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A New Pendant Oxygen-Conserving Cannula Which Allows Pursed Lips Breathing

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Multiple benefits of oxygen therapy for hypoxemic patients with chronic lung disease are well established. Steady flow oxygen therapy is inefficient, wasteful and has a high cost. The Oxymizer pendant improves efficiency of oxygen delivery compared with SF. However, the device requires that the patient inhale and exhale nasally to maximize its oxygen-saving properties. When patients do PLB they may not receive full oxygen-saving benefit of the pendant. Yet PLB itself can increase SaO_2. We evaluated an AP, which does not require nasal exhalation, in nine patients with COPD. We measured SaO_2 while breathing oxygen via SF and the AP with nasal-only breathing and PLB. Results indicate that the AP maintains an increase in SaO_2 over SF during nasal-only breathing and a further increase during PLB. We conclude that AP acts as an oxygen conserver during PLB; PLB with the AP achieves greater savings than with nasal-only breathing. *(Chest 1989; 95:857-60)*

PLB = pursed lips breathing; SaO_2 = arterial oxygen saturation; AP = auto-resetting pendant; VC = vital capacity; FEV_1 = forced expiratory volume in 1 s; SF = steady flow; FVC = forced vital capacity; CO_2 = carbon dioxide

The benefits of long-term oxygen therapy for hypoxemic COPD patients are well understood and accepted.[1-14] The British Medical Research Council[13] demonstrated increased survival when oxygen was provided during the night in comparison with no oxygen. The Nocturnal Oxygen Therapy Trial[14] studies demonstrated greater survival when oxygen was provided continuously as compared with 12 h of nocturnal oxygen. Most patients with chronic lung disease, who are prescribed oxygen, are ambulatory and thus require portable oxygen. Patients undergoing pulmonary rehabilitation are taught and encouraged to ambulate as a step toward independence and improving their quality of life.[15,16] Thus, ambulatory oxygen is an important part of their medical management.

Oxygen therapy is commonly delivered via a SF nasal cannula, which is inefficient and wasteful.[17-19] The waste occurs because SF oxygen is delivered throughout the respiratory cycle, whereas the important delivery takes place during early inspiration. The oxygen delivered during the rest of the respiratory-time cycle is wasted as it is lost to the atmosphere. The amount of oxygen which must be stored represents one of the major limitations of long-term oxygen therapy. For patients receiving portable oxygen, the limitations of oxygen therapy become most evident. Portable oxygen containers must have the oxygen storage capacity to meet the patient's oxygen needs for several hours away from the stationary source.

Because we now perceive a need to reduce the cost of oxygen therapy and improve upon the portability of ambulatory oxygen, several new devices have been developed to increase the efficiency of oxygen delivery.[17-19] One such device is the Oxymizer pendant, an oxygen-conserving nasal cannula which stores oxygen during exhalation for delivery during early inhalation.[20-24] The pendant was found to reduce oxygen flow required to provide adequate saturation during both rest[20] and exercise conditions.[21,22] The pendant achieved oxygen savings of between 2:1 and 4:1 as compared to SF delivery.

However, the pendant requires both nasal inhalation and exhalation to maximize its oxygen-saving properties. When patients do PLB they often occlude their nasal passages during exhalation.[25] Since PLB is a common breathing retraining technique taught in pulmonary rehabilitation programs, we found it desirable to remodel the pendant so that it will function while the patient is using this method of breathing.[25-29]

In the present study, we evaluated a pendant, which we altered to cause the membrane to spring back to resetting position at the end of inhalation. As a result of this modification, nasal exhalation is not required through the pendant for it to function as an oxygen conserver. We compared the AP in hypoxemic COPD patients, during both PLB and non-PLB with SF oxygen delivery.

Methods

Pendant Conserver Cannula

The standard pendant conserving nasal cannula[20-24] (Chad Therapeutics, Inc, Chatsworth, CA; Fig 1) consists of nasal prongs attached to cannula tubing which is connected to the pendant reservoir. Oxygen enters the system at the junction of the tubing and the reservoir. The actual storge of oxygen occurs in the tubing rather

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FIGURE 1. The Oxymizer pendant oxygen-conserving nasal cannula.

than in the reservoir. At the beginning of exhalation, the reservoir fills with dead space gas and some oxygen. During most of exhalation, the tubing fills with oxygen. When the patient is ready to inhale, the reservoir provides the means to reflux the oxygen stored in the tubing in addition to the steady supply flow to the patient. The overall effect is early inspiratory delivery of an oxygen bolus.

We modified the pendant so that the membrane of the reservoir does not rely on the patient's exhalation to reset for oxygen storage; it auto-resets. This allows PLB.

