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Original article

Do PICU patients meet technical criteria for performing indirect calorimetry?

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SUMMARY

Background & Aims: Indirect calorimetry (IC) is considered gold standard for assessing energy needs of critically ill children as predictive equations and clinical status indicators are often unreliable. Accurate assessment of energy requirements in this vulnerable population is essential given the high risk of over or underfeeding and the consequences thereof. The proportion of patients and patient days in pediatric intensive care (PICU) for which energy expenditure (EE) can be measured using IC is currently unknown. In the current study, we aimed to quantify the daily proportion of consecutive PICU patients who met technical criteria to perform indirect calorimetry and describe the technical contraindications when criteria were not met.

Methods: Prospective, observational, single-centre study conducted in a cardiac and general PICU. All consecutive patients admitted for at least 96 h were included in the study. Variables collected for each patient included age at admission, admission diagnosis, and if technical criteria for indirect calorimetry were met. Technical criteria variables were collected within the same 2 h each morning and include: provision of supplemental oxygen, ventilator settings, endotracheal tube (ETT) leak, diagnosis of chest tube air leak, provision of external gas support (i.e. nitric oxide), and provision of extracorporeal membrane oxygenation (ECMO).

Results: 288 patients were included for a total of 3590 patient days between June 2014 and February 2015. The main reasons for admission were: surgery (cardiac and non-cardiac), respiratory distress, trauma, oncology and medicine/other. The median (interquartile range) patient age was 0.7 (0.3–4.6) years. The median length of PICU stay was 7 (5–14) days. Only 34% (95% CI, 32.4–35.5%) of patient days met technical criteria for IC. For patients less than 6 months of age, technical criteria were met on significantly fewer patient days (29%, $p < 0.01$). Moreover, 27% of patients did not meet technical criteria for IC on any day during their PICU stay. Most frequent reasons for why IC could not be performed included supplemental oxygen, ECMO, and ETT leak.

Conclusions: In the current study, technical criteria to perform IC in the PICU were not met for 27% of patients and were not met on 66% of patient days. Moreover, 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. This data represents a major gap in the feasibility of current recommendations for assessing energy requirements of this population. Future studies are needed to improve methods of predicting and measuring energy requirements in critically ill children who do not meet current criteria for indirect calorimetry.

1. Introduction

Critical illness in infants and children is characterized by metabolic changes involving stress hormones, inflammation, catabolism, and changing energy requirements [1]. Clinical

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parameters have not proven useful for assessing energy requirements in the pediatric intensive care unit (PICU) where children may be hypermetabolic, hypometabolic, or have normal metabolic needs [2,3]. Studies have failed to find a correlation between illness severity, as measured by the Pediatric Risk of Mortality III score, age, or diagnosis and measured energy expenditure (EE) [3,4]. Overall energy requirements cannot be estimated from clinical variables therefore measured EE is imperative for every critically ill child and should guide care throughout the stages of illness [4].

Indirect calorimetry (IC) is the gold standard for determining resting energy expenditure whereby respiratory gas volumes are quantified and EE calculated using the Weir equation [5,6]. Accurate results require capture of all inspired and expired gas volumes from the patient therefore certain technical criteria must be met in order to perform IC [7]. If a patient is not intubated, they must not be receiving supplemental oxygen or non-invasive mechanical ventilation [8]. If a patient is mechanically ventilated, criteria includes: less then 10% volume leak from the endotracheal tube (ETT), no air leak from chest tubes [9,10], not receiving high-frequency oscillation ventilation, and not receiving inhaled nitric oxide (iNO) or other gases different from oxygen [7,8]. Error in measure of oxygen volume increases significantly in patients when the fraction of inspired oxygen (FiO_2) is greater than 60% and positive end-expiratory pressure (PEEP) greater than 12 [5,9,11]. Changes to the ventilator settings prior to IC measurement may also lead to inaccurate results [5,11]. Gas exchange lost through extracorporeal membrane oxygenation will also prevent accurate IC testing [12,13]. Continuous renal replacement therapy (CRRT) may prevent reliable IC energy expenditure measurement due to gas loss across the dialysis membrane [9] however there is controversy in the literature regarding the significance of this loss [14,15]. Due to this controversy, CRRT was not considered a technical exclusion to performing IC for the purposes of the present study. Failure to meet technical criteria may prevent a significant number of patients in the PICU from receiving optimized nutrition assessment using IC. The proportion of patients and patient days in PICU for which EE can be measured using IC is currently unknown. In the current study, we aimed to quantify the daily proportion of PICU patients who met technical criteria to perform indirect calorimetry and describe the technical contraindications when criteria were not met.

