Effectiveness of Open-Circuit and Oxyhood Delivery of Helium-Oxygen*

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The combination of helium with oxygen is less dense than air and as such has been beneficial to patients with airflow obstruction within the large airways. The purpose of this study was to evaluate the effectiveness of delivering He-O₂ by open-circuit systems by measuring $DD_{\text{av}}$ in five adult volunteers. The mean ($\pm 1$ SD) $DD_{\text{av}}$ with a nonrebreathing mask was 1.32 ± 0.99, with a simple mask was 1.51 ± 0.87, and with a nasal cannula was 1.00 ± 0.13; the $DD_{\text{av}}$ with the nonrebreathing mask and the simple mask was statistically greater than with the cannula ($p<0.05$). Two infant oxygen hoods were assessed by measuring the nitrogen concentration at different locations in the hoods. The $N_2$ concentration increased progressively from top to bottom, indicating that the helium was concentrated at the top. We conclude that the nonrebreathing mask and simple masks are probably satisfactory He-O₂ delivery systems, that the infant oxyhood may be suboptimal, and that the nasal cannula is ineffective. (Chest 1989; 95:1222-24)

Therapeutically, a helium-oxygen mixture has been used to try to reduce complications related to airflow obstruction in asthmatic subjects,¹ in patients with partial upper airway obstruction,²,³ in infants with bronchopulmonary dysplasia,⁴ and in patients with COPD.⁵ During tidal breathing of a lower density gas, the transpulmonary pressure required for a given tidal volume is less because there is less resistance to airflow.⁶,⁷ The potential benefits of lowered resistance to flow are several: decreased work of breathing; less dynamic airway collapse; and less hyperinflation. These physiologic advantages may avoid respiratory muscle fatigue and subsequent acute respiratory failure in some patients.²³

The He-O₂ mixture is less dense than air and allows a higher flow rate throughout the vital capacity, except at very low pulmonary volume.⁷ The degree of DD of maximal airflow can be measured from MEFV curves as the ratio of flow breathing He-O₂ to the flow breathing air at a given pulmonary volume.⁷ For optimal therapeutic benefit, He-O₂ should be delivered in a closed-circuit system to avoid entrainment of room air, which will dilute the He-O₂ and thus increase the density of the gas mixture. Such systems can be cumbersome and hard to utilize in uncooperative patients or in pediatric patients. The purpose of this study was to examine the delivery of He-O₂ under open-circuit conditions.

MATERIALS AND METHODS

Delivery of He-O₂ was evaluated in two open-circuit systems (nasal cannula and simple face mask) and one closed-circuit system (standard nonrebreathing mask). The effectiveness of He-O₂ delivery for each system was measured by calculating the $DD_{\text{av}}$, anticipating that inefficient gas delivery would produce a low DD. A commercially available mixture of 80 percent helium and 20 percent oxygen (Mid South Oxygen) was delivered to subjects by each of the three systems for a minimum of five minutes, as shown in the following tabulation detailing the testing sequence:

- Standing air spirometry
- Supine He-O₂ nonrebreathing mask (13 L/min for five minutes)
- Supine He-O₂ spirometry
- Air breathing (> five minutes)
- Supine air spirometry
- Supine He-O₂ nasal cannula (6 L/min for five minutes)
- Supine He-O₂ spirometry
- Air breathing (> five minutes)
- Supine air spirometry
- Supine He-O₂ face mask (6 L/min for five minutes)
- Supine He-O₂ spirometry

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The flow rate with the nonrebreathing mask was generally 13 L/min. The flow rate used with the simple mask and nasal prongs was 6 L/min. These flow rates were determined by an oxygen flowmeter (Ohio model 304-5501-800) and were not corrected for He-O₂; the same flowmeter was used for each delivery system studied.

Five healthy adult volunteers (three male and two female subjects; mean age, 33.2 years) who were all previously experienced in spirometric maneuvers, participated in the study. Standing room-air spirometry was performed initially to assure normal baseline pulmonary function. All measurements were made with a 13-L wedge spirometer (525 Pulmonizer; Med Science) with computer-assisted data printout that provided both MEFV curves and spirometric values. Testing was done in the supine position to simulate actual clinical conditions. Maximal expiratory maneuvers were performed breathing air prior to each type of He-O₂ delivery system, so that each calculation of DD was made with an FEF50 (air) obtained immediately prior to the FEF50 (He-O₂). The DDₜ was calculated as the ratio of FEF50 (He-O₂) to FEF50 (air). The nonrebreathing system was tested first in each subject to assure a normal DDₜ. The nasal prongs were evaluated next, followed by the simple mask. Several minutes elapsed between the testing of each delivery system to allow adequate washout of He-O₂ before the next air test. Each subject mastered the technique of taking a slow maximal inhalation through both the simple mask and the nonrebreathing mask, holding their breath at maximal inhalation while transferring from the mask to the mouthpiece of the spirometer, then beginning the forced exhalation maneuvers. This was to avoid exceeding the flow rate of He-O₂ during inspiration, entraining room air, and decreasing the difference in density of gases. While breathing He-O₂ through the nasal prongs, each subject breathed only through his or her nose and took slow maximum inspiration through the nose prior to beginning the spirometry. Testing was repeated until the FVC between tests varied less than 5 percent.

