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Original article

Can energy intake alter clinical and hospital outcomes in PICU?☆

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SUMMARY

Background & aims: Energy is essential for the treatment and recovery of children admitted to Pediatric Intensive Care Units (PICU). There are significant immediate and long-term health consequences of both under- and over-feeding in this population. Energy requirements of critically ill children vary depending on age, nutritional status, sepsis, fever, pharmacotherapy, and duration and stage of critical illness. This study aimed to determine the incidence of over- and under-feeding and to compare hospital outcomes between these feeding categories. Secondary outcomes were collected to describe the association between feeding categories and biochemistries (serum lactate, triglycerides, C-reactive protein).

Methods: An ethics approved retrospective study of children admitted to PICU was performed. All intubated patients admitted to PICU (2008–2013) were included, except those in which an IC test was not feasible. Data collection included demographics, the primary outcome variable reported as under feeding (<90%MREE), appropriate (MREE ±10%) or overfeeding (>110% MREE) determined through comparison of measured resting energy expenditure (MREE) using indirect calorimetry (IC) to actual energy intake based on predicted basal metabolic rate (PBMR) and clinical outcomes mechanical ventilation and PICU length of stay (LOS). Data were analysed with descriptive methods, ANOVA and linear regression models.

Results: A total of 139 patients aged 10 (range 0.03–204) months were included. Sixty (43%) were female and 77 (55%) were admitted after a surgical procedure. A total of 210 IC tests were conducted showing a statistically significant difference between MREE measurements and PBMR ($p = 0.019$). Of the 210 measurements, only 26 measures (12.4%) demonstrated appropriate feeding, while 72 (34.3) were underfed and 112 (53.3%) were overfed. Children who were overfed had significantly longer PICU LOS (median 45.5, IQR 47.8 days) compared to those children in the appropriately fed (median 21.0, IQR 54.5 days), and underfed groups (median 16.5, IQR 21.3 days). There was a mean difference between the over and under feeding category and ventilation days after adjusting for age and PRISM score ($p = 0.026$), suggesting decreased mechanical ventilation days for underfed. Children who were underfed had significantly higher CRP (median 75.5, IQR 152.8 mg/L) compared to those children in the appropriately fed (median 57.8, IQR 90.9 mg/L) and overfed groups (median 22.4, IQR 56.2 mg/L).

Conclusions: This retrospective study confirms that estimations of energy expenditure in critically ill children are inaccurate leading to unintended under and overfeeding. Importantly under feeding seems to be associated with fewer mechanical ventilation days and PICU LOS. Further research is required to elucidate the role of optimal nutrition in altering clinical variables in this population.

Introduction

Energy is essential for the treatment and recovery of critically ill children in pediatric intensive care units (PICU). Significant immediate and long-term health consequences of both under- and

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over-feeding in this unstable population include increased risk of infection, sepsis, ventilation days, length of stay and duration of antibiotic use [1–5]. Underfeeding impairs the regeneration of respiratory epithelium and contributes to muscle weakness and respiratory dysfunction while overfeeding may worsen metabolic stress and increase work of breathing promoting ventilator dependence [6,7]. The energy requirements of critically ill children may vary depending on the patient's age, nutritional status, initial diagnosis, severity, duration and stage of acute illness, and medications [8–10]. However, studies have not been conclusive and the relationship between biomarkers, nutritional requirements, and clinical outcomes is not clear. Critically ill infants and children endure unpredictable and diverse metabolic states.

Predicting energy requirements to optimize nutrition support is a major challenge for clinicians in pediatric critical care. Indirect calorimetry (IC) directly measured resting energy expenditure (MREE), however, technical challenges may prohibit its use, ultimately affecting feeding prescription [11]. A recent study suggested that technical criteria to perform IC in the PICU were not met for 27% of patients and not met on 66% of patient days illustrating incongruity with the current recommendations for assessing energy requirements of this population [12]. Adequate feeding (matching energy intake with energy expenditure) has been reported to be achieved in 10% of ventilated children using IC [13]. In the absence of IC, predicted basal metabolic rate has been the target for initial energy intake [14] If IC is unavailable or testing criteria is not met, recently published guidelines suggest using the Schofield equation without stress factors or the WHO equations to prescribe energy expenditure [15].

Several studies have tried to determine if biochemical markers such as C-reactive protein (CRP), prealbumin (PA), or albumin can help to predict hospital outcomes including days of mechanical ventilation and length of stay [16–18]. Over- and under-feeding has been associated with metabolic dysregulation, including hypertriglyceridemia, hyperglycemia and azotemia [19]. The exploration of biochemistries and metabolic dysregulation in different feeding groups is critical, as persistent high CRPs and low prealbumin may infer catabolism, while normalization may reflect transition to normalization and more energy requirements.

