Short Communication

Energy expenditure in severe sepsis or septic shock in a Thai Medical Intensive Care Unit

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Background and Objectives: Energy expenditure in severe sepsis/septic shock patients was measured by indirect calorimetry and the correlation of energy expenditure between indirect calorimetry and predictive equations was determined. **Methods and Study Design:** This was a prospective, observational analytical study. Severe sepsis or septic shock patients were measured for energy expenditure over 72 hours by indirect calorimetry that was measured by a mechanical ventilator (EngströmCarestation, GE Healthcare). Predictive equations for energy expenditure by the Harris-Benedict equation (HBE), Ireton-Jones 1992 equation (IRE) and ACCP equation (ACCP) were calculated and then correlations and agreement between indirect calorimetry and predictive equations were tested. **Results:** The 16 patients had a mean age of 71.6±5.5 years and a mean APACHE II score of 26.9±4.0. The average energy expenditure by indirect calorimetry over 72 hours per kilogram body weight was 26.7±5.3 kcal/kg/day. For predictive equations, IRE was moderately significantly correlated with indirect calorimetry over 72 hours (intraclass correlation 0.46, 95% CI -0.01 to 0.77, p=0.028), but the HBE and ACCP equations were not significantly correlated (intraclass correlation for HBE -0.52, 95% CI -0.8 to -0.06, p=0.985 and intraclass correlation for ACCP 0.29, 95% CI -0.21 to 0.68, p=0.121). **Conclusions:** Energy expenditure over 72 hours in severe sepsis or septic shock was about 26.7±5.3 kcal/kg/day. The use of predictive equations should be further examined in future studies.

Key Words: energy expenditure, severe sepsis, septic shock, indirect calorimetry, predictive equations

INTRODUCTION

Sepsis is a systemic host response to infection which is a leading cause of intensive care unit (ICU) admissions.[1] Adequate nutritional support is a crucial role in sepsis survival. A report from the tight calorie control study (TICACOS) found that critically ill patients who received nutritional support guided by measurements of resting energy expenditures (REE) had a trend toward a lower mortality.[2]

The most valuable methods for measurement of energy expenditure (EE) in critical illnesses are indirect calorimetry and predictive equations[3] e.g. American College of Chest Physician (ACCP) equation,[4] Harris-Benedict equation (HBE),[5] Ireton-Jones 1992 and 1997 equations (IRE),[6,7] Penn State 1998 and 2003 equations,[8] and the Swinamer 1990 equation.[9] The REE in septic patients is about 1.37 times higher during the days 9 to 12 of hospitalization than under normal conditions.[10] The REE from indirect calorimetry, however, did not agree with the REE from the Harris-Benedict equation.[11] Indirect calorimetry is an accurate method to assess EE but it is expensive and not widely used in general hospitals. Therefore, predictive equations, especially the ACCP equation, are being applied throughout the world.

This study aimed to measure energy expenditure in severe sepsis/septic shock patients by indirect calorimetry and the assessment of the correlation of energy expenditures between indirect calorimetry and predictive equations.

MATERIALS & METHODS

This was a prospective, observational analytical study. The study was conducted at the Medical Intensive Care Unit (MICU) of the Srinagarind Hospital in Khon Kaen, Thailand, from June 2012 to December 2012. Eligible participants were adults 18 years and over with severe sepsis or septic shock with required invasive mechanical

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Table 1. Predictive equations for energy expenditure (kcal/d)

Name	Equation
Harris-Benedict equation	Men: BEE = 66 + (13.7 x weight) + (5 x height) - (6.76 x age) Women: BEE = 655 + (9.6 x weight) + (1.8 x height) - (4.7 x age) Calculated energy requirement = BEE x stress factor (1.6 for sepsis)
Ireton-Jones 1992 equation	= 1925 – (10 x age) + (5 x weight) + (281 if male) + (292 if trauma present) + (851 if burns present)
ACCP equation	= 25 x weight

BEE: basal energy expenditure; ACCP: American College of Chest Physician.
†Weight in kg. Height in cm. Age in years.

ventilation. Ineligible participants were those (a) who had chest drains or bronchopleural fistulas (b) who had undergone hemodialysis and (c) who had PEEP applied at more than 12 cm H_2O or an FiO_2 of more than 0.6.

All competent patients provided written informed consent while those with an altered mental status had consent given by their legal representatives. This trial was approved by the Khon Kaen University Ethics Committee for Human Research (HE551090)

Procedures

After enrollment, patients were connected to mechanical ventilators and had energy expenditures by indirect calorimetry that was measured by a mechanical ventilator (EngströmCarestation, GE Healthcare). The D-lite flow sensors and gas sampling ports between the Y-pieces of the ventilator circuit and endotracheal tubes were installed. The gas module measured oxygen consumption (VO_2) and carbon dioxide production (VCO_2) on a breath-by-breath basis and was then calculated into energy expenditure. The mean of the energy expenditure for 6 hours per day for total 3 days was calculated. Finally, the energy expenditure at 24, 48 and 72 hours was calculated.

