Abstract

A Bench Study to Compare Portable Therapies for Respiratory Insufficiency: Continuous Flow Oxygen (CF), Intermittent Flow Oxygen (IF), and Non-Invasive Open Ventilation (NIOV)

Background
Respiratory insufficiency affects both ventilation and oxygenation for a multitude of diseases. CF oxygen therapy has been the standard treatment for improving oxygenation, with IF oxygen therapy recently becoming popular due to improved efficiency of delivery. Augmented ventilation with oxygen therapy is used in the hospital to treat respiratory insufficiency, yet mobility has not been possible. A new Non-Invasive Open Ventilation system (Breathe Technologies, San Ramon, CA) is available to augment ventilation and provide supplemental oxygen therapy while a patient is ambulatory. This simple bench comparison is intended to differentiate assorted performance characteristics of CF, IF and NIOV.

Method
A lung simulator (Hans Rudolph, Shawnee, KS) was equipped with a simulated nose and programmed to breathe a sinusoidal-type waveform at 20 BPM with 600 Vt and 1:2 I:E ratio. CF O₂ delivery was via an OCD (DeVilbiss Healthcare, Somerset PA) at various settings (2, 4, 6); NIOV was delivered via proprietary pillows cannula at mL delivery settings of 150 and 250. Measured characteristics for each therapy included Vt, FIO₂, volume flow, and airway pressure.

Results
Tidal volume was 679/934 for 150/250 mL NIOV; 608 for 2/4/6 LPM CF; 606 for IF at 2/4/6. FIO₂% was 37.6/39.6 for 150/250 mL NIOV; 35.3 for 6 LPM CF; 31.7 for IF at 6. NIOV significantly increased both peak flow and volume at 150/250 mL settings; CF and IF at all settings tested did not. Peak pressures during inhalation were: NIOV 150/250- 2.3/5.0cmH2O; CF and IF at all settings showed no significant change from 0cmH2O.

Conclusion
Oxygen delivery characteristics differed between therapy modes. NIOV was able to provide higher FIO₂, peak flow and peak inspiratory pressure than both CF and IF in this comparison. NIOV was also able to provide supplemental volume to augment ventilation. Bench testing suggests that NIOV may be able to provide sufficient oxygen and respiratory support for patients with respiratory insufficiency. Further study is recommended.
White Paper

A Bench Study to Compare Portable Therapies for Respiratory Insufficiency: Continuous Flow Oxygen (CF), Intermittent Flow Oxygen (IF), and Non-Invasive Open Ventilation (NIOV)

Introduction
Respiratory insufficiency affects both ventilation and oxygenation for a multitude of diseases. Continuous Flow oxygen therapy (CF) has been the standard treatment for improving oxygenation, with intermittent flow oxygen therapy (IF) recently becoming popular due to improved efficiency of delivery. Augmented ventilation with oxygen therapy is used in the hospital to treat respiratory insufficiency, yet mobility has not been possible. A new Non-Invasive Open Ventilation (NIOV) system manufactured by Breathe Technologies is available to augment patient ventilation and provide supplemental oxygen therapy while the patient is ambulatory. This simple bench comparison is intended to differentiate assorted performance characteristics of CF, IF and NIOV in a standard breath cycle.

Methods for Testing
A Hans Rudolph Series 1101 lung simulator was equipped with a simulated nose and programmed to breathe a sinusoidal-type waveform at 20 BPM with 600 V̇, and 1:2 I:E ratio. Resistance and Compliance values were set to 5 cmH2O/l/s and 100 ml/cmH2O, respectively. Baseline volumes and flow and airway pressure profiles were recorded for reference. In separate tests for each therapy mode under evaluation:

• Continuous flow O₂ was delivered to the simulated nose/test lung via nasal cannula at three liter flow settings- 2, 4, and 6 LPM. Oxygen was sourced from a pressurized tank fitted with an adjustable regulator and run through a TSI 4140 flowmeter to ensure flow rates were +/- 0.1 LPM of the desired flow rate.

• Intermittent flow O₂ was delivered to the simulated nose/test lung via nasal cannula attached to DeVilbiss Healthcare’s PulseDose OCD (PD1000) sourced by a pressurized oxygen tank. Tests were completed at three settings, 2, 4, and 6.

• NIOV was delivered to the simulated nose/test lung via Breathe NIOV (sourced by a pressurized oxygen tank) and proprietary pillows cannula at mL delivery settings of 150 and 250. Sensitivity and delivery time were set to defaults.

Measured characteristics for each mode of therapy included tidal volumes, FiO₂, volume flow, and airway pressure.
Results and Observations

Tidal Volumes
Recorded tidal volumes for each mode of therapy are shown below:

Tidal Volumes: 600 mL Vt; 20 BPM; 1:2 Sinusoidal

![Tidal Volumes Chart]

Tidal volumes from CF and IF therapy at all settings tested (608 mL, 606 mL, respectively) were minimally larger than baseline (599 mL). Tidal volumes from NIOV therapy were significantly larger than baseline- 679 mL at the 150 mL NIOV setting and 934 mL at the 250 mL NIOV setting.
FIO2

Recorded FIO2 percentages for each mode of therapy are shown below:

FIO2 percentages from NIOV therapy were 37.6% at the 150 mL NIOV setting and 39.6% at the 250 mL NIOV setting. Note that, as shown earlier, resultant tidal volumes for these settings were significantly higher than in the baseline and CF/IF tests. As expected in the CF/IF tests, FIO2 percentages increased with an increase in setting. CF FIO2 values were 27.3%, 31.2%, and 35.3% for flow rates of 2 LPM, 4 LPM, and 6 LPM, respectively. Pulse OCD (IF) FIO2 values were 26.2%, 30.9%, and 31.7% for settings of 2, 4, and 6, respectively. All recorded FIO2 percentages were above the 20.9% baseline FIO2 (not shown).
Volume Flow Profiles
Flow profiles during one breath cycle are shown for each mode of therapy below:

Flow profiles for CF and IF therapy at all settings were nearly identical to the baseline profile, with no indication of volume augmentation, as expected. Flow profiles during NIOV therapy show a significant increase in peak flow and modification to the baseline flow profile. Baseline (and CF/IF) peak flow was approximately 55 LPM; NIOV at a setting of 150 mL resulted in a peak flow of 72 mL, NIOV at a setting of 250 mL resulted in a peak flow of 93 LPM.
Airway Pressure Profiles
Recorded FiO2 percentages for each mode of therapy are shown below:

Airway pressure profiles for CF and IF therapy at all settings were nearly identical to the baseline profile during inhalation, with no indication of pressure support, as expected. Airway pressure profiles during NIOV therapy show an increase in peak pressure and sustained pressure support during inhalation over the baseline profile. NIOV at a setting of 150 mL resulted in a peak pressure of 2.3 cmH2O. NIOV at a setting of 250 mL resulted in a peak pressure of 5.0 cmH2O.
Conclusions

Oxygen delivery characteristics differed between all three of continuous flow, intermittent flow and NIOV therapy modes. NIOV was able to provide higher FIO2, peak flow and peak inspiratory pressure than both CF and IF in this simple bench evaluation. NIOV was also able to provide supplemental volume to augment ventilation. This bench testing suggests that NIOV may be able to provide sufficient oxygen and respiratory support for patients with respiratory insufficiency. Further study is recommended.

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