



# Noninvasive proportional assist ventilation and pressure support ventilation during arm elevation in patients with chronic respiratory failure. A preliminary, physiologic study

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## KEYWORDS

Noninvasive positive pressure ventilation;  
COPD;  
Rehabilitation;  
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## Summary

**Background:** It has been shown that upper limbs activity increases the respiratory workload in patients with chronic respiratory failure (CRF). The object of the present study was to investigate whether, in these patients: (i) noninvasive positive pressure ventilation (NPPV) could sustain the inspiratory muscles to meet the greater ventilatory demand during upper limbs activity with the arm elevation test (AE); (ii) proportional assist ventilation (PAV) might be superior to pressure support ventilation (PSV) during AE, because of its potential more adaptable response to sudden changes in the ventilatory pattern.

**Methods:** The study was performed in the pulmonary function laboratory of the Pulmonary Division in Verona General Hospital, Verona, Italy. We studied 8 male patients with CRF due to chronic obstructive pulmonary disease (COPD). Each patient received 2 treatment in random order with a crossover design: spontaneous breathing (SB), SB with AE, either PSV or PAV without and with AE, SB without and with AE, either PSV or PAV without and with AE. We measured: lung function tests, lung mechanics, ventilatory pattern and diaphragmatic effort (pressure time product,  $PTP_{di}$ ).

**Results:** (i) AE increases minute ventilation (+14%) and  $PTP_{di}$  (+64%); (ii) ventilatory support, both with PSV and PAV unloads the diaphragm both at rest ( $PTP_{di}$  -77% and -54%, respectively) and during arm elevation ( $PTP_{di}$  -54% and -44%, respectively).

**Conclusions:** PAV and PSV unloads the diaphragm in patients with CRF due to COPD both during SB and AE; PAV can be more efficient than PSV in assisting the diaphragm during AE in producing a greater level of minute ventilation for a similar rise in  $PTP_{di}$

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compared to PSV. Noninvasive ventilatory support should be considered in rehabilitation programs for training of upper limbs activity.

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## Introduction

It has been reported that pulmonary rehabilitation is an effective intervention in the management of patients with chronic obstructive pulmonary disease (COPD).<sup>1–3</sup> However, poor exercise tolerance due to the mechanical abnormalities of the respiratory system in those patients might cause significant limitation to rehabilitation programs.<sup>4–6</sup> Artificial ventilatory assistance could improve exercise tolerance and hence help severe COPD patients to achieve a higher level of training.<sup>7–10</sup> This approach has been applied during lower limbs exercise only, whereas also upper limbs exercise can be important for the daily activities and the quality of life of such patients.<sup>11</sup>

Some years ago, a series of papers by Celli and colleagues<sup>12–15</sup> showed that, in patients with severe COPD, simple arm elevation (AE) for a few minutes determined a sharp and remarkable increase in the patient's inspiratory effort to meet the substantial rise in the metabolic load and ventilatory demand. More recently, Velloso and colleagues<sup>11</sup> showed that many daily activities involving arm exercise determined a substantial rise in ventilatory demand. We wondered whether noninvasive positive pressure ventilation (NPPV) could be helpful during AE as it was shown to be during conventional cycle exercise. If so, NPPV could help in more complete rehabilitation programs, including upper limb exercise.

In a few recent reports, proportional assist ventilation (PAV) was applied<sup>16–19</sup> while either pressure support ventilation (PSV)<sup>7,9,10</sup> or continuous positive airway pressure (CPAP)<sup>8</sup> was the mode of ventilatory assistance in previous studies. Theoretically, PAV should better adapt to a sharp rise in ventilatory demand than PSV.<sup>20</sup> In fact, PAV is a patient-guided ventilatory mode in which the level of assistance is proportional to the patient's ventilatory drive and timing. To our knowledge, PAV and PSV were compared in stable COPD patients,<sup>21,22</sup> and during lower limb exercise,<sup>16,17</sup> but not yet during arm exercise.

Therefore, this study was designed to answer to 2 questions. First we aimed to investigate whether ventilatory assistance could unload the inspiratory muscles and meet the greater ventilatory demand during upper limb exercise in the form of the AE

test. Second we compared PAV and PSV to investigate whether PAV was superior to PSV as it might be hypothesized on the basis of theory.

## Methods

This protocol was approved by the Institutional Ethics Committee of the Azienda Ospedaliera di Verona, where the experimental procedure was performed and informed consent was given by the patients.

## Patients

We studied 8 male patients ( $64.9 \pm 11.4$  years) with chronic respiratory failure (CRF) due to COPD. In 2 of the 8 patients also kyphoscoliosis was present. Diagnosis of COPD was made initially according to the European Respiratory Society Guidelines.<sup>23</sup> The diagnosis of CRF was based on the clinical records showing chronic hypoxia and chronic CO<sub>2</sub> retention, i.e. values of PaCO<sub>2</sub> >45 mmHg, consistently in the months, if not years, preceding the study. Values of arterial blood gases at the time of inclusion in the study are shown in Table 1. In all patients with one exception, arterial blood was sampled after a few minutes of breathing room air. In one patient (no. 7) arterial blood was sampled while breathing oxygen (2 L/min)-enriched air, because the patient did not tolerate oxygen withdrawn. Spirometric values from clinical records are also reported in Table 1. In addition to the evidence of CRF and COPD, inclusion criteria were the followings: (i) stable clinical condition, i.e. stability in blood gas values and pH (>7.35), and lack of exacerbations in the preceding 4 weeks; (ii) absence of exclusion criteria. The latter were: (i) presence of other chronic organ failure (e.g. renal, hepatic or cardiac failure documented by certified clinical history); (ii) any kind of neoplastic disorder; (iii) inability to cooperate; (iv) lack of informed consent.

All patients were on long-term oxygen therapy. Seven patients were also on home NPPV, in the PSV mode with bi-level ventilator for 5–6 h in the day or night, depending on the patient's and caring physician's choice. All the patients received regular treatment with inhaled bronchodilators, inhaled

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