Evaluation of a Low-Flow Oxygen-Conserving Nasal Cannula[1,2]

SUMMARY Oxygen therapy is one of the most frequently ordered therapies for patients with chronic obstructive pulmonary disease (COPD). In a large percentage of these cases, oxygen therapy is supplied via nasal cannula. With the rising cost of medical care and the search for more effective means of oxygen delivery, a new oxygen-conserving nasal cannula (CNC) that incorporates a closely coupled 20-ml reservoir was developed. Oxygen is stored in the reservoir during exhalation so that 20 ml of approximately 85% oxygen is the first gas inhaled. To test the hypothesis that the CNC is more efficient than the standard nasal cannula (SNC), 20 patients with COPD were evaluated. All patients were chronically hypoxemic at rest. Results indicate that when the CNC was compared with the SNC, arterial oxygen saturation levels were significantly different ($p < 0.001$) at flow rates of 0.5, 1.0, and 2.0 L/min. Oxygen saturations were 2.9% higher at 0.5 L/min, 2.9% higher at 1 L/min, and 2.6% higher at 2 L/min for the CNC than for the SNC. In summary, the CNC offers a more efficient oxygen delivery system for those patients requiring supplemental oxygen administration by nasal cannula. AM REV RESPIR DIS 1984; 130:500–502

Low-flow continuous oxygen is an accepted form of therapy in patients with chronic obstructive lung disease (COPD) with hypoxia (1–5). An increasing number of patients are prescribed oxygen for chronic use. The drawbacks of portable oxygen are its inconvenience and cost.

Supplemental oxygen is commonly delivered by means of a nasal cannula through which the oxygen flows continuously. The greatest benefit of oxygen to the patient occurs during early (nondead space) inspiration. Thereafter, most of the remaining oxygen is lost to the atmosphere. It would, therefore, be desirable to concentrate oxygen delivery in the initial phase of inspiration.

An oxygen cannula was developed that contains a closely coupled reservoir that stores oxygen on exhalation to be delivered during early inhalation (Oxymizer; Chad Therapeutics, Inc., Woodland Hills, CA). The goal of the device is to reduce the oxygen flow and still achieve adequate oxygen saturation. This study evaluated patients from 2 hospitals to compare oxygen saturation achieved using the new conserver cannula versus the standard steady flow cannula.

The oxygen conserver cannula, as shown in figure 1, consists of nasal prongs, an attached, closely coupled, 20-ml reservoir with a collapsible membrane, and an oxygen supply line at the distal end of the reservoir on each side (6). The cannula with its reservoir covers the face in a mustache distribution extending out to the cheeks. The oxygen tubing extends laterally from the reservoir over the ears and merges into a single supply tube similar to most standard cannulas. In order to operate the conserver cannula, the patient must do at least some nasal breathing. The conserver cannula stores oxygen in the following manner: during the early portion of exhalation, the dead space gas pushes the membrane out filling the cannula reservoir. After the reservoir is filled and during the remaining portion of exhalation, oxygen displaces the original dead space gas medially by venting it through the nasal prongs. During early inspiration, the patient inhales the 20-ml bolus of approximately 85% oxygen from the reservoir, thus collapsing its membrane.

Twenty patients with stable COPD, and with a mean age of 64.8 yr, volunteered for this study. As shown in table 1, all patients had severe COPD with a mean forced expiratory volume in one second of 0.76. Subjects were allowed to continue their medication schedule, except that inhaled bronchodilators were withheld for at least 1 h prior to the study. All subjects signed an informed consent, in compliance with the policy of the Institutional Review Boards of the 2 institutions. Each subject met the following criteria: (*1*) severe chronic lung disease, (*2*) resting hypoxemia with an oxygen saturation less than 90%, and (*3*) no significant bronchospasm at the time of study. Oxygen saturation was measured using the Biox 11A ear oximeter (Biox Technology, Inc., Boulder, CO), and recorded on a strip-chart recorder. Oxygen supply flow was metered via spirometrically calibrated Gilmont rotometer (Gilmont Inc., Great Neck, NY), which could be adjusted within ± 0.05 L/min. Subjects were all studied in an upright, comfortably seated, position.

Saturation measurements were made at 0.5, 1, 2, 3, and 4 L/min using the standard nasal cannula, and at 0.5, 1, 1.5, and 2 L/min using the conserver cannula. The subjects were allowed to return to their room air saturation level between cannula changes. The choice of cannulas was randomized, but flow rates started with the lowest value and increased incrementally. Equilibration time was determined by allowing oxygen saturation to stabilize; after stabilization, an additional 2 min of data were recorded to assure that equilibration had occurred. Final oxygen saturation values were used in the data analysis. Statistical comparisons were made using analysis of variance, followed by the Duncan's multiple-comparison technique.