Calculated predictive equations for energy expenditure by use of the Harris-Benedict equation, Ireton-Jones 1992 equation and the ACCP equation are shown in Table 1. The patient's actual body weight was applied to estimate energy expenditure from predictive equations.

Statistical analysis

Data analyses were performed using R software and STATA version 13.0. Sample size calculations for correlation coefficients (r) which were used were r=0.5, alpha level 0.05 and power 80%. 29 patients were needed to participate in this study.

Correlations and agreements between indirect calorimetry and predictive equations used intraclass correlations (ICC) and the Bland-Altman method for testing.

RESULTS

Between June 2012, and December 2012, 16 participants, were enrolled; 9 were men and 7 were women. The mean ages and APACHE II scores were 71.6±5.5 years and 26.9±4.0, respectively. The mean body mass index was 22.0±2.9 kg/m^2. The mean energy expenditures calculated by the Harris-Benedict equation, by the Ireton-Jones 1992 equation, and by the ACCP formula were 2259±305, 16523±185, and 1426±223 kcal/day, respectively. The energy expenditures measured by indirect calorimetry at 24, 48 and 72 hours were 1488±261, 1459±270 and 1560±363 kcal/day, respectively. The average 72 hours energy expenditure by indirect calorimetry per kilogram body weight was 26.7±5.3 kcal/kg/day (Table 2).

Agreement and correlations between indirect calorimetry and predictive equations

On average, EEs over the 72 hours using IC and the Bland-Altman analysis showed a mean difference (limits of agreement) of -757 kcal/day (-96.2 to -1418) between EE using IC and EE using HBE. Moreover, EE using HBE did not correlate with EE using IC; the intraclass correlation coefficient was -0.52 (95% CI -0.8 to -0.06, p=0.985). On the other hand, EE from IRE had a moderately significantly correlation with EE using IC; the intraclass correlation coefficient was 0.46 (95% CI -0.01 to 0.77, p=0.028), and had a mean difference (limits of agreement) of -150 kcal/day (251 to -552). There was no significant correlation between EE from IC and EE from

Table 2. Baseline Characteristics and energy expenditure

Characteristics	Participants (n=16)
Men (%)	9 (56.25)
Age, mean (SD), years	71.6±5.5
Body mass index (SD), kg/m^2	22.0±2.9
APACHE II Score, mean (SD), points	26.9±4.0
Energy expenditure by in indirect calorimetry (kcal/day)	
At 24 hours, mean (SD)	1488±261
At 48 hours, mean (SD)	1459±270
At 72 hours, mean (SD)	1560±363
Average for 72 hours, mean (SD), kcal/kg/day	26.7±5.3
Energy expenditure by predictive equations (kcal/day)	
Harris-Benedict equation, mean (SD)	2259±305
Ireton-Jones 1992 equation, mean (SD)	1653±185
ACCP formula, mean (SD)	1426±223

SD: standard deviation; APACHE: Acute Physiology and Chronic Health Evaluation.

the ACCP formula; the intraclass correlation coefficient was 0.29 (95% CI -0.21 to 0.68, p=0.121) and the mean difference between them was 76.4 kcal/day (648 to -495) (Table 3).

The estimated correlation between EE from IC and EE from IRE at 24 hours was 0.51 (95% CI 0.04 to 0.79, p=0.017) with a mean difference of -165 kcal/d (-513 to 184). Similarly, EE from ACCP had a significantly moderate correlation with EE from IC; the intraclass correlation coefficient was 0.43 (95% CI -0.05 to 0.75, p=0.039), with a mean difference of 62 kcal/day (-447 to 571). EE using HBE was not correlated with EE using IC at 24 hours; the intraclass correlation coefficient was -0.48 (95% CI -0.78 to -0.01, p=0.997), with a mean difference of -771 kcal/day (-192 to -1351) (Table 3).

EE from IC at 48 hours was not correlated with EE from predictive equations. The intraclass correlation of EE from HBE was -0.58 (95% CI -0.83 to -0.14, p=0.993), EE from IRE was 0.31 (95% CI -0.18 to 0.69, p=0.104), and EE from ACCP was 0.22 (95% CI -0.28 to 0.63, p=0.194). The mean difference between EE from IC and EE from HBE was -800 kcal/d (-97 to -1503), from IRE was 194 kcal/day (-635 to 248), and from ACCP was 33.3 (-583 to 650) (Table 3).

The EE from IC at 72 hours was not correlated with EE from predictive equations. The intraclass correlation of EE from HBE was -0.43 (95% CI -0.75 to 0.06, p=0.959), EE from IRE was 0.37 (95% CI -0.12 to 0.72, p=0.067), and EE from ACCP was 0.15 (95% CI -0.34 to 0.59, p=0.271). The mean difference between EE from IC and EE from HBE was -699 kcal/d (142 to -1541), from IRE was -92.7 kcal/day (-721 to 536), and from ACCP was 134 (-620 to 888) (Table 3).

