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Evaluation of Molecular Sieve Oxygen Concentrators at Varying Flow Rates

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Abstract:

Background:
Long term oxygen therapy (LTOT) for patients with hypoxic chronic bronchitis and emphysema is critically important; it has been shown to positively impact longevity and reduces repeat hospital admission rates. Correspondingly, the technical performance of each device is of great import. In this missive, the authors purport to evaluate the FiO2 levels of home oxygen concentrators at various flow rates from two to five LPM. The accuracy of the oxygen concentrator, as compared to the manufacturer's claims, was determined.

Methods:
The oxygen concentrators used in this study were: Invacare Perfecto 2, Respironics Everflow, Respironics Millenium, and the Airsep VisionAire. In order to simulate inhalation and exhalation, a 2010 Hans Rudolph, Inc. Series 1101 Breathing Simulator was attached to a Laerdal VitalSim® manikin using large bore corrugated tubing and two one-way valves for isolated input and output. A new sensor was placed in a Hudson RCL galvanic fuel cell oxygen analyzer, calibrated every 15 hours to room air and 100% oxygen to measure FiO_2 delivered to the carina. One nasal cannula was connected to each of the aforementioned concentrators. Baseline respiratory values were as follows: Raw 3 cmH_2O/L/sec, Cst 80 mL/cmH_2O, respiratory rate of 18 breaths/minute, percent inhale 20%, effort slope of 4, and Amplitude 23 cmH_2O, Peak inhale flow 60 LPM. The fraction of inspired oxygen was evaluated over a period of 45 hours; the oxygen concentrations were sampled every 5 minutes, for 15 hours at each flow rate (2, 3.5, and 5 LPM).

Results:
The FiO_2 for each concentrator evaluated remained consistent for each flow rates, with the standard deviation of the measurements slightly more than the resolution of the oxygen analyzer, which reported FiO_2 percent to 1%. The reported standard deviations were equivalent to the expected detector deviation (±0.5%) and were thus negligible. Measured standard deviations were all less than 0.6%. Although some minor variation around the mean output was observed, it was clinically negligible.

Conclusion:
The four measured oxygen concentrators showed clinically negligible variance of delivered FiO_2. It is reasonable to assume that the in-home use of oxygen concentrators is a valuable tool for the treatment of patients requiring increased arterial oxygen concentrations.

Introduction:

Given the impact on at-home care-giving and the lack of literature that is both available and current, the fraction of inspired oxygen provided by home oxygen concentrators is a topic of great import to the aesculapian community at large and to patients in particular.

Long term oxygen therapy (LTOT) for patients with hypoxic chronic bronchitis and emphysema is critically important; it has been shown to positively impact longevity. [3] While it cannot prevent deterioration of lung function, when titrated appropriately, oxygen therapy stabilizes arterial blood gases, PaO_2 and $PaCO_2$, reduces polycythemia, [1, 6, 7] ameliorates pulmonary arterial hypertension, [1, 6, 7] and reduces repeat hospital admission rates from exacerbations. [2] Studies have confirmed that patients receive maximum benefit with continuous oxygen (≥ 15 h/d), rather than intermittent or nocturnal LTOT. [2] Correspondingly, the technical performance of each device is of great import; should the fraction of inspired oxygen (FiO_2) show significant deviation from indicated flow rates, the subsequent repercussions can include pulmonary hypertension with resultant right-heart failure. [2]

In this missive, the authors purport to evaluate the FiO_2 levels of home oxygen concentrators at flow rates of 2, 3.5 and 5 LPM. In conjunction, the accuracy of the oxygen concentrator, as compared to the manufacturer's claims, will be determined. Precise FiO_2 measurements aide medical practitioners in titrating appropriate flow rates in order to achieve desired arterial and pulsatile oxygenation. To the best of the author's knowledge, a study has not been conducted in the last 19 years [3, 9] of the efficacy and variability of home oxygen concentrators.