Oxygen saturation for each level of oxygen flow for all subjects can be seen in table 2. The mean room air Sa_{O_2} was 88% with both the standard and conserver cannulas in place. The mean room air Sa_{O_2} improved with either cannula. At flows of 0.5 and 1 L/min, the oxygen saturation was 2.9% greater with

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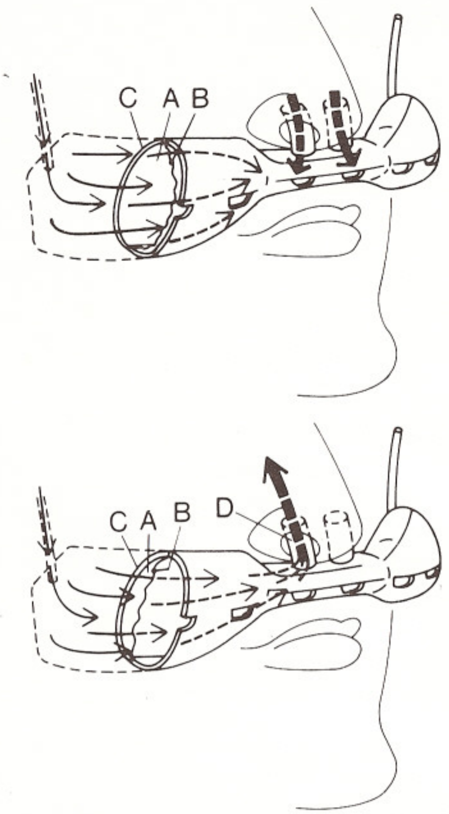

Fig. 1. While the patient is exhaling (*top*), oxygen is accumulating in the reservoir (A) formed by the inflated diaphragm (B) and the back wall of the conserver (C). While the patient inhales (*bottom*), the diaphragm (B) collapses, and the oxygen-enriched gas from the reservoir (A) is released to the patient (D).

the conserver than with the standard cannula. At 2 L/min the saturation was 2.6% higher with the conserver. These differences were significant ($p < 0.001$). The results obtained at the 2 centers showed no significant differences. Oxygen saturations with the conserver and with the standard cannula for each subject at supply flows of 0.5, 1, and 2 L/min are shown in figure 2. It is apparent that the conserver cannula improves Sa_{O_2} for similar supply flows.

A comparison of oxygen saturation curves for both the standard cannula and the conserver can be seen in figure 3. Plotted are mean values at each flow for all subjects. When the supply flow to the conserver cannula is set at 0.5 L/min, the oxygen saturation is equivalent to that achieved by the standard cannula set at 1.8 L/min. When the supply flow to the conserver is set at 2 L/min, the saturation is equivalent to that achieved by the standard cannula set in excess of 4 L/min. The mean benefit ratio of the conserver to the standard cannula, when set at 0.5 L/min, is 3.6:1 (with a range of 2:1 to 6:1). However, the mean benefit ratio reduces to 2:1 (with a range of 1.8:1 to 3:1) as the supply flow to the conserver cannula approaches 2 L/min.

* * *

This study demonstrated that essentially the same arterial oxygen saturation values can be obtained at reduced flow rates when using the conserver nasal cannula as when using the standard cannula. This phenomenon should not be surprising if one critically evaluates the principles of operation of both cannulas along with the mechanics of breathing.

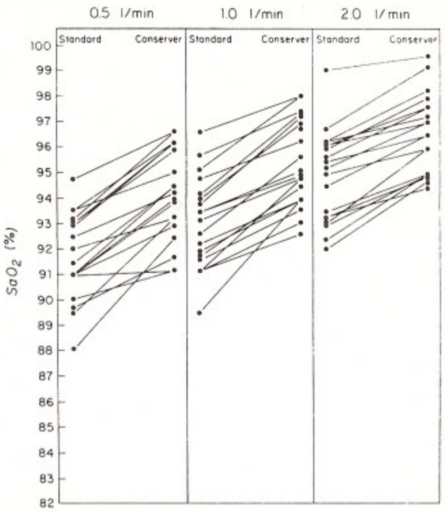

Fig. 2. The conserver is compared with the standard (steady-flow) cannula at 0.5, 1, and 2 L/min. At each supply flow the conserver achieves significant improvement in oxygen saturation (Sa_{O_2}) over the standard cannula ($p < 0.001$).

The standard nasal cannula is designed to provide flow rates of 0.5 to 6.0 L/min. Estimates for fraction of inspired oxygen ($F_{I_{O_2}}$) range from 24 to 44% at flows of 1 to 6 L/min, respectively. During a normal respiratory cycle, 60 to 70% of the time is expended for the expiratory process; thus, only 30 to 40% of the available flow occurs during inhalation. Further, the presence of a 150-ml dead space with a 450-ml tidal volume reduces available supply still further. In contrast, the conserver cannula design permits approximately 20 ml of oxygen to become trapped during expiration; thus, the oxygen is available as a bolus during the first phase of inspiration. This mechanism amplifies the benefit of oxygen administration by providing a greater concentration of oxygen early in the inspiratory phase, thus providing a higher $F_{I_{O_2}}$ at the alveolar level. Once the bolus is delivered, the cannula performs similarly to the stan-

TABLE 1

DEMOGRAPHIC AND PULMONARY FUNCTION DATA

	Number	Males (*n*)	Age (*yr*)	FVC (*L*)	FEV_1 (*L*)	FEV_1/FVC (%)
COH	10	6	66.7 ± 5.2	2.30 ± 0.70	0.66 ± 0.18	28.7 ± 2.4
UTHCT	10	7	62.9 ± 9.0	2.02 ± 0.68	0.85 ± 0.39	42.1 ± 5.7
Total	20	13	64.8 ± 7.1	2.16 ± 0.69	0.76 ± 0.29	35.4 ± 4.1

Definition of abbreviations: FVC = forced vital capacity; FEV, forced expiratory volume in one second; COH = City of Hope National Medical Center; UTHCT = University of Texas Health Center at Tyler.

TABLE 2

MEAN OXYGEN SATURATIONS ACHIEVED BY THE CONSERVER NASAL CANNULA VERSUS THE STEADY FLOW CANNULA

	Administered O_2 Using Nasal Cannula (*L/min*)						
	Room Air	0.5	1	1.5*	2	3†	4†
Standard cannula							
Mean O_2 saturation, %	88.3	90.3	91.6	—	93.6	95.1	96.1
SD	6.8	6.3	6.3	—	5.7	3.6	2.7
Conserver cannula							
Mean O_2 saturation, %	88.0	93.2	94.5	95.4	96.2	—	—
SD	6.9	5.8	4.1	2.9	2.3	—	—
Difference in O_2 saturation between standard and conserver cannula, %	0.3	2.9	2.9	—	2.6	—	—

* Saturations were measured at 1.5 L/min only while using the conserver.
† Target saturations were achieved by the conserver at 2 L/min; therefore, measurements were not taken at 3 and 4 L/min.

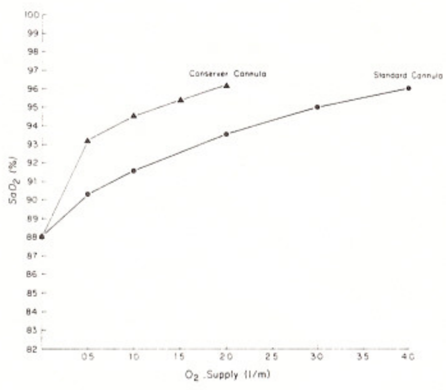

Fig. 3. Oxygen saturation (Sa_{O_2}) is shown for the conserver and for the standard (steady-flow) cannula at supply flows from 0.5 to 4 L/min. At 0.5 L/min, the conserver provides an equivalent saturation to the standard cannula at 1.8 L/min. At 2 L/min, the conserver provides the equivalent to 4 L/min via the standard cannula.

dard cannula by providing additional oxygen through constant flow. The most common level of oxygen prescribed is 2 L/min (7,8). If adequate oxygen saturation could be achieved with a conserver cannula at supply flows of 0.5 or 1.0 L/min, the financial savings could be substantial, particularly in portable oxygen. The sources of savings would be (*1*) reduction of oxygen supply consumption, (*2*) reduction in home tank deliveries, and (*3*) the potential to use less costly portable compressed gas transfill systems as an alternative to more expensive liquid systems. In addition, the conserver would allow an increasing time away from the mother reservoir while using portable transfill oxygen systems.

Subjects were questioned as to the comfort of the conserver. Most subjects found it quite comfortable because the cannula weight was distributed over a larger portion of the face and the prongs were not as sharp as those on their present cannula. Responses to the appearance of the conserver varied; patient acceptability is a question that will remain for future studies.

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