To determine the distribution of helium in infant oxyhoods, He-O₂ was delivered into the hood at 10 L/min through the standard port just below the top of the hood. The N₂ concentration was measured by a N₂ analyzer (505 Nutralizer; Med Science), attached to a tape measured at various levels from the top to the bottom of the hood. The helium concentration was inferred by the following equation derived from Dalton's law of partial pressures:

\[ F_{He} = 1.0 - F_{O₂} - F_{N₂} \]

The Fₐₙ was constant between room air and the He-O₂. Two different sizes of infant oxygen hoods were studied: (1) one with a ten-inch diameter (Olympus); and (2) the smaller with dimensions of 71/8 inch by 71/4 inch near its midpoint (Shiley).

The group mean DDₜ for each He-O₂ delivery system was compared by the two-tailed t-test. The relationship between the location in the hoods and the N₂ concentration was evaluated by linear regression.

**RESULTS**

Both the nonrebreathing mask (DDₜ₀ = 1.32 ± 0.89) and the simple mask (DDₜ₀ = 1.21 ± 0.89) produced increased flows, to a similar degree (p < 0.05). Both the nonrebreathing mask (p = .01) and the simple mask (p = 0.04) had DDₜ₀ greater than the nasal cannula (DDₜ₀ = 1.00 ± 0.13). Most subjects had difficulty consistently producing DD using the simple mask because a rapid maximal inspiration with this system did not always result in an increase in flow, presumably due to entrainment of room air. No matter how slow the inspiration was with the nasal prongs, DD could not be produced despite repeated attempts.

The N₂ concentrations within the large oxygen hood (Olympus) are shown in Figure 1. The relationship is significant (p ≤ 0.0001) and appears to be linear, suggesting that in an undisturbed and unoccupied hood, the helium accumulates at the top of the hood with the nitrogen concentrating at the bottom. The findings were the same for the smaller infant hood (Shiley) (p < 0.0001; r = −0.91; n = 24).

**DISCUSSION**

Our study shows that the delivery of He-O₂ with the nonrebreathing mask and with the simple face mask was sufficiently effective to produce increased flow as assessed by the DDₜ₀. Because the nonrebreathing mask is a closed circuit, we expected the delivery of He-O₂ to produce increased flow rates.²⁸ Although the DDₜ₀ with the simple mask was not significantly different from the closed nonrebreathing system, it was difficult to consistently produce DD with the simple mask. When the maximal inspiration was performed too rapidly, there was no DD. This suggests

![Figure 1. Measured N₂ concentration within infant oxyhood at varying levels from top to bottom.](http://journals.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21595/ on 06/27/2017)
that entrainment of room air occurs with rapid inspiration, thereby diluting the He-O₂ and diminishing the difference in gas density. Therefore, for the hyperpneic or tachypneic patient, the simple mask might not provide the He-O₂ in sufficient concentration to derive the potential benefits of a less dense gas. Delivery through the nasal cannula, as used in our study design, was ineffective despite scrupulous attempts at slow inspiration exclusively through the nose.

It is not surprising that the helium was concentrated at the top of the unoccupied, undistributed infant oxyhood. At the level of the infant's mouth and nose (ie, 10 to 12 cm from the bottom of hood), the helium concentration appears to be significantly less than the concentration entering the hood (Fig 1). For the infant whose FIO₂ requirement is greater than 20 percent, the helium concentration delivered into the hood will be reduced (ie, 80:20 to 60:40), further reducing the potential benefit of lowered gas density. Despite these reservations, a recent study suggests that He-O₂ delivery by infant oxygen hood or similar device to sick children with upper airway obstruction is clinically efficacious; however, the infants in that report had several other concomitant therapeutic maneuvers that may have been responsible for their clinical improvement. Alternatively, an active and dyspneic infant within the oxygen hood may provide enough agitation of the gases within the hood to prevent the helium from concentrating at the top, and thus make the oxyhood an appropriate delivery system. With the recent advances in infant pulmonary function testing, it may soon be possible to determine whether or not this delivery system allows an increased flow rate or a decrease in the work of breathing.

In conclusion, we found in healthy trained adult volunteers that the nonrebreathing mask and simple face mask were adequate for the delivery of He-O₂, but the nasal cannula was not. Because of the distribution of gases within infant oxyhoods, we question the efficacy of this delivery system; however, until additional studies disprove their usefulness, there is sufficient clinical evidence to warrant continued use of the oxyhood for He-O₂ delivery in selected infants who are carefully monitored.

REFERENCES