Comparison of pulsed flow from portable oxygen concentrators with continuous oxygen delivery

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Introduction

Long term oxygen therapy has been shown to prolong life in patients with chronic obstructive pulmonary disease.1,2 More recently, intermittent delivery methods have been developed as portable or cost saving alternatives to continuous flow oxygen (CFO).3-5 Portable oxygen concentrators (POCs) are the latest class of devices in the intermittent delivery paradigm.3

The present study had two primary objectives. The first was to compare the performance of several POCs against each other and against CFO, using volume-averaged F2O2 at the trachea. The second objective was to characterize the transport of oxygen pulses from the trachea through the conducting airways via computational modelling.

Methodology

In-vitro Experiments

Each of four POCs was connected via nasal cannula to a 30-printed replica of an adult human nasal airways. A test lung simulated three breathing patterns representative of a COPD patient at rest, during exercise and while asleep. The inspiration and expiration flow waveforms were each modelled using a half-sinusoid and actuated using a lung simulator.

The flow of oxygen passing through the trachea over time was calculated by multiplying inspiration flow with measured oxygen concentrations at the same point in time. These oxygen flows were then numerically integrated from the start to the end of inspiration to determine a volume of oxygen inspired for that breath. Finally, volume-averaged F2O2 was obtained by dividing the inspired volume of oxygen by Vt.

An O2 Conserver Testing System was used to obtain oxygen pulse volumes, durations and delays for each setting and each POC.

Computational Modelling

Using oxygen concentration waveforms measured at the trachea over time from the in vitro oxygen measurements described above as a boundary condition, a computational model simulated the transport of oxygen to the alveolar region.

The equation modelling dispersion and transport through the airways is a 1-dimensional convection-diffusion equation. Equation (1) was discretized over finite divisions of length using an upwind approximation for the convective term and a central difference approximation for the diffusive term. Concentrations were then advanced in time explicitly using the Euler method. Based on grid size dependence studies, a grid size of 5 divisions per alveolar generation was chosen. For such a grid size, it was previously found that 5000 time steps per breath were necessary to ensure convergence.

Due to high repetability, very small differences in F2O2 were statistically significant. In addition to statistical significance, a threshold for an anticipated clinically significant difference in F2O2 was defined to be more than 2% (absolute percentage oxygen) following Zhou and Chatburn.4

Using this more demanding threshold, CFO delivered a significantly higher F2O2 than pulse flow in at least one of the devices at all nominally equivalent device settings of 2 and greater (up to 13% absolute for the exercise breathing pattern). Large differences in pulse volumes between POCs at the same numerical device setting tended to result in large differences in volume-averaged F2O2.

Conclusions

Significant differences in oxygen delivery were found between pulse flow (PF) and CFO, and between PF modes in different POCs. In general, CFO delivered significantly more oxygen to the trachea than PF.

Computational modelling revealed that while PF may be a more efficient mode of delivery of oxygen to the alveolus than CFO, CFO delivers a greater absolute per breath for the POCs that were considered.

References


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