

A New Pendant Storage Oxygen-conserving Nasal Cannula*

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With increasing interest in reducing the cost of oxygen therapy, we recently designed an oxygen-conserving cannula. It reduces the oxygen supply flow necessary to achieve adequate oxygen saturation, but because it requires the use of a reservoir situated under the nose, some patients find it obtrusive. We therefore designed a similar system but displaced the reservoir away from the face and onto the anterior chest wall where it could be hidden from view by the patient's clothing. We evaluated this pendant conserving nasal cannula (PNC) in seven hypoxemic patients with chronic obstructive pulmonary disease. We compared oxygen saturations achieved using the PNC vs the standard

It is now established that low flow oxygen therapy is beneficial to hypoxemic patients with chronic obstructive pulmonary disease (COPD). The Nocturnal Oxygen Therapy Trial,¹ British,² and other studies³⁻⁵ have demonstrated that such low oxygen given between 12 and 24 hours daily improves survival, reduces pulmonary hypertension, improves cor pulmonale, reduces polycythemia, improves psychomotor skills, and reduces depression. Oxygen is generally administered via a nasal cannula flowing continuously throughout the respiratory cycle. However, the greatest benefit of oxygen therapy occurs during early inspiration with much of the remaining oxygen lost to the surrounding environment.

There has been some recent interest in improving the efficiency of oxygen delivery by a redesign of the oxygen cannula. We recently described an oxygen-conserving nasal cannula with a storage reservoir over the mustache area of the face.^{6,7} The goal of this device was to increase the proportion of oxygen flow during early inspiration and thereby achieve adequate saturations with a reduction in total oxygen delivered. At flows of 0.5 L/min to the conserver cannula, the benefit was nearly that achieved at 2 L/min using the steady flow cannula. One difficulty with prescribing oxygen is patient acceptance. While the conserver can reduce to one third to one half the present cost of oxygen, some patients found the reservoir over the mustache area

steady flow nasal cannula (SNC) at 0.5 through 4 L/min. The mean improvement in oxygen saturation using the PNC vs the SNC was 3.3 percent at 0.5 L/min, 4.3 percent at 1 L/min and 3.1 percent at 2 L/min. These differences were statistically significant ($p < 0.001$). The saturation achieved by the PNC at 0.5 L/min was equivalent to that achieved by the SNC at 1.8 L/min. We conclude that the PNC provides effective oxygen delivery to patients at supply flows substantially less than the SNC. The device is aesthetically acceptable to patients and its widespread use in patients requiring chronic oxygen therapy could bring about significant financial savings.

more obtrusive than standard cannulas. In an effort to reduce the relative size of the cannula at the front of the face, we have redesigned the conserver cannula by displacing the storage reservoir off the face. In this design, the storage reservoir resides in a pendant which hangs below the neck on the anterior chest where it can be hidden under the clothing. In this study, we evaluated the efficacy of the pendant conserver cannula by comparing it to the standard steady flow cannula at various oxygen supply flows using oxygen saturation measured via ear oximetry.

METHODS

Pendant Conserver Cannula

Figure 1 shows the pendant conserver cannula. It consists of nasal prongs attached to tubular conduit leading to the oxygen reservoir. The oxygen flows to the juncture of the conduit and reservoir bag. The bag stores 40 mL of gas and is available for oxygen enrichment. The tubing also provides some storage. Like the previously described conserver cannulas,^{6,7} the patient must do some nasal breathing during inspiration and expiration in order to derive added benefit from oxygen stored in the reservoir. The pendant conserver stores oxygen during exhalation; during early exhalation, the increase in nasal pressure forces oxygen into the reservoir. When the reservoir is filled, oxygen fills the conduit (20 mL) leading to the patient. The effect is that oxygen enriched gas is poised for early inhalation.

Protocol

We recruited seven patients with stable chronic lung disease with a mean age of 55.6 ± 14.6 years and a mean FEV₁ of 0.72 ± 4 L for this study. All subjects either had a resting oxygen saturation of 90 percent or less or desaturated to less than 90 percent during low level exercise. They were allowed to continue their medications except they could not receive inhaled bronchodilators within one hour prior to the study. Each subject gave informed consent to participate in the study. Oxygen saturation was measured by means of an ear oximeter.