Protocol

Nine patients with COPD with a mean age of 69 ± 6.4 years, an FVC of 1.7 ± 0.4 L and an FEV_1 of 0.7 ± 0.2 L were recruited from the inpatient pulmonary rehabilitation program at Casa Colina Hospital for Rehabilitative Medicine in Pomona, CA, and the outpatient pulmonary rehabilitation program at Little Company of Mary Hospital in Torrance, CA. The subjects were hypoxemic at rest and all were on long-term oxygen therapy. Informed consent was obtained in accordance with the standards set by the Institutional Review Boards of the two institutions in which the study was performed.

Pulmonary function measurements were obtained using a calibrated electronic spirometer (Hewlett Packard, Inc, Palo Alto, CA). The best of three forced expiratory efforts was recorded for each subject.

Oxygen saturation values were measured with the use of a Biox IIA ear oximeter (Ohmeda, Inc, Boulder, CO) at rest and at the various flows, allowing sufficient time for equilibration to take place. The order of presentation of the cannulas was randomized but we always started with the lowest supply flows and proceeded to the higher supply flows. Oxygen delivery via SF was set for 1, 2, 3 and 4 L/min, and for the pendant the settings were 0.25, 0.5 and 1.0 L/min both during non-PLB and PLB. The PLB was taught by a nurse according to a previously set method used in our former study which demonstrated a significant increase in SaO_2 by the technique in patients breathing room air.[29] All of the patients in this study were experienced pursed lips breathers. We closely monitored the patients to assure that they were using the appropriate breathing method for each section of the study. Oxygen supply flow was metered via spirometrically calibrated settings of a liquid oxygen system (Liberator Stroller). Data were compared by analysis of variance techniques followed by Duncan's multiple range comparison.

RESULTS

Oxygen saturation performance curves for SF delivery, and the AP during PLB and non-PLB are shown in Figure 2. Oxygen saturation was improved using supplemental oxygen delivered by either cannula. At 0.25 L/min, the AP, during non-PLB and PLB, achieved the equivalent of SF at 1 and 1.7 L/min, respectively. At 0.5 L/min, the AP, during non-PLB and PLB, achieved the equivalent of steady flow at 2.3 and 2.9 L/min, respectively. At 1 L/min, the AP, during non-PLB and PLB, achieved the equivalent of SF at 4 and 4.5 L/min, respectively. In each instance, the AP conserver yielded higher saturations than the SF cannula during non-PLB and there was a further increase during PLB. These differences in oxygen requirement to achieve equivalent saturations, between non-PLB and PLB conditions were statistically significant ($p<0.01$).

The SF equivalents as depicted in Figure 3 demonstrate the oxygen savings using the AP during non-PLB and PLB as compared with SF oxygen. At 0.25 L/min the AP oxygen savings were 4.2:1 and 6.8:1 as compared with SF during non-PLB and PLB, respectively. At 0.5 L/min, the AP oxygen savings were 4.5:1 and 5.8:1 as compared with SF during non-PLB and PLB, respectively. At 1 L/min, the AP oxygen savings were 4:1 and 4.5:1 as compared with SF during non-PLB and PLB, respectively.

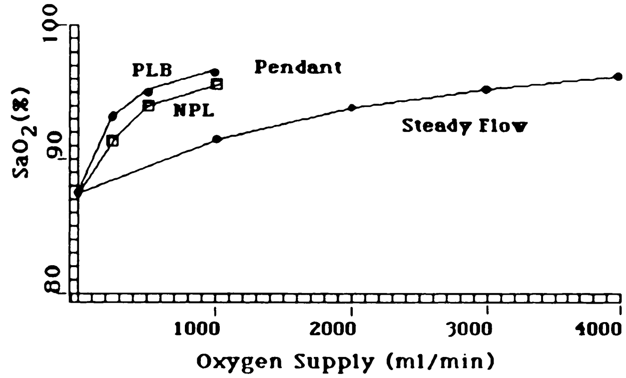

FIGURE 2. Oxygen saturation performance curves for SF delivery, and the AP during non-PLB (NPL) and PLB.

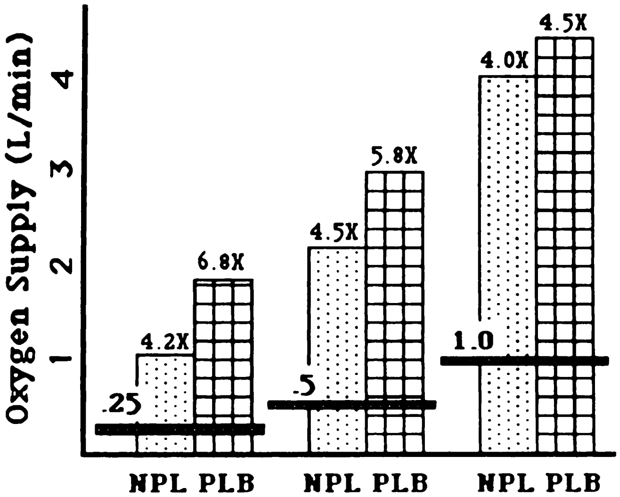

FIGURE 3. Oxygen saturation equivalents during SF as compared with the AP during non-PLB (NPL) and PLB.