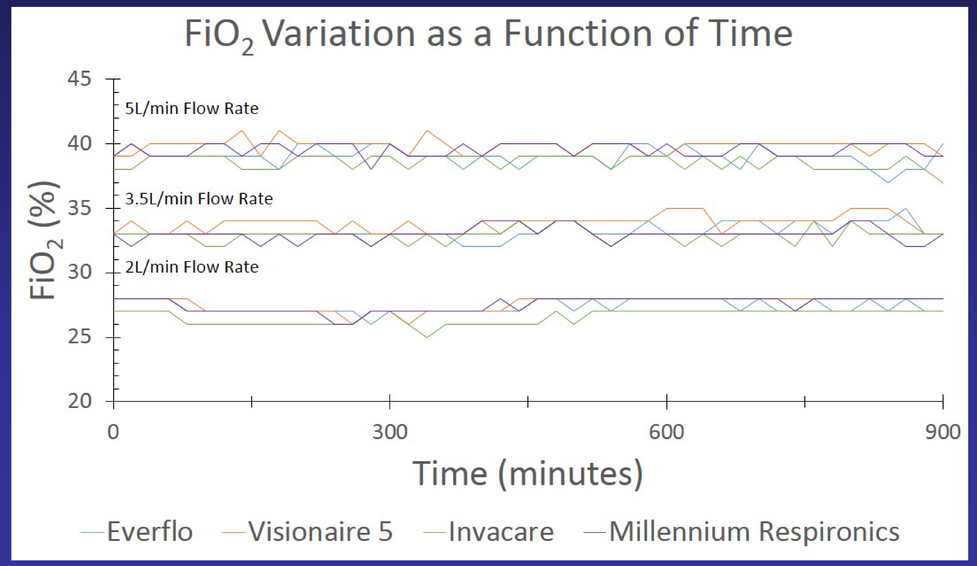

Figure 1: Measured FiO_2 as a function of time. Note the clinically insignificant variance of the four oxygen concentrators over 900 minutes (15 hours) of measurement.

	2 LPM	3.5 LPM	5 LPM
Everflo	27.26 ± 0.74	33.22 ± 0.59	39.00 ± 0.70
Visionaire 5	27.52 ± 0.66	33.83 ± 0.57	39.83 ± 0.53
Invacare	26.43 ± 0.69	32.89 ± 0.57	38.57 ± 0.54
Millenium Respironics	27.41 ± 0.80	33.00 ± 0.56	39.50 ± 0.55

Figure 2: Average FiO2 and standard deviation

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Materials and Methods:

In order to simulate inhalation and exhalation, a *2010 Hans Rudolph, Inc. Series 1101 Breathing Simulator* was attached to a *Laerdal VitalSim®* manikin using large bore corrugated tubing and two, one-way valves for isolated input and output. A new sensor was placed in a *Hudson RCL galvanic fuel cell oxygen analyzer,* calibrated once a day to room air and 100% oxygen to measure FiO_2 delivered to the carina. One nasal cannula was connected to each of the following concentrators: Invacare Perfecto 2, Respironics Everflow, Respironics Millenium, and the Airsep VisionAire. Baseline respiratory values were as follows: R_{aw} 3 cm H_2O/L/sec, C_{st} 60 mL/cm H_2O, respiratory rate 20 breaths/minute, percent inhale 20%, load effort SHORTIE and an effort slope of 20. These values reflect a normal spontaneous breathing pattern. [4] The functional dependence of oxygen concentration on oxygen flow rate was measured; each flow rate was evaluated over a period of 15 hours; [5] oxygen concentration was sampled every 15 minutes at a flow rate of 2, 3.5, and 5 LPM.

Before testing the FiO_2 and flow rate, one nasal cannula was connected to each concentrator and set at a flow rate of 2 LPM for 30 minutes. This delay allowed for appropriate damping of the transient response, and assured stabilization of FiO_2 and flow rates prior to the collection of data. Over the course of 15 hours,[5] a nasal cannula was connected to the nares of the Laerdal VitalSim® manikin; equilibration took place for 3 minutes prior to the sampling of FiO_2 and flow rate at the carina. Following measurement of the Invacare platinum, the *Hans Rudolph breathing simulator* restored the Laerdal VitalSim® to baseline with a 21% oxygen flush, ensuring that baseline oxygen concentrations were reached before the following nasal cannula and concentrator were tested. The same measurement technique was repeated for each of the 5 concentrators with a new flow rate of 2, 3.5, and 5 LPM for 15 hours at each flow rate.[5]
Before the measurement of each flow rate, the galvanic fuel cell oxygen analyzer was calibrated by a measurement of baseline (21%) and pure (100%) concentration of oxygen and the appropriate response recorded
Check flowrate used.

Results:

All of the oxygen concentrators showed clinically insignificant departures from the anticipated value at all flow rates; a larger variance was measured at larger flow rates, but the standard deviation of the data were less than 0.5% in all cases. The maximum variance for any concentrator did not exceed a deviation of 2% FiO_2 from the mean.

Conclusions:

Modern oxygen concentrators demonstrate excellent long-term reliability, as shown in the presented data. Given that only clinically insignificant deviations of FiO_2 were observed, long-term oxygen therapy remains an effective outpatient treatment modality with reliable device support to ensure positive patient outcomes during the in-home treatment of hypoxic chronic bronchitis and emphysema.

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