Clinical Nutrition 32 (2013) 118–121

Contents lists available at SciVerse ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Indirect calorimetry in mechanically ventilated patients. A systematic comparison of three instruments☆

Martin Sundström, Inga Tjäder, Olav Rooyackers, Jan Wernerman*

Department of Anaesthesiology and Intensive Care Medicine, K32, Karolinska University Hospital Huddinge and Karolinska Institutet, 14186 Stockholm, Sweden

ARTICLE INFO

Article history:
Received 15 December 2011
Accepted 9 June 2012

Keywords:
Energy expenditure
Respiratory quotient

SUMMARY

Background & aims: Indirect calorimetry is the gold standard in determining energy expenditure to dose nutritional therapy for critically ill patients. The most commonly used system for indirect calorimetry in the ICU setting (Deltatrac Metabolic Monitor) is no longer in production. The aim of this study was to compare two new instruments for IC (Quark RMR, CCM Express) to the Deltatrac in mechanically ventilated patients.

Methods: Sequential measurements with all three instruments were performed in randomized order on 24 mechanically ventilated ICU patients. Resting energy expenditure (REE), respiratory quotient (RQ), oxygen consumption and carbon dioxide production were recorded during a stable 10–30 min period.

Results: There was no difference in mean REE measurements between Deltatrac, 1749 ± 389 kcal/24 h and Quark RMR, 1788 ± 494 kcal/24 h ($P = 0.166$). CCM Express produced 64% higher mean REE values (2876 ± 656 kcal/24 h) than Deltatrac ($P < 0.0001$). All instruments registered different values for RQ and expiratory minute volume.

Conclusion: Available instruments for indirect calorimetry give conflicting estimates of energy expenditure in mechanically ventilated patients. Whilst the Quark RMR compares better with the Deltatrac than CCM Express, the mechanisms behind this difference needs to be further explored.

1. Introduction

Providing optimal nutrition for the critically ill patient is an important part of ICU therapy, reducing both morbidity and mortality.[1] Actual energy expenditure is important information for deciding the optimal caloric content of the nutrition to be given.[2] Indirect calorimetry, i.e. determining energy expenditure by measuring O_2 consumption and CO_2 production, is considered to be the gold standard for assessing energy expenditure of mechanically ventilated patients.[3–6]

During the last two decades the most extensively used system for indirect calorimetry has been the Deltatrac Metabolic Monitor (Datex-Ohmeda, Finland), an instrument that has been validated in the intensive care setting.[7] Production of the Deltatrac has now been discontinued, creating the necessity of validating new instruments for indirect calorimetry in mechanically ventilated patients. Presently there are two new instruments for measuring energy expenditure in mechanically ventilated patients (Quark RMR [Cosmed, Rome, Italy] and the CCM Express [Medgraphics Corp, St Paul, Minneapolis, USA]). Recently the three instruments have been compared in spontaneously breathing healthy subjects using mouthpiece and canopy systems.[8] The three instruments were in good accordance in that comparison.

The aim of this study was to measure resting energy expenditure in mechanically ventilated patients using the three instruments according to the recommendations of the manufacturers. The primary endpoint was comparing energy expenditure measurements of the new instruments to the Deltatrac Metabolic Monitor using Bland–Altman plots. Secondary endpoints were to compare the different instrument's assessments of respiratory quotient (RQ). Minute volume (MV) measurements were also determined by all three devices and compared to the ventilator readings.

2. Materials and methods

2.1. Patients and setting

Mechanically ventilated patients in the general ICU of Karolinska University Hospital Huddinge were included in the study. Inclusion criteria were (i) intubation or tracheostomy, (ii) a fractional inspired oxygen level (FiO_2) of ≤50%, (iii) ≥18 years of age,

☆ Conference presentations: ESPEN, Gothenburg 2011 and ESICM, Berlin 2011.

* Corresponding author. Tel.: +46 8 58586395; fax: +46 8 7795424.
E-mail address: jan.wernerman@karolinska.se (J. Wernerman).

0261-5614/$ – see front matter
http://dx.doi.org/10.1016/j.clnu.2012.06.004

(iv) constant rate of continuous parenteral and/or enteral nutrition during the study period. Continuous renal replacement therapy was not an exclusion criterion, given that filtration was constant during the measurement period. Exclusion criteria were gas leakages and chest drains. Treatment with nitric oxide (NO) or extracorporeal machine oxygenation (ECMO), also possible exclusion criteria, are not available in the unit. The study protocol was approved by the Ethics Committee. Informed consent was obtained from the patients themselves or their close relative, after explaining the protocol and the risks involved orally and in writing.

All patients were ventilated using the Evita XL ventilator (Dräger, Germany) in pressure support (CPAP/ASB) or pressure controlled (BIPAP/ASB) modes. The study period was November–December 2010.

Patients were studied on one or multiple occasions 3–5 days apart, the number of measurements was related to the length of mechanical ventilation. Treatment was in all details decided by the attending intensive care physician. The only requests by the study protocol was that the nutrition provided should not be changed during 3 h before and during the individual study period and that ventilator settings and continuous renal replacement therapy settings were not changed 1 h before and during the individual study period.