2. Materials and methods

2.1. Study design and population

This was a prospective, observational, single-centre study conducted in the cardiac and general PICUs between June 2014 and February 2015. The Health Research Ethics Board of the University approved the study. All children 0–18 years of age admitted to the cardiac or general PICU for at least 96 h were included in the study in order to capture the children at high nutrition risk who may benefit most from IC. Members of the established indirect calorimetry team carried out data collection within the same 2 h each morning. Demographic variables collected were age, length of stay (LOS), and admission diagnosis. Technical criteria variables collected included type of respiratory support being provided (if applicable), endotracheal tube (ETT) cuffed or not (if intubated), presence of air leak around ETT cuff (if intubated), changes to mechanical ventilation settings, diagnosis of air leak from chest tube, provision of other external gas support (ie. nitric oxide), and provision of extracorporeal membrane oxygenation (ECMO). Technical criteria for IC were not met in any of the following circumstances: supplemental oxygen including non-invasive ventilation (NIV) and nasal cannula provided to non-intubated patients, intubated patients with ETT leak >10% or FiO2 > 60% or PEEP >12 or changes to ventilator settings in the previous 2 h, high frequency ventilation, presence of chest tube air leak, provision of iNO, or provision of ECMO. Although technical criteria were assessed in all included patients, IC was not actually performed for the purposes of this study. The primary outcome was the number of patients meeting technical criteria for IC on at least one day during their stay in PICU. The secondary outcome measured was the number of total patient days when technical criteria for IC was met.

2.2. Statistics

There is no published data on the number of children who will meet technical criteria to perform indirect calorimetry. Assuming that 25% of critically ill children would meet IC criteria, 288 patients were needed to estimate the rate with a 95% confidence interval of ±5%

Descriptive statistics were used to analyze variables. Data is expressed as median with interquartile range (IQR) for continuous variables and number and percent for proportions. Categorical variables were compared using the Chi-square test. Two-sided p-value <0.05 was considered statistically significant. Confidence intervals (95% CI) were calculated using the modified Wald method. Analysis was performed using Prism version 5.0 (GraphPad Software, La Jolla California USA).

3. Results

Two hundred and eighty eight patients with a median (IQR) age of 0.7 (0.3–4.6) years were included. Patient intubation status and admission diagnosis are shown in Table 1. Less than 1% of intubated patients had uncuffed ETTs. Patients received supplemental oxygen or NIV on 73% of non-intubated patient days. The median (IQR) LOS was 7 [5–14] days. Survival to PICU discharge was 97% (95%CI, 94.5–98.7%).

Overall, 77 patients (27%, 95%CI 22.0–32.1) did not meet technical criteria for IC on at least one day during their stay in PICU. The causes for not meeting technical criteria are depicted in Fig. 1. Supplemental oxygen delivery, including non-invasive ventilation and nasal cannula to non-intubated patients accounted for more than half (56%) of days when criteria were not met. The “other” category includes patients who were using home ventilation machines that were incompatible with IC equipment and times when patients were undergoing an operation or were in transfer between units.

Table 1
Patient intubation status and admission diagnosis.

	N (%)	Patient days (%)
Total population	288	3590
Intubation status		
Patient intubated		1891 (53%)
Patient not intubated		1699 (47%)
Admission diagnosis		
Cardiac surgery	99 (35%)	1214 (34%)
Surgery (non-cardiac)	25 (9%)	202 (6%)
Cardiac nonsurgical	24 (9%)	451 (13%)
Respiratory distress	55 (20%)	888 (25%)
Trauma	12 (4%)	203 (6%)
Oncology	3 (1%)	63 (2%)
Medicine other	63 (22%)	510 (14%)