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Original article

Energy expenditure in mechanically ventilated patients: The weight of body weight!

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SUMMARY

Background & aims: Optimal nutritional care for intensive care unit (ICU) patients requires precise determination of energy expenditure (EE) to avoid deleterious under- or overfeeding. The reference method, indirect calorimetry (IC), is rarely accessible and inconstantly feasible. Various equations for predicting EE based on body weight (BW) are available. This study aims at determining the best prediction strategy unless IC is available.
Methods: Mechanically ventilated patients staying ≥72 h in the ICU were included, except those with contraindications for IC measurements. IC and BW measurements were routinely performed. EE was predicted by the ESPEN formula and other predictive equations using BW (i.e. anamnestic (AN), measured (MES), adjusted for cumulated water balance (ADJ), calculated for a body mass index (BMI) of 22.5). Comparisons were made using Pearson correlation and Bland & Altman plots.
Results: 85 patients (57 ± 19 y, 61 men, SAPS II 43 ± 16) were included. Correlations between IC and predicted EE using the ESPEN formula with different BW (BW_{AN}, BW_{MES}, BW_{ADJ}, and $BW_{BMI22.5}$) were 0.44, 0.40, 0.36, and 0.47, respectively. Bland & Altman plots showed wide and inconsistent variations. Predictive equations including body temperature and minute ventilation showed the best correlations, but when using various BWs, differences in predicted EE were observed.
Conclusion: No EE predictive equation, regardless of the BW used, gives statistically identical results to IC. If IC cannot be performed, predictive equations including minute ventilation and body temperature should be preferred. BW has a significant impact on estimated EE and the use of measured BW_{MES} or $BW_{BMI\ 22.5}$ is associated with the best EE prediction.
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Ethical committee number: CE-14-070.

1. Introduction

Optimal nutritional care for intensive care unit (ICU) patients requires precise determination of the energy expenditure (EE) to avoid under- or over-feeding, both being deleterious [1,2]. Although indirect calorimetry (IC) is considered the reference method to determine EE, it is rarely available and suffers from some limitations in its feasibility. Various equations for predicting EE based on body weight (BW) have been proposed. This study aims at determining the best EE prediction strategy when IC is not available.

EE can be determined by three methods in ICU patients. Firstly EE can be computed from pulmonary artery catheter measurements, using the Fick equation; however this method is highly invasive as it requires a right heart catheter. Secondly EE can also be measured by IC, which is the recommended method [3,4]. However, IC requires a trained staff, an expensive and validated calorimeter for accurate measurements [5,6] and is contraindicated in a number of clinical situations in the critically ill patient (e.g. air leaks in the circuit, ventilation with inspired fraction of oxygen (FiO_2) > 60%, end-expiratory pressure (PEEP) > 9 cm H_2O, gas

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exchange therapy or inhaled nitrogen gas). Only about 70% of the critically ill ICU patients can be measured by this method [7]. Finally, EE can be estimated by using predictive equations. Of note is that most of these equations were developed for healthy people. For ICU patients, a number of correction factors have been suggested taking account of different stress levels, type of treatments, and body compositions such as severe obesity or extreme leanness (i.e. sex, age, height, weight, body temperature, minute ventilation, pathology, severity of disease…). All predictive equations include patients' body weight (BW). However, the use of BW in ICU patients is highly controversial because it largely varies according to fluid retention and edema related to the inflammation process and resuscitation therapies [8].

This quality of care study is part of a global effort to improve and harmonize our clinical practices. It aims at identifying the best EE prediction strategy, with regard to the choice of the BW and of the predictive equation, when IC is not available.

2. Materials and methods

2.1. Patients

Patients mechanically ventilated, staying ≥72 h in the ICU were included. Due to our infection control policy, patients with respiratory multi-drug resistant bacteria were excluded as well as those with unstable pH, $FiO_2 > 60\%$, PEEP > 9 cm H_2O, and pulmonary fistula.

The Ethical Committee of the Geneva University Hospital approved this study. They waived the need for a written consent because the study was part of a continuous quality of care improvement in our ICU, and because the study did not generate any additional risks for the patient as the measurements are routinely performed in our ICU.

2.2. Methods

The clinical data were prospectively collected from our electronic medical records. These data included gender, body temperature, details of mechanical ventilation (type of ventilator, spontaneous or controlled ventilation, minute ventilation, etc), hemodynamic parameters (heart rate, arterial pressure, etc), laboratory data, treatments received the day of IC measurement (morphine, sedatives etc.), anthropometric data (height, anamnestic BW, age), ICU admission diagnosis and severity scores (APACHE II and SAPS II) during the first 48 h after ICU admission and at the time of the IC measurement.