DISCUSSION

The target energy goal in each critically ill patient was determined by the simplistic formula (25-30 kcal/kg/day). In this study it was found that mean energy expenditure from indirect calorimetry over 72 hours was 26.7±5.3 kcal/kg/day. Reid found that mean total energy expenditure in ICU patients was 27.4±4.6 kcal/kg/day.[12] The average energy requirement in the first week of sepsis was 25±5 kcal/kg/day[10] and mean resting energy expenditure that was measured from indirect calorimetry in mechanically ventilated patients was 25±6 kcal/kg/day.[13] In contrast, Frankenfield et al, found that the mean resting energy expenditure over the first 10 days of septic patients was 45±8 kcal/kg/day.[8]

Although indirect calorimetry is the gold standard for determination of energy expenditure, it is generally not accessible in general hospitals. Therefore, predictive equations are the only tools for energy expenditure calculation of critically ill patients. It was found that the Ireton-Jones 1992 equation had a modest correlation with indirect calorimetry over 72 hours but the Harris-Benedict and ACCP equations were not correlated with indirect calorimetry. Reid[12] found that TEE from indirect calorimetry was moderately correlated with HBE and ACCP (r=0.524 and 0.592, respectively), but was poorly correlated with the Ireton-Jones equation (r=0.278). Different results from the present study might have been due to stress factor calculations in HBE that were used. A 60% stress factor, typical of critically ill patients, and duration of 72 hours of measurement was used. Septic shock patients require more energy expenditure than patients who have acute respiratory distress syndrome (ARDS), cardiogenic shock, congestive heart failure or pneumonia.[14] Cheng et al[15] found that HBE was not significantly different than the values of energy expenditure from indirect calorimetry in all groups but energy expenditures that were calculated by IRE resulted in an overestimation by 11.9%. For energy expenditure in sepsis, Subramaniam et al[16] studied correlations of measured energy expenditure (MEE) derived from the Weir equation with predictive equations. They found that MEE was strongly correlated with HBE among severe sepsis patients (r=0.9) and moderately correlated with HBE among septic shock patients (r=0.43). Moreover, HBE with an activity factor of 1.2 was demonstrated to be unbiased and precise. The Ireton-Jones equation was precise but biased. In addition, the ACCP formula was biased and imprecise.[17]

There are various results about correlation of indirect

Table 3. Bland-Altman analysis and intraclass correlations between indirect calorimetry and predictive equations

Predictive equations	Mean difference (Limits of agreement)	Intraclass correlation (95% CI)	p-value
Mean IC over 72 hours			
HBE	-757 (-96.2 to -1418)	-0.52 (-0.8 to -0.06)	0.985
IRE	-150 (251 to -552)	0.46 (-0.01 to 0.77)	0.028
ACCP	76.4 (648 to -495)	0.29 (-0.21 to 0.68)	0.121
IC at 24 hours			
HBE	-771 (-192 to -1351)	-0.48 (-0.78 to -0.01)	0.997
IRE	-165 (-513 to 184)	0.51 (0.04 to 0.79)	0.017
ACCP	62 (-447 to 571)	0.43 (-0.05 to 0.75)	0.039
IC at 48 hours			
HBE	-800 (-97 to -1503)	-0.58 (-0.83 to -0.14)	0.993
IRE	194 (-635 to 248)	0.31 (-0.18 to 0.69)	0.104
ACCP	33.3 (-583 to 650)	0.22 (-0.28 to 0.63)	0.194
IC at 72 hours			
HBE	-699 (142 to -1541)	-0.43 (-0.75 to 0.06)	0.959
IRE	-92.7 (-721 to 536)	0.37 (-0.12 to 0.72)	0.067
ACCP	134 (-620 to 888)	0.15 (-0.34 to 0.59)	0.271

IC: indirect calorimetry; HBE: Harris-Benedict equation; IRE: Ireton-Jones 1992 and 1997 equations; ACCP: American College of Chest Physician.

calorimetry and predictive equations as a result of the measurement method of indirect calorimetry, type of patients, duration and timing of measurements and values of stress factors that were used for calculation in the predictive equations. Furthermore, the main technical issue limiting measurement of indirect calorimetry in this study was the difficulty to obtain steady-state conditions because some severe sepsis patients had unstable vital signs and were varied in minute ventilation which can cause fluctuations in cardiac output, oxygen consumption and carbon dioxide production.[18]

The limitations of this study were (a) the small sample size, (b) the indirect calorimetry was measured only 6 hours per day and did not occur randomly during the day, (c) activities were not recorded during the measurements. In summary, energy expenditure in severe sepsis and septic shock patients during the first 72 hours was 26.7±5.3 kcal/kg/day which approximates the severe sepsis and septic shock guidelines. The correlations between indirect calorimetry and predictive equations, however, need to be addressed in consideration of the important technical limitations.

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AUTHOR DISCLOSURES

All authors report no competing interests relevant to this article.

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