2.2. Protocol

Measurements were performed sequentially with the three systems in a randomized order. Randomization was performed drawing sealed notes with the names of the three instruments from a basket. In addition a forth measurement was performed with the first instrument studied at the end of the sequence. For the instruments used twice in the sequence the average values of the two measurements were used as the result. In a schematic figure the connections of the 3 instruments to the ventilator are depicted (Fig. 1).

Ventilator parameters were registered at the beginning and end of the measurement with each instrument. In the case where the ventilator registered a gas leakage, the respiratory circuit and patient connection was checked for leaks and measurement discontinued until leakage was $\leq$10%.

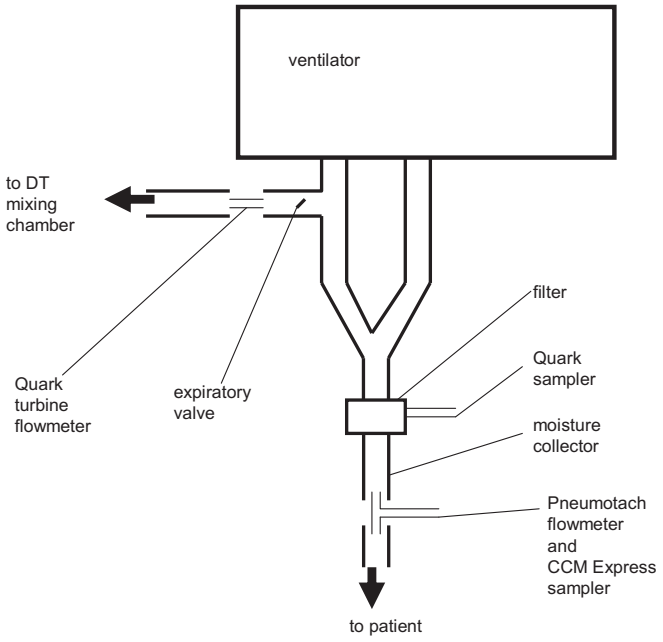

Fig. 1. A schematic figure over the different sampling points at the ventilator for the 3 instruments for indirect calorimetry compared.

Patients were given a resting period of 60 min if any potentially strenuous or stressful events, such as patient hygiene, physiotherapy, invasive or diagnostic procedures, had been performed prior to the measurement. In the event that any type of such distraction had occurred during the study period, the event was recorded and the patient was given an extra 15 min resting period before proceeding with further measurements.

Data were collected when the patient and instrument readings were considered stable for a minimum of 10 min. For Quark RMR and CCM Express the variability was given on the display, and in accordance with the manufacturer's recommendation a variability $<$10% was required for stability. Measurements with the Deltatrac were conducted at a minimum of 20 min in accordance with manufacturer's recommendations. Still the variability was larger and estimated by visual inspection of the graphical trends displayed on the monitor. In practice a variability of $<$20% was the target.

Harris–Benedict's equation was used without any stress factor.[3]

2.3. Instruments

2.3.1. Detatrac metabolic monitor (Datex-Ohmeda, Helsinki, Finland)

The Deltatrac measures inspiratory and expiratory O_2/CO_2 concentrations with a paramagnetic and infrared analyzer respectively. Exhaled gas is sampled through a line of Nafion tubing permeable to water vapor, bringing humidity into equilibrium with ambient air. The air exhaled by the patient is collected at the expiratory port of the ventilator and gathered in a mixing chamber. Gas from the mixing chamber is then diluted with room air drawn at a set flow rate (Q) and CO_2 production (VCO_2) is calculated from the known flow rate and partial pressure of CO_2 in the diluted gas (fCO_2). Respiratory quotient (RQ) is derived through Haldane transformation,[9] and O_2 consumption (VO_2) is calculated from these two variables. Thus, the Deltatrac does not directly measure the minute ventilation of the patient. All gases released at the expiratory port of the ventilator are sampled and consequently the Deltatrac lacks a specific flow measurement technique, and can therefore not distinguish any bias flows from ventilator flow triggering systems from the exhaled gas of the patient.

2.3.2. Quark RMR (Cosmed, Italy)

The Quark RMR measures VCO_2 and VO_2 using a breath-by-breath technique. Gas is sampled through a PVC line connected proximally to the Y-piece of the ventilator tubing and dried to ambient humidity through a Nafion line. Like the Deltatrac, it uses a paramagnetic O_2 and infrared CO_2 analyzer. Patient minute ventilation is measured by a turbine flowmeter connected to the expiratory port of the ventilator. The software of the Quark has a function for detecting any bias flow from the ventilator and compensating for this when calculating VCO_2 and VO_2.

2.3.3. CCM Express (Medgraphics Corp, St Paul, Minneapolis, USA)

The CCM Express also applies a breath-by-breath technique for determining gas exchange. It uses a pneumotach flowmeter connected directly to the endotracheal tube, where inspiratory and expiratory gas is collected through a sampling line connected to the flowmeter. O_2 measurement is performed using a galvanic fuel cell, and CO_2 is measured with an infrared analyzer. Since patient ventilation is measured at the endotracheal tube no considerations have to be taken to any bias flow provided by the ventilator.

2.4. Measurements

Immediately before the study the Deltatrac Metabolic Monitor flow constant and RQ was calibrated by a quantitive alcohol