DISCUSSION

This study demonstrates that the AP improves the efficiency of oxygen delivery whether the patient is breathing strictly nasally or with pursed lips. The oxygen savings are greater when the patient is doing PLB. This study did not evaluate the standard pendant while the patient does PLB. However, it is known that patients who breathe with pursed lips exhale solely through their mouths[25] and the reservoir mechanism of the standard pendant requires nasal exhalation to be able to reset the reservoir membrane. If patients who do PLB completely occlude their nasal passages during exhalation, it is unlikely that they will be able to reset the reservoir membrane in order to benefit from the oxygen-conserving mechanism of the pendant.

Previous PLB studies have demonstrated several benefits of PLB. Patients enjoy the subjective benefit of being able to breathe more comfortably and also the physiologic benefits of increasing the SaO_2 and CO_2 removal.[26-29] Pursed-lips breathing appears to be a rather natural method that patients discover spontaneously because it relieves dyspnea. Pulmonary rehabilitation programs regularly include PLB retraining as a standard part of their education program.[29]

Early studies on the pendant demonstrated that the standard pendant oxygen-conserving nasal cannula achieves significantly greater SaO_2 values than the SF cannula during both rest and exercise.[20-24] In most of these studies the savings benefit of the standard pendant over the SF cannula was 4:1 at 0.5 L/min, 3:1 at 1 L/min and 2:1 at 2 L/min. Those findings were almost identical to those found with the mustache-configured Oxymizer.[30-32]

The pendant functions by storing oxygen during exhalation for early inspiratory delivery during the next inhalation.[20-24] The mechanism for oxygen savings via the pendant is based on the fact that SF oxygen therapy is inefficient and wasteful. If the respiratory-time cycle were divided into thirds, typically two thirds of the time might be spent on exhalation, leaving one third for inhalation.[19,32] When one examines the inhalation portion of the respiratory-time cycle, the inspiratory flow curve is steepest during early inhalation with relatively more time spent on dead space inhalation. We estimate that one third to one half of inhalation is early inhalation. Thus, one could conclude that about one eighth of the respiratory-time cycle might be spent in early inhalation—contributing to alveolar oxygenation. One might then expect the oxygen saving to approach 8:1 over SF if all oxygen delivery could be effectively focused on early inhalation.

However, the standard pendant does not reach the level of savings suggested by the previously noted model. An explanation is that the patient must exhale through the cannula to reset the membrane and create the chamber. As a result, no oxygen storage is possible during late (dead space) inhalation—wasting some time which could be devoted to oxygen storage. Electronic demand pulsed-oxygen delivery devices such as the Oxymatic do achieve a greater oxygen delivery efficiency because no oxygen is wasted during dead-space inhalation.[33-35] The savings reported in the present study are greater than those reported via the standard pendant, particularly at 1 L/min.[20-23] We recommend a future study to determine if the AP, which does not wait for exhalation before resetting the membrane, is more or less efficient than the standard pendant.

An earlier PLB study, without supplemental oxygen, demonstrated that patients could be taught to raise their SaO_2 using that breathing retraining technique with the biofeedback guidance of ear oximetry.[29] In that study, there was a significant increase in tidal volume, a significant decrease in respiratory rate but no significant change in minute volume. It was the results of that study which inspired the attempt to combine the effects of PLB with the oxygen-conserving properties of the pendant.

The present study did not evaluate PLB on room air vs supplemental oxygen or the standard pendant during PLB. However, we did study PLB at various liter-flows of oxygen using the AP. There was a consistent increase in saturation; hence, the effect was likely to be additive. Also, we found consistently higher saturations via the AP during PLB than achieved by nasal-only breathing for the same liter flow of oxygen. This also supports the notion that the effect of PLB is additive to the oxygen-conserving properties of the pendant.

This study did not evaluate patients under exercise conditions, which would be important in patients using ambulatory oxygen. Those studies need to be performed prior to widespread clinical use because its most important application is in the ambulatory patient.

In summary, the AP improves oxygen delivery efficiency as compared to SF. In addition, patients can do their PLB and further improve upon their oxygenation. The use of this device could result in substantial cost savings, increased portability and extended time away from the stationary oxygen source.

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