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Mechanical ventilation mode (volume × pressure) does not change the variables obtained by indirect calorimetry in critically ill patients☆

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Abstract

Purpose: The aim of the study was to analyze the difference between the results obtained by indirect calorimetry (IC) using volume-controlled and pressure-controlled mechanical ventilation in 2 different ventilators and to characterize the variables achieved by IC after well-defined changes in minute volume (Vm).

Materials and Methods: Prospective study of 20 critically ill patients under volume-controlled (n = 15) or pressure-controlled (n = 5) mechanical ventilation. Three IC measurements of 45 minutes each were taken; values of oxygen consumption (V_{O_2}), carbon dioxide production (V_{CO_2}), Vm, resting energy expenditure (REE), and respiratory quotient (RQ) were obtained. For the last measurement, Vm was set at 20% above the baseline.

Results: There were no differences between the results obtained by IC during volume-controlled and pressure-controlled mechanical ventilation. The most relevant changes in the variables obtained by IC before and after intervention in Vm were a significant increase in V_{CO_2} (from 165 to 177 $mL \cdot min^{-1}$; $P < .01$), a decrease in Pa_{CO_2} (from 38.49 to 28.46 mm Hg; $P < .01$), and a rise in pH (from 7.41 to 7.49; $P < .01$). There were no alterations in V_{O_2}, REE, or RQ.

Conclusions: Ventilators and ventilation modes do not influence the IC measurements. The observed changes have no clinical effects and are reversible, provided that increased Vm is maintained for no longer than 45 minutes.

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1. Introduction

Indirect calorimetry (IC) estimates resting energy expenditure (REE) by measuring the exchange of respiratory gases

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between the organism and the environment, and the lung plays an important role in this context [1-3]. Indirect calorimetry is widely applicable in critically ill patients and largely used to measure carbon dioxide production (V_{CO_2}) [4,5], oxygen consumption (V_{O_2}) [6], REE [4,7], and rate of substrate use or interconversion by means of the respiratory quotient (RQ) [4,8,9]. This methodology can also be used to obtain more specific and objective hemodynamic variables, such as cardiac output, in a noninvasive way [10]. With the advance in mechanical ventilation techniques, there has been growing interest in the measurement of expired gases as well as in the analysis of ventilation and transport of oxygen and carbon dioxide in critically ill patients [11]. Although most IC studies involving mechanically ventilated individuals use the volume-controlled mode, there is no explanation as to why this is the most commonly used ventilation mode. The present investigation analyzes the differences between volume-controlled and pressure-controlled ventilation.

The aim of this study was to evaluate the effect of immediate changes in minute volume (Vm) on V_{O_2}, V_{CO_2}, RQ, and REE in mechanically ventilated, critically ill individuals. The influence of changes in V_{O_2} and V_{CO_2} on the energy expenditure of the patients and blood gas dynamics is also examined.

2. Subjects and methods

This is a prospective, self-controlled study conducted in the intensive care unit (ICU) of Unidade de Emergência do Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (Brazil). The research protocol was approved by the research ethics committee of Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto. A signed informed consent was obtained from the subjects' legally authorized representatives.

2.1. Subjects

Twenty patients, 13 male and 7 female, with a mean age of 62.0 ± 17.2 years, mean weight of 76.7 ± 12.8 kg, and mean height of 171 ± 8 cm were included in the study. At ICU admission, the patient's weight was determined using a portable digital scale (Slingscale 2002, Instrucom/Hill-Rom series, Hillenbrand Industries, Batesville, Ind). The patient's height was determined as the mean value from 2 independent measures performed by the medical assistants, using a flexible measuring tape (3M do Brasil Ltda, Sumare, São Paulo, SP, Brazil) properly positioned from the apical region of the skull to the heel with the patient placed in supine position [12]. Disease severity was classified by means of the Acute Physiologic and Chronic Health Evaluation II score, calculated upon ICU admission [13]. The ventilators consisted microprocessed equipment (Savina; Drägermedical, Lübeck, Germany, or Bird 8400; Tri-Bird Prod Co, Palm Springs, CA, USA) operating in the volume-controlled (n = 15) or pressure-controlled (n = 5) mode. The patients were hemodynamically stable, sedated, and presented no spontaneous breathing. All the measurements were carried out on the subjects placed in supine position. There was no perturbation throughout the measurements, and no procedures were performed on the individuals. Exclusion criteria included hemodynamically unstable patients, subjects taking vasoactive drugs, age older than 80 years and younger than 15 years, need for fraction of inspired O_2 (F_{IO_2}) greater than 0.6, mean blood pressure less than 50 mm Hg, heart rate of less than 50 or more than 140 beats per minute, oliguric renal insufficiency of any etiology, pressure support ventilation mode, presence of bronchopleural fistula, irreversible circulatory shock, encephalic death, and refusal by the individual's legal representative to sign an informed consent allowing patient's participation in the study.

2.2. Indirect calorimetry and mechanical ventilation

The patients were submitted to 3 consecutive IC measurements (portable calorimeter DELTATRAC II Metabolic Monitor; Datex-Ohmeda, Helsinki, Finland) of 45 minutes each, with a 30-minute interval between each measurement. Data on V_{O_2}, V_{CO_2}, Vm, REE, and RQ were obtained. The protocol was initiated after the warming up of DELTATRAC II equipment for 30 minutes. The gas and pressure had been calibrated according to the manufacturer's instructions. Bronchial hygiene was performed during equipment heating and calibration, so that it would not be necessary to carry it out during calorimetry. After equipment heating and calibration, 2 measurements of 45 minutes each were accomplished at the Vm of the patient, considered baseline. A 30-minute interval was allowed between each measurement, in case bronchial hygiene was necessary. Another 15 minutes were then allowed to elapse for gas stabilization. Next, Vm was adjusted to 20% above the patient's baseline, which was immediately followed by the last 45-minute measurement. Change in Vm was induced by raising the tidal volume to 20% above the initial value, the peak pressure was limited to 40 cm H_2O, but the respiratory rate remained constant. All the measurements were accomplished in the morning because, according to Smyrnios et al [14], the physiologic variables are closer to the daily mean values until 15:00 hours. Blood gas analysis by means of arterial gasometry was performed in 11 patients after a 20% rise in Vm. Arterial blood samples, collected before calorimetry, had been requested by the medical team of the ICU as part of patient routine examination.

2.3. Statistical analysis

Statistical analysis was carried out with the aid of the software SAS 9.1 (Statistical Analysis System; SAS Institute Inc, Cary, NC). Comparisons between the IC and arterial

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