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FIGURE 1. The pendant oxygen conserving nasal cannula showing the nasal prongs, storage/reflux conduit, and reservoir.

and oxygen flow was metered via a spirometrically calibrated Gilmont rotometer accurate to ± 0.05 L/min. The study was performed with the subjects in a comfortable upright seated position. We measured oxygen saturations at room air, 0.5, 1.0, 2.0, 3.0 and 4.0 L/min using the standard steady flow nasal cannula and at 0.5, 1.0 and 2 L/min using the pendant conserver cannula. The order of presentation of cannulas was randomized, but all measurements started with lowest flow progressing to the highest flow. They were allowed to return to baseline by breathing room air between cannula changes. We determined the time required for saturation equilibration to occur and added two minutes to each oxygen flow level prior to recording saturation in an effort to assure that equilibration had taken place. We compared the mean saturations for each cannula at .5, 1, and 2 L/min using an analysis of variance.

Table 1—Oxygen Saturations Achieved by the Pendant Conservor Nasal Cannula vs the Steady-Flow Cannula

	Patient No.							Mean O ₂ Saturation
	1	2	3	4	5	6	7	
SNC*								
0.5	93	92	86.5	86	88.5	92	92	90 \pm 2.9
1.0	93.5	94	86.5	87	91	93	93	93 \pm 3.1
2.0	95	94.5	92	94.5	95	95	93	93 \pm 1.3
3.0	96	96	94	96	97	96	94	95 \pm 1.1
4.0	97	97	97	97.5	96	96	95	96 \pm .8
PCC†								
0.5	94.5	96	88	92	94	95.5	93	93.3 \pm 2.7
1.0	96	97	90.5	96	96	97.5	94	95.3 \pm 2.4
2.0	97	97	96	97	97	99	95	96.8 \pm 1.2

*Steady-flow nasal cannula.

†Pendant conservor cannula.

RESULTS

Table 1 summarizes the observed oxygen saturations achieved by each patient using the standard steady flow cannula and the pendant conservor cannula at various supply flows. The mean room air saturation was 88.4 ± 2.8 percent. The mean saturation at .5 L/min was 90 ± 2.9 percent for the standard cannula and 93.3 ± 2.7 percent for the pendant conservor. At 1 L/min, the mean saturation was 91 ± 3.1 percent for the standard cannula and 95.3 ± 2.4 percent for the pendant conservor. At 2 L/min, the saturation was 93.7 ± 1.3 percent for the standard cannula and 96.8 ± 1.2 percent for the pendant conservor. These differences in oxygen saturations between the two cannulas were found to be statistically significant ($p < 0.001$) by analysis of variance. Figure 2 compares the oxygen saturations achieved by using the standard cannula and pendant conservor for each subject at 0.5, 1.0, and 2 L/min. The first point in each panel represents the standard cannula, and the second point represents the pendant conservor at each supply flow. In each instance, the pendant conservor yields a higher saturation compared to the steady flow cannula. Figure 3 represents the oxygen saturation performance curves for the standard steady flow cannula and the pendant conservor. At 0.5 L/min, the benefit of supplemental oxygen via the pendant conservor is equivalent to that achieved from 1.85 L/min using the standard steady-flow cannula. This provides a benefit ratio of 3.7:1. At 1 L/min of oxygen delivered to the pendant conservor, the mean saturation is equivalent to the standard steady-flow cannula at 2.8 L/min, yielding a benefit ratio of 2.8:1. At 2 L/min flow to the pendant conservor cannula, the mean oxygen saturation is equivalent to

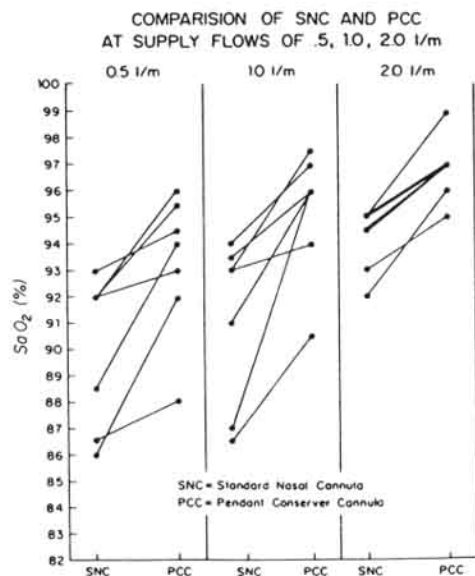


FIGURE 2. Comparison of SNC and PCC at supply flows of .5, 1.0, 2.0 L/min.