To date, studies examining the role of under and overfeeding in clinical outcomes of critically ill children have used predictive equations or anthropometric measures as indirect indices of nutritional status [5,20,21]. This study explored the incidence of over- and under-feeding during a 48 h period, as determined by IC, in a cohort of children admitted to a tertiary PICU. The study also explored the association between under and overfeeding feeding, biochemical markers, and clinical outcomes, in an attempt to provide clinicians with possible objective markers to guide nutrition prescription in a context where IC may not be possible.

Materials and methods

A retrospective cohort study was conducted on a convenience sample (based on availability of staff to perform IC) of 3585 children admitted to the Stollery Children's Hospital PICU from October 2008 to June 2013. A recent publication from the same centre revealed that IC criteria were met on only 29% of days for infants 6 months and younger where children 24 months of age and older still only met criteria on 40% of patient days [12]. The unit is a tertiary academic general and cardiac ICU with approximately 1000 admissions annually, and the referral centre for heart surgery and solid organ transplantation in Western Canada. Patients were included in the study if they were admitted to the PICU and met the previously published ASPEN Clinical Guidelines criteria for energy measurement using indirect calorimetry (IC) and subsequently completed a metabolic cart test [22]. Exclusion criteria included patients who were non-ventilated; did not meet the criteria for indirect calorimetry or had a metabolic test with technical failure. This study was approved by the University of Alberta Health Research Ethics Board (HREB) in Edmonton, Alberta.

The primary outcome variable was appropriate daily feeding. Patients were classified as over-, under and appropriate -feeding categories by comparing measured resting energy expenditure (through IC) to the past 24-h period of actual nutrition intake using a standardised worksheet. Daily intakes were documented by full-time bedside dietitian. Standard nutrition practice for the study population included EN, PN and other energy sources (dextrose, lipid-based medications), to meet nutritional requirements based on WHO or as determined by registered dietitians. All energy and protein intakes were accounted for (IV drugs, dextrose lines and lipid based medications). Appropriate feeding was defined as energy intake matching MREE ±10% while overfeeding was defined as energy intake >110% MREE and underfeeding was defined as energy intake <90% MREE [23]. Researchers collected data from the same 24 h of energy intake (kcal/kg/day) including method of nutrition delivery (parenteral nutrition (PN) and/or enteral nutrition (EN), or no nutrition support) actual MREE using indirect calorimetry, and predicted basal metabolic rate (calculated using the WHO equation). The secondary outcome variables were other clinical measures (in the same 24-h period) in relation to feeding category mechanical ventilation, hospital (HLOS) and PICU length of stay (PICU LOS). Independent variables analysed included Pediatric Risk of Mortality (PRISM) III score; and biochemical indicators including glucose, C-reactive protein (CRP), lactate, triglycerides, and lymphocytes. The PRISM III is a physiologically based score used to quantify physiologic status, and when combined with other independent variables, it can compute expected mortality risk and expected morbidity risk. The score is based on only the first 24 h in PICU.

Indirect calorimetry

An indirect calorimeter (VMax Encore Sensor Medics, Yorba Linda, California, USA) performs a calculation of heat production by measuring pulmonary gas exchange through measured continuous inspired oxygen and expired carbon dioxide. This measurement determines resting energy expenditure and respiratory quotient. The researchers did not include RQ data or its analysis. All patients were supine and mechanically ventilated during the 20–30 min measurement period. Testing occurred according to the manufacturer's instructions and previously described [24]. Patients were not fasted. Very few patients were measured twice (3–4 days apart) during their stay; energy expenditure changes with clinical picture over the course of a PICU stay. All measurements were used to alter nutrition prescription. Patients received maintenance dextrose fluids, PN, or EN nutrition, or a combination of the above.

Statistics

Descriptive analysis and statistical modelling included the use of one-way ANOVA, and linear regression analysis using SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 22. Armonk, NY: IBM Corp.), and SAS (Version 9.3) by SAS Institute INC, Cary, NC, USA. Categorical variables were summarised using frequencies and percentages. Continuous variables were summarised using mean and standard deviation (SD) or median and interquartile range (IQR) as appropriate.

The relationship between feed category and admitting diagnosis (Table 1) was analysed using Pearson's Chi-square test. One-way analysis of variance (ANOVA) was used to determine differences