INTRODUCTION

Malnutrition is a persisting problem in intensive care patients worldwide. A negative energy balance, in particular, is consistently associated with significant organ dysfunction,[1] enhanced infection risk[2] and worse outcome.[3] Also, deleterious consequences of underfeeding are not easily measurable and may even become apparent after discharge from the intensive care unit (ICU).

Assessment of energy expenditure is a cornerstone of an adequate nutrition policy in the critically ill. However, whether energy expenditure in critically ill patients should be measured or estimated remains matter of debate. Consensus is that indirect calorimetry (IC) is the most accurate method to determine resting metabolic rate.[4] However, IC is not always available. Measurements require trained personnel and are time-consuming. IC devices also are expensive and not all currently commercialized calorimeters produce comparable within-subject results.[5] Patient-related factors represent another potential bias. Indeed, many ICU conditions (e.g. ventilation at FiO₂ levels exceeding 60%, air leaks, high PEEP levels…) impede or prohibit IC use.[4,6] Finally, many critically ill patients have an unstable metabolic course and may display significant variations of energy expenditure over time. This implies that an IC measurement at one time point may fail to appreciate the calorie need during a prolonged treatment period.

Predictive equations as surrogate for indirect calorimetry

From a multiple regression analysis of biometric variables, Arthur Harris and Francis Benedict constructed almost a century ago a landmark formula that predicted basal energy expenditure (BEE) in healthy male \([66.4730 + (13.7516 \times \text{weight}) + (5.0033 \times \text{height}) - (6.7550 \times \text{age})]\) and female \([655.0955 + (9.5634 \times \text{weight}) + (1.8496 \times \text{height}) - (4.6756 \times \text{age})]\) subjects.[7]

In this Harris–Benedict equation (HBE), BEE represented energy expenditure

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occuring at complete rest after an overnight fast. In general, BEE is considered to be synonymous with resting energy expenditure (REE). However, it might be questioned whether this is also applicable in hospitalized patients.

In a review of 19 studies, including 1256 hospitalized subjects, REE measured with IC was compared with BEE estimated with the HBE. Patients with burns, head injuries, and fever who are known to be hypermetabolic were excluded. For all studies taken together, mean REE/BEE ratio was 113% ± 11%. The ratio was 117% ± 3% in fed patients (11 studies) as compared to 105% ± 4% in fasting patients (5 studies) \((P = 0.047)\). Also, higher values (124 to 130%) were observed in more severely ill (i.e., trauma and ICU patients) than in stable postoperative and cancer patients. Thus, indiscriminate use of the “original” HBE may underestimate energy needs in a large proportion of hospitalized patients, and particularly in critically ill subjects. This led to the introduction of “corrected” HBEs. Basically, the calculated HBE was multiplied by correction factors adapting the REE to the level of stress induced by the underlying clinical condition or disease (×1.3 per °C above 37°C; ×1.2 for minor surgery; ×1.35 for major surgery and trauma; ×1.6 for severe infection or sepsis). Also, an adjusted formula was proposed for obese patients.

Today, as many as 200 equations for calculating REE have been developed. Grossly, they can be divided in formulas based on “static” variables (i.e., gender, age, weight) only (e.g., Harris–Benedict, Fusco, Mifflin, ACCP recommendation,…) and formulas in which dynamic variables (i.e., body temperature, tidal and minute ventilation volume) reflecting the patient’s metabolic state were added (e.g., Penn-State, Swinamer, Faisy,…). New formulas were also conceived to allow adaptation to pathology (e.g., Iretton-Jones for trauma and burns), stress (e.g., the corrected HBE) or type of patient (e.g., obesity).[9]

**Value of predictive equations in the critically ill**

Few studies have validated the accuracy of calculated energy needs in critically ill patients. Kross et al. retrospectively compared five equations (HBE, Owen, Mifflin, Iretton-Jones equation for obesity, and ACCP recommendation) with measured energy expenditure in 927 critically ill patients.[10] None of the equations accurately matched measured REE, most of them underestimating energy needs. However, this study is not representative for a general ICU population. In fact, 4 of the 5 studied formulas comprised “static” variables only, 43% of the enrolled patients had a body mass index >30 kg/m², and mean measured REE was very high (2456 ± 807 kcal/d). The latter could be explained by the use of the MedGraphics CCM Express calorimeter in this study. This calorimeter was shown to produce 64% higher mean REE values as compared to the Deltatrac Metabolic Monitor which is the most extensively used and validated — though no longer produced — system for performing IC in an ICU setting.[11]

We conducted a retrospective observational study in 161 critically ill mechanically ventilated adult medico-surgical patients.[12] REE was measured with the VmaxTM Encore 29n calorimeter at 8 ± 6 days after ICU admission and compared with 10 equations commonly used by ICU physicians [Table 1]. All equations failed to achieve a clinical acceptable accordance with measured REE.

In 70 medical metabolically stable ventilated ICU patients, aged 61 ± 18 years, Faisy et al. identified weight, height, expired minute ventilation \( (V_m) \) and body temperature \((T)\) as independent variables for calculation of REE. The resulting formula \( (8 \times \text{weight}) + (14 \times \text{height}) + (32 \times V_m) + (94 \times T) - 4834 \) showed good correlation \((r^2 = 0.61)\) with IC and proved to be highly superior to the HBE, either corrected or not.[13] The Faisy equation was subsequently validated prospectively in 45 mechanically ventilated patients of similar gender composition and age. Compared to the original study, patients were less severely ill (SAPS II score on day of IC monitoring 39 ± 13 vs. 49 ± 13) and had less pneumonia (8 vs. 27). Again, the Faisy equation correlated well \((r^2 = 0.62)\) with measured REE and provided precise and unbiased REE estimations. In contrast, other simultaneously studied equations (Swinamer, Fusco, Iretton-Jones, and (corrected) HBE) did not reach acceptable correlation and tended to over- or underestimate caloric needs.[14]

Frankenfield et al. conducted the largest prospective validation study to date comparing energy expenditure equations to IC measurements in mechanically ventilated medico-surgical and trauma patients.[15] In this study, 202 patients were divided in four groups according to age and body mass index (BMI), with cut-off values for “young age” and “non-obesity” respectively <60 years and BMI <30kg/m². Accurate estimation of REE was defined as the percentage of estimates that fell within 10% above or below the measured value. Of 17 equations tested, including original, “stress-corrected” and weight-adjusted formulas, the Penn State equation (PSE, Table 2) provided the most accurate assessment of REE (ranging from 69% to 77%), except in older overweight patients.[16] A modified equation for this patient segment was proposed by the same investigators[17] and was later shown to have an accuracy rate of 74%.[18] Interestingly, the Faisy equation proved almost as accurate as the PSE in non-obese and obese patients younger than 60 (respectively 65% and 72%) but dramatically underperformed in patients older than 60.[13] This is somewhat unexpected given the much
The performance also predicted REE within 5% of the value measured in critically ill patients. Despite better insight and considerable progress in the field, further research into more accurate bedside estimation of energy needs in critically ill patients, particularly regarding outcome, remains imperative.

REFERENCES


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