❖ Anthropometric data and predictive equations

Anamnestic body weight (BW_{AN}) was obtained from the electronic medical file or from the family members. Actual body weight (BW_{MES}) was measured using the built-in bed scale. Adjusted body weight (BW_{ADJ}) was determined by correcting the measured body weight (BW_{MES}) according to the cumulative fluid balance calculated from the ICU admission to the day of the IC measurement. Ideal BW (IBW) was calculated for a reference body mass index (BMI) at 22.5 kg/m^2 ($IBW_{22,5}$), and at 25 kg/m^2 (IBW_{25}) or calculated using the Metropolitan Life Insurance tables (IBW_{MLI}), the Lorentz equation (IBW_{LO}) (height (cm) − 100 − ((height (cm) − 150)/2.5 for women and/4 for men)) and the Broca equation (IBW_{BRO}) (height (cm) − 100). We then used the following equations to calculate EE with the different BWs listed above: ESPEN formula [9], Harris–Benedict, Black et al. [10], Faisy et al. [7], Frankenfield et al. [11], Brandi et al. [12], Ireton-Jones et al. [13], Penn State et al. [14] and Swinamer et al. [15] (web Appendix Table 4).

❖ Indirect Calorimetry

IC was performed using the Deltatrac II® (Datex, Finland) as previously described [5]. Each measurement was done by trained professionals for at least 25 min. Data of the first 5 min were discarded. Patients were measured in standardized conditions [16] and on-going feeding was not interrupted.

2.3. Statistical analysis

Data are presented as mean ± standard deviation (SD), or median and range, as appropriate. Parametric analyses were used after confirming the normal data distribution using Skewness and Kurtosis tests.

We compared the different BWs by one-way ANOVA followed, in case of significance, by a Bonferroni post-hoc test. T-tests were used to assess the differences of mean EE obtained from IC measurements with binary variables such as gender, fever, surgical versus medical patients, fed versus fasting patients, and spontaneous versus controlled ventilation modes.

We correlated the predictive equations with different BWs and IC by Pearson's correlation tests. The distribution of patients with predicted EE below 90% of measured EE by IC (underestimation), between 90 and 110% (acceptable), and over 110% (overestimation) were calculated in percentage. These percentages were considered as a measure of the precision of the predictive strategies. Bland & Altman plots were performed to determine the variability between the IC data (considered as the reference) and the predictive equations with the various BWs. Mean differences with limits of agreement (±2 SD) were recorded as the reflection of the accuracy. STATA version 13.0 (StataCorp, Texas, USA) was used for the analyses and the level of significance was set at 0.05.

3. Results

Eighty-five patients were included (Table 1 and web Appendix Fig. 1), of which 26 patients were on controlled and 59 on spontaneous ventilation. The different BWs are presented in Table 1 and show significant differences with measured BW ($p < 0.001$) (web Appendix Table 1). The influence of the different BWs used in the EE predictive equations is significant for the Black equation ($p = 0.0001$), the Brandi equation ($p = 0.0017$), the ESPEN formula ($p < 0.0001$), the Frankenfield equation ($p = 0.0018$), the Harris–Benedict equation ($p < 0.0001$) and the Penn State equation ($p = 0.0001$), but has no impact for the Ireton-Jones equation ($p = 0.7744$), the Faisy equation ($p = 0.0950$) and the Swinamer equation ($p = 0.7900$).

Measured EE was obtained by IC performed on the median of the 4th day after admission (range 1–15). No statistical difference was observed between the results of medical and surgical patients ($p = 0.6935$), fed and fasting patients ($p = 0.3967$), and spontaneous and controlled ventilation ($p = 0.1126$). On the contrary, gender and temperature ≥ 37 °C were associated with significant difference in EEs ($p = 0.0004$ and 0.0051, respectively).

Calculated EEs with predictive equations differed from EE measured by IC (Table 2; more details on web Appendix Table 2). Best Pearson correlations with measured EE are observed with results from the Frankenfield or the Penn State predictive equations, whereas the ESPEN formula, whatever the BW selected, presented poor correlation (0.36).

The occurrence of underestimation of EE when calculated, compared to the measured EE is least frequent with the Penn State equation using measured BW, whereas overestimation of EE is the least frequent with the Frankenfield equation using the ideal BW calculated for a BMI at 22.5 kg/m^2 (Fig. 1, web Appendix Table 3).

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