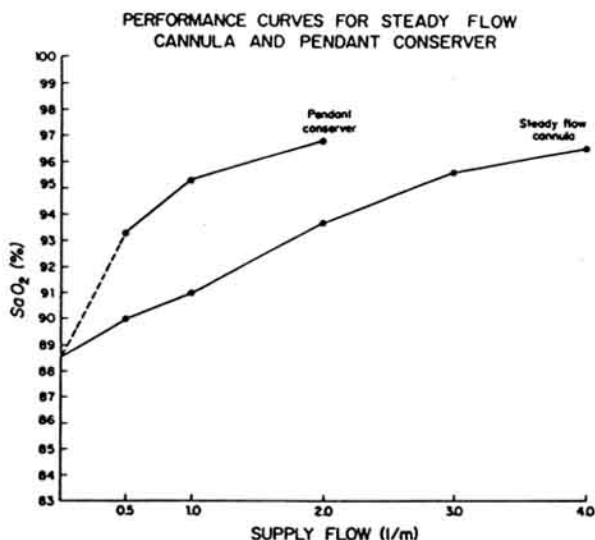


FIGURE 3. Performance curves for steady flow cannula and pendant conserver.

that of 4 L/min for the standard steady flow cannula yielding a benefit ratio of 2:1.

DISCUSSION

We found that the pendant conserver achieved significantly better saturations than the standard steady flow cannula at the same supply flows (Fig 3). The error stated by the manufacturer of the ear oximeter is ± 1.7 percent at saturations of 90 to 100 percent. Notwithstanding this range of error, this study is significant. These results are expected since exhalation occupies 60 to 70 percent of the respiratory cycle. In addition, during the last 30 to 40 percent of inhalation, gas flows principally to dead space. Therefore, gas exchange occurs primarily in the first 20 to 30 percent of the respiratory cycle. The pendant conserver stores a bolus of oxygen during exhalation making it available for early inspiration. In addition to this stored bolus, the pendant conserver operates as a steady flow cannula.

The goal of oxygen therapy is to prevent tissue hypoxia. The usual steady flow prescription is 2 L/min with adjustments for sleep and exercise.^{8,9} If the pendant conserver cannula provides adequate saturations at lower supply flows, substantial financial savings could be achieved. This is particularly useful to patients requiring ambulatory oxygen.

Our previous studies described a similar benefit using a storage cannula with a reservoir residing in the mustache area of the face.^{6,7} While both efficacy and

comfort were improved, some patients found it obtrusive. Therefore, it became apparent that there would be some advantage to removing the reservoir from the face and hanging it around the neck like a pendant. The reservoir could then be hidden by clothing, thereby diminishing its obtrusiveness while retaining the value of its storage capabilities. Subjects were asked to comment about the comfort and appearance of the pendant conserver. Most subjects report that the pendant conserver is more comfortable than the standard steady flow cannula and felt it to be less obtrusive than the presently marketed mustache conserver. Both the pendant and mustache conservers could diminish the obtrusiveness of the oxygen cannister by reducing the storage requirement, thus making smaller and lighter oxygen containers more feasible.

In conclusion, the pendant oxygen conserving cannula provides effective oxygen delivery at substantially reduced oxygen supply flows as compared to the standard steady flow cannula. Because of this improved efficacy, the pendant conserver could significantly reduce the cost of oxygen therapy. It is more comfortable than the standard steady flow cannula. Furthermore, the fact that the reservoir is hidden from view makes the system aesthetically more acceptable than the mustache configured conserver.

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