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Long-term reduction of hyperinflation in stable COPD by non-invasive nocturnal home ventilation

Stephan Budweiser[a,b,*], Frank Heinemann[a,b], Wolfgang Fischer[a,b], Jakob Dobroschke[a,b], Michael Pfeifer[a,b]

[a]*Fachklinik für Erkrankungen der Atmungsorgane, Donaustauf, Germany*
[b]*Medizinische Klinik II, Universitätsklinik, Regensburg, Germany*

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Summary
Objective: The role of non-invasive positive pressure ventilation (NPPV) in stable COPD with chronic ventilatory failure remains controversial. The impact of long-term home nocturnal NPPV treatment on deflation has not yet been evaluated in detail.
Methods: Retrospective explorative study of 46 patients with stable COPD undergoing NPPV treatment. Effects of NPPV on bodyplethysmographic parameters, blood gas tensions and inspiratory muscle function after 6.2 ($\pm$1.7) and 12.7 ($\pm$2.1) months of treatment. Further, evaluation of 1-year survival, compliance and ventilation parameters.
Results: One-year survival was 89.1%. The effectiveness of ventilation was proven by a significant reduction in nocturnal and daytime $PaCO_2$. We observed a decrease in the ratio of residual volume (RV) to total lung capacity (TLC) on the average of 5.2$\pm$9.8% (or 15.2$\pm$29.7% pred.; $P<0.01$) at six and 3.9$\pm$9.0% (or 12.9$\pm$18.6% pred.; $P<0.001$) at 12 months. As a consequence, we found significant improvements in inspiratory capacity (IC), vital capacity (VC) and forced expiratory volume in one second (FEV_1). For patients with the most severe hyperinflation (RV/TLC $>$ 75%), we found a significant positive correlation between inspiratory positive airway pressure (IPAP) and reductions in $PaCO_2$ ($r = 0.56$; $P<0.05$) and RV/TLC ($r = 0.50$; $P<0.05$).

Abbreviations: BE, base excess; BMI, body-ass index; CPAP, continuous positive airway pressure; COPD, chronic obstructive pulmonary disease; CRP, C-reactive protein; EPAP, expiratory positive airway pressure; EELV, end-expiratory lung volume; FEV_1, forced expiratory volume in one second; Hb, haemoglobin; HRQL, health-related quality of life; IC, inspiratory capacity; IPAP, inspiratory positive airway pressure; LTOT, long-term oxygen therapy; NPPV, non-invasive positive pressure ventilation; $P_{0.1}$, mouth occlusion pressure at 100 ms; $PaCO_2$, arterial carbon dioxide tension; PaO_2, arterial oxygen tension; $PEEP_i$, intrinsic positive end-expiratory pressure; PI_{max}, maximal inspiratory pressure; RV/TLC, ratio residual volume/total lung capacity; SaO_2, arterial oxygen saturation; SR_{tot}, total specific resistance; TLC, total lung capacity; VC, vital capacity

*Corresponding author. Ludwigstraße 68, D-93093 Donaustauf, Germany. Tel.: +49 9403 800; fax: +49 9403 80211.
E-mail address: stephan.budweiser@klinik.uni-regensburg.de (S. Budweiser).

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Conclusions: In severe hypercapnic stable COPD long-term nocturnal NPPV can reduce hyperinflation with sustained improved daytime blood gas parameters.

Introduction

Non-invasive positive pressure ventilation (NPPV) has attained an important role in the treatment of COPD with acute respiratory failure by avoiding intubation and prolonging survival.[1–4] Despite the lack of prospective controlled trials, NPPV is also an accepted treatment option for chronic ventilatory failure in patients with neuromuscular and chest wall diseases,[5–9] although controversy remains regarding the effectiveness of long-term home ventilation in patients with hypercapnic but stable COPD.[10] Numerous studies have described positive effects on blood gas parameters, sleep quality and hospital admission as well as on functional status and health-related quality of life.[11–18] In contrast, no changes or only marginal improvements in these parameters were reported in some controlled investigations, mostly on small samples of COPD patients.[19–22] However, it was noted that these results were possibly due to patient selection, ineffective ventilation, poor compliance or too short of an application time.[23–25] Although there is growing evidence that at least subgroups of COPD patients profit from NPPV,[26,27] the mechanisms responsible for the beneficial effects, especially improving blood gas parameters, are not completely understood and have yet to be defined. More recently, in a prospective controlled trial, it could be shown that the short-term use of NPPV during the day improves blood gas tensions in relation to a decrease in lung hyperinflation, while no relief in inspiratory muscle fatigue could be observed.[28] To evaluate the impact on lung deflation of patients receiving long-term home ventilation, we performed a retrospective analysis of different lung function parameters including inspiratory capacity and respiratory muscle function in a collective of severe symptomatic COPD patients in a stable status of their disease.

Materials and methods

Patient selection

All COPD patients discharged with NPPV from the respiratory clinic in Donaustauf, University of Regensburg, Germany from 1995 to October 2003 were retrospectively collected in a computerized database. We usually initiated NPPV in severe symptomatic COPD in case of persistent hypercapnia after exhaustion of medical treatment (all patients had received β-agonists, anticholinergic agents, theophylline, inhaled steroids and on occasion systemic steroids). In order to examine the effects of NPPV on stable COPD, we selected the patients based on the following clinical and physiological criteria:

- severe form of the disease according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) IV;
- FEV $<50\%$ of predicted and $PaCO_2 > 45$ mmHg while breathing room air;
- no clinical signs of exacerbation based on the definition of Anthonisen et al.[29] taken from the anamnesis;
- leucocytes $<10{,}000$/ul at time of admission;
- CRP $\leqslant 5$ mg/dl at time of admission;
- pH value $\geqslant 7.35$;
- current oxygen therapy (LTOT);
- no previous exposure to domiciliary NPPV;
- exclusion of patients which were switched from tracheostomy to non-invasive mask ventilation;
- exclusion of patients in which a sleep apnoea was detected (assessed by polysomnography) and/or BMI $\geqslant 40\,kg/m^2$.

Measurements

Diurnal and nocturnal blood gas measurements (Rapidlab; Bayer Inc; East Walpole, MA, USA) were routinely taken from the hyperaemic earlobe, where the values being closest to the initiation time of NPPV and showing best oxygenation ($SaO_2 > 90\%$ or $PaO_2 > 60$ mmHg) were considered as baseline values. We registered blood gas parameters in the daytime during spontaneous breathing of room air and during long-term oxygen therapy (LTOT) using their usual oxygen flow. Whole bodyplethysmography (Masterlab; Jaeger Inc; Würzburg, Germany) was performed following the guidelines of the American Thoracic Society,[30] based on the reference values of the European Community for Steel and Coal.[31] Inspiratory capacity was calculated as the difference between total lung capacity and intrathoracic gas volume. Inspiratory mouth occlusion pressure at 100 ms ($P_{0.1}$)