of energy requirements for mechanically ventilated, critically ill patients using nutritional status. Crit Care 2003;7:R108-15.
2. AARC clinical practice guideline. Metabolic measurement using indirect calorimetry during mechanical ventilation. American Association for Respiratory Care. Respir Care 1994;39:1170-5.
3. McClave SA, Lowen CC, Kleber MJ, McConnell JW, Jung LY, Goldsmith LJ. Clinical use of the respiratory quotient obtained from indirect calorimetry. JPEN J Parenter Enteral Nutr 2003;27:21-6.
4. Lo HC, Lin CH, Tsai LJ. Effects of hypercaloric feeding on nutrition status and carbon dioxide production in patients with long-term mechanical ventilation. JPEN J Parenter Enteral Nutr 2005;29:380-7.
5. Hwang TL, Huang SL, Chen MF. The use of indirect calorimetry in critically ill patients – The relationship of measured energy expenditure to Injury Severity Score, Septic Severity Score, and APACHE II Score. J Trauma 1993;34:247-51.
6. Mansell PI, Macdonald IA. Reappraisal of the Weir equation for calculation of metabolic rate. Am J Physiol 1990;258 (6 Pt 2):R1347-54.
7. Klein S. Nutritional therapy. In: Ahya S, Flood K, Paranjothi S, editors. The Washington Manual of Medical Therapeutics. 30th ed.. Philadelphia: Lipincott Williams and Wilkins; 2000. p. 27-42.
8. Dhaliwal R, Cahill N, Lemieux M, Heyland DK. The Canadian critical care nutrition guidelines in 2013: An update on current recommendations and implementation strategies. Nutr Clin Pract 2014;29:29-43.
9. Brandi LS, Bertolini R, Calafà M. Indirect calorimetry in critically ill patients: Clinical applications and practical advice. Nutrition 1997;13:349-58.
10. Fujii TK, Phillips BJ. Quick review: The metabolic cart. Internet J Intern Med 2003;3:1-3.
11. Chioléro R, Revelly JP, Tappy L. Energy metabolism in sepsis and injury. Nutrition 1997;13 9 Suppl: 45S-51S.
12. Meyer R, Briassouli E, Briassoulis G, Habibi P. Evaluation of the M-COVX metabolic monitor in mechanically ventilated adult patients. Eur E J Clin Nutr Metab 2008;3:e232-9.
13. Chakravarty C, Hazarika B, Goswami L, Ramasubban S. Prevalence of malnutrition in a tertiary care hospital in India. Indian J Crit Care Med 2013;17:170-3.
14. O'Leary-Kelley CM, Puntillo KA, Barr J, Stotts N, Douglas MK. Nutritional adequacy in patients receiving mechanical ventilation who are fed enterally. Am J Crit Care 2005;14:222-31.
15. Walsh TS. Recent advances in gas exchange measurement in intensive care patients. Br J Anaesth 2003;91:120-31.
16. Kaiyala KJ. What does indirect calorimetry really tell us? Mol Metab 2014;3:340-1.
17. Maurya I, Pawar M, Garg R, Kaur M, Sood R. Comparison of respiratory quotient and resting energy expenditure in two regimens of enteral feeding – Continuous vs. intermittent in head-injured critically ill patients. Saudi J Anaesth 2011;5:195-201.
18. Samra T, Sharma S, Pawar M. Metabolic monitors as a diagnostic tool. J Clin Monit Comput 2011;25:149-50.

Appendix 1: Content of feeding formula given to patients in the ICU

Content (per 100g powder)	Vitamins	Electrolytes
Protein 15.10 g	A 1170 IU	Sodium 288 mg
Carbohydrate 56 g	D 86 IU	Potassium 536 mg
Fat 13.50 g	K 18 IU	Calcium 224 mg
Saturated fat 3.99g		Magnesium 72 mg
Monounsaturated 6.35 g		
Polyunsaturated 2.72 g		

Preparation: For preparing 220 mL of feed, 6 level scoops (53.4 g) of feeding formula powder was gradually added and mixed in 190 mL of water in a glass which provided energy equivalent to 1 kcal/Ml. Energy per 100 g of feeding formula=406 K cal