Computation and monitoring of CO2 elimination for 'open lung' recruitment

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Introduction

Patients with Acute Respiratory Distress Syndrome (ARDS) present a shortness of breath and typically experience a partial lung collapse (atelectasis) caused by inflammation of lung parenchyma leading to an impaired gas exchange: lower oxygenation and lower CO2 elimi- nation, which can cause hypoxemia, hypercapnia and eventually other organ failures. One of the therapeutic options is to introduce artificial ventilation based on an ''Open Lung'' strategy. Its principle is to open the lung and keep it open [1]. However, the assessment of the lung state (still closed or already open) is necessary during the recruitment maneuvers. Basically, the technique for evaluation is based on oxy- genation, either arterial oxygen tension (PaO2) [2] or arterial oxygen saturation (SaO2) [3]. However, in this article, CO2 elimination is computed in every breath and observed during 'Open Lung' recruit- ment maneuvers as an alternative for assessing the state of the lung, which is a noninvasive approach.

Methods

The system is composed of a Panel PC Control Unit (PPC-154T), an artificial ventilator (EVITA XL, Dra¨ger), and some other measuring devices like spectrophotometry (CeVOX, Pulse Medical System) for measuring SaO2 and a special sensor called Capno Plus (Option for EVITA XL, Dra¨ger), which is used to measure exhaled carbon dioxide. The data of airway flow and carbon dioxide are transferred to the Panel PC by a serial Medibus connection. The intensive compu- tation is carried out in every 8 ms in order to display CO2 elimination for every breath provided in the following equation, which simply means the content of CO2 in ml pro minute computing in every single cycle of exhalation.

$$\dot{V}\mathrm{CO}_2 = RR \cdot \int_{t_{insp}}^{t_{exp}} \dot{V}(t) \cdot \mathrm{CO}_2(t)\mathrm{d}t \qquad (1)$$

where V_ CO2 : CO2 elimination; RR: Respiratory Rate; V_ ðtÞ: Airway Flow; CO2 ðtÞ: Measured Carbon Dioxide in percent

An animal study was implemented at Charite´ Hospital in Berlin, which was approved by the local animal ethics committee. A female domestic pig with 35 kgs received pre- medication and proper anes- thesia before the experiment. The pig was induced by lavage with isotonic saline solution for an acute lung failure. Subsequently, an 'Open Lung' recruitment maneuver was applied in order to improve the gas exchange by monitoring CO2 elimination and SaO2 as a ref- erence for oxygenation. All necessary parameters including the computing CO2 elimination were recorded in the panel PC for further analysis.

Results

Peak Inspiratory Pressure (PIP) and Positive End-Expiratory Pres- sure (PEEP) were set at 20 and 10 mbar before the recruitment. To perform 'Open Lung' recruitment, higher PIP at 45 mbar was applied for 3–5 breaths to open the atelectatic areas of the lung and PIP was reset to its previous value at 20 mbar after that excitation, while PEEP was kept at the same proper value 10 mbar to keep the lung open. The overall settings with FiO2 = 0.21 and the responses of SaO2, CO2 and CO2 elimination during 'Open Lung' recruitment are shown in Fig. 1.

Discussion

With the advance in computer technology and Medibus protocol, it is possible to compute CO2 elimination in every 8 ms leading to the monitoring of this vital parameter in every single breath. According to the results, it is clearly to observe that CO2 elimination improves suddenly after the first pulse of higher PIP excitation and, after recruitment, CO2 elimination increases more than double, which is a good sign for better gas exchange in the lung. If we consider the oxygenation parameter SaO2, SaO2 increases dramatically from 89 % to 99 % after the recruitment under the same ventilator settings, which confirms the recruitment of the atelectatic areas of the

lung. With this experiment, CO2 elimination at 183 ml/min or CO2 elimination per unit weight at 5.2 ml/min/kg shows the state of opening lung. Therefore, the computation and monitoring of CO2 elimination would be a promising parameter to observe a condition of gas exchange in the lung of patients with ARDS, which gives us an insight for the state of collapsed lung in a noninvasive way.

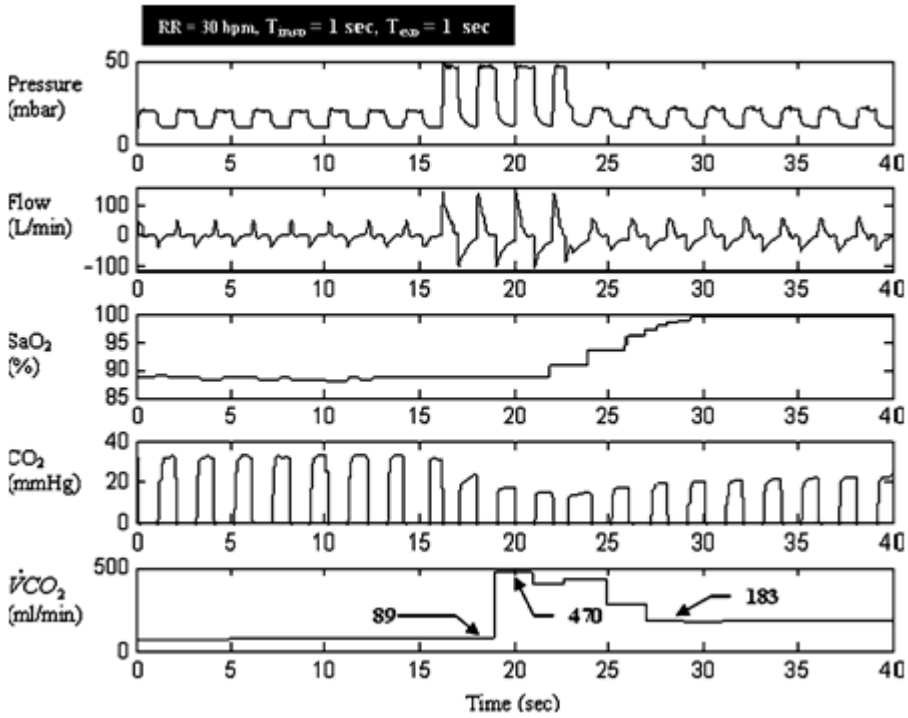

Fig. 1 Measured parameters from EVITA XL with Capno Plus for further computation of CO2 elimination

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