

## Improvement of oxygen delivery in severe hypoxaemia by a reservoir cannula

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*Improvement of oxygen delivery in severe hypoxaemia by a reservoir cannula.*  
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**ABSTRACT:** In 36 severely hypoxaemic patients (arterial oxygen tension ( $P_{aO_2}$ ) less than 7.3 kPa or 55 mmHg), candidates for long-term oxygen therapy, we compared the effectiveness of three oxygen-delivery systems, the standard nasal prongs, a so-called oxygen-conserving reservoir device ("Oxymizer Pendant") and the reference pharyngeal catheter, at a preset flow rate of 2 l·min<sup>-1</sup>. After 30 min, the conserving device (OX) was at least as efficient as the pharyngeal catheter (PC) and did significantly better than the nasal prongs (NP), the mean increments in  $P_{aO_2}$  and arterial oxygen saturation ( $S_{aO_2}$ ) being, respectively, 1.1 kPa (8.1 mmHg) and 1.3% higher with OX than with NP. Twenty patients did not reach the target level of 8.6 kPa (65 mmHg)  $P_{aO_2}$  with the nasal prongs, but the reservoir cannula allowed nine of these "refractory" patients to hit this therapeutic goal, a result indicating a clear trend towards improved immediate oxygen response. Although initially designed to spare gas, we suggest that a reservoir cannula could serve another purpose, namely to optimize oxygenation in patients treated by an oxygen concentrator. Indeed, since the oxygen flow rate cannot be reliably increased over 3 l·min<sup>-1</sup> with the available oxygen concentrators, the reservoir device could be more effective in some selected patients whose hypoxaemia cannot be adequately corrected by standard nasal prongs.

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Long-term oxygen therapy (LTOT) is recognized as the mainstay for the treatment of patients with chronic and severe hypoxaemia. There is considerable evidence that home oxygen therapy improves the quality of life and extends survival in proportion to the number of hours of treatment [1-3]. LTOT is recommended for patients in a stable state with an arterial oxygen tension ( $P_{aO_2}$ ) <7.3 kPa. Patients with a  $P_{aO_2}$  of 7.3-8.0 kPa should also be assigned to oxygen supplementation if there is evidence of right heart failure, pulmonary hypertension or erythrocytosis. Oxygen should be administered at a flow rate allowing a  $P_{aO_2}$  of at least 8.6 kPa to be reached, in order to increase the arterial oxygen content adequately; furthermore, carbon dioxide retention should not be substantially increased [4].

Since an increasing number of patients are assigned to LTOT, there is considerable interest in improving methods of oxygen administration and conservation, with the perspective of saving costs, increasing the autonomy with portable cylinders and allowing the construction of smaller concentrators [5-8]. Currently available methods include demand-delivery systems that supply oxygen only during inspiration and transtracheal delivery; furthermore, some cannulae are coupled with a reservoir allowing oxygen to be stored during expiration and delivered as a

bolus during the first phase of the next inspiration, when it is most efficient for gas exchange [5, 6].

The purpose of the present study was to compare the efficacy of three oxygen delivery systems, namely the routinely used nasal prongs, the reference pharyngeal catheter and nasal cannulae coupled with a reservoir, in stable patients with severe hypoxaemia meeting the conditions for LTOT. Whether such a device could provide a more efficient oxygenation in patients "refractory" to standard