Respiratory Medicine (2006) **100**, 1526–1533

ELSEVIER

respiratoryMEDICINE

Physiological response to intrapulmonary percussive ventilation in stable COPD patients

Stefano Nava*[,1], Nicola Barbarito, Giancarlo Piaggi, Elisa De Mattia[1], Serena Cirio

Respiratory Intensive Care Unit, Fondazione S.Maugeri, IRCCS, Istituto Scientifico di Pavia, Via Ferrata 8, 27100 Pavia, Italy

Received 26 September 2005; accepted 12 January 2006

KEYWORDS
Intrapulmonary percussive ventilation;
COPD patients;
Randomized study;
Respiratory muscle

Summary Intrapulmonary percussive ventilation (IPV) is a ventilatory technique that delivers bursts of high-flow respiratory gas into the lung at high rates, intended for treating acute respiratory failure and for mobilization of secretions. We performed a study, aimed at assessing the physiological response to IPV, on patients' breathing pattern, inspiratory effort, lung mechanics and tolerance to ventilation.

Ten COPD patients underwent randomized trials of IPV through a face mask at different pressure/frequency combinations (1.2 bar/250 cycles/min; 1.8/250; 1.2/350; 1.8/350), separated by return to baseline (SB), using the IMP2 ventilator. In 5 patients we have also compared the physiological changes of IPV with those obtained during pressure support ventilation (PSV).

Minute ventilation did not vary among the trials, but tidal volumes (V_T) were significantly greater during 1.2/250, 1.2/350 and 1.8/350 compared to SB. The pressure time product of the diaphragm per minute (PTPdi/min) estimate of the diaphragm oxygen expenditure was also significantly reduced during 1.2/250 and 1.8/250 (209 $cmH_2O \times s/min$ for SB vs. 143 and 125 for 1.2/250 and 1.8/250, respectively $P<0.05$), as well as dynamic intrinsic end-expiratory pressure (PEEPi,dyn). Similar reduction in PTPdi/min were obtained also during PSV. Tolerance to ventilation and oxygen saturation were satisfactory and did not change during the different trials. In 5 normal subjects a prolonged apnea trial lasting >2 min was also performed, without any significant decrease in SaO_2 or subjective discomfort. In conclusion, IPV was able to guarantee an adequate ventilation, while inducing a significant unloading of the diaphragm during the "low-frequency" trials.

*Corresponding author. Tel.: +39 382 592 806; fax: +39 382 592 075.
E-mail address: snava@fsm.it (S. Nava).
[1]S.N. and E.D.M. received a travel grant from Breas Medical, Sweden, to participate in the ERS meeting of Stockholm 2002 and Glasgow 2004, respectively.

0954-6111/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rmed.2006.01.010

Introduction

Intrapulmonary percussive ventilation (IPV) is a ventilatory technique that delivers small bursts of high flow respiratory gas into the lung at high rates,[1] intended for mobilization of secretions that has been employed in several pathologies, characterized by excessive secretion, both in adults and children.[2–5] In a very recent randomized-controlled study [6] conducted in ICU and performed in COPD patients with initial respiratory acidosis, IPV has been shown to prevent the deterioration of acute exacerbation, avoiding therefore the use of invasive mechanical ventilation. Potential mechanisms of actions include enhanced alveolar recruitment, improved mucus clearance, and/or a direct high-frequency oscillatory ventilation like effect.[1] Surprisingly, so far no study has been performed to evaluate the physiological changes induced by IPV. In order to better understand the effects of this modality of ventilation, we describe the changes of IPV on breathing pattern, diaphragmatic function, respiratory mechanics and patient's tolerance in stable COPDs with chronic respiratory failure, and we compared, in a subset patients, those effects with the ones obtained during non-invasive pressure support ventilation (PSV). We also verify the potentiality of IPV in providing effective ventilation during a prolonged apnea trial in a group of normal subjects.

Materials and methods

Patients

Ten severe COPD patients, with minimal mucus hypersecretion (<10 ml/d) naïve to ventilation, and affected by chronic hypercapnic respiratory failure were studied during a phase of clinical stability during sessions of IPV. Clinical stability was defined as the absence of exacerbations of their respiratory disease in the preceding 3 months. The patients were admitted to the hospital for a scheduled short control of their clinical conditions. The quantity of mucus secretion was assessed asking the patients to collect their sputum in a box for the 48 h preceding the experimental trial. Collection and quantification of sputum weight was performed every 12 h. Patients' characteristics are illustrated in Table 1. All the patients were on long-term oxygen therapy.

Table 1 Patients' characteristics at enrolment.

Variable	
Age (years)	65.2 ± 6.7
Sex (M/F)	8/2
pH	7.37 ± 0.02
$PaCO_2$ (mmHg)	52.3 ± 8.1
PaO_2 (mmHg)	53.1 ± 7.0
FVC (% predicted)	89 ± 11
FEV_1 (% predicted)	31 ± 9
FEV_1/FVC	35 ± 8

Intervention

IPV is a ventilatory versatile form of high-frequency ventilation (HFV) that delivers bursts of high-flow respiratory gas in the lung at high respiratory rates. HFV techniques have three essential common elements: a high-pressure flow generator, a valve for flow interruption, and a breathing circuit for connection to the patients. Many variants of this definition were further developed as flow interruption ventilation (HFFI), high-frequency oscillation (HFO) and high-frequency positive pressure ventilation (HFPPV) based on the specific techniques that discriminate them. Similar to HFV, IPV delivers subphysiologic tidal volumes (V_T) at rapid rates. Unique to the IPV is the presence of a sliding venturi system (phasitron), powered by compressed gas that can be changed from 0.8 up to 3.5 bar and that generates the oscillations in the range of 80–650 cycles/min.[7] During this ventilation a continuous positive pressure is maintained, while a high-velocity percussive inflow opens airways and enhances intra-bronchial secretion mobilization. During IPV the high pressures generated by the ventilator are mostly dissipated in the mask and in the upper airways. IPV was delivered with a specific ventilator (IMP2, Breas Medical Mölnlycke, Sweden) through a full face mask. The inspiration-to-expiration time (I/E ratio) was adjusted to 1/2.5 and the proximal expiratory pressure was set to 3 cmH_2O. The I/E ratio of the administered oscillatory flow pattern generated by the device (that is independent of the patient's breathing pattern) was set at 1/2.5 because this was the setting used in the only clinical study performed in COPD patients with respiratory failure.[6] Indeed, since the setting of the I/E ratio influences the mean airway pressure, it was recommended by the distributors of the device, the use of a 1/2.5 ratio in COPD patients, to avoid pressure higher than 30 cmH_2O.

Protocol

First trial

As illustrated in Fig. 1, upper part, 10 COPD patients were randomly assigned to 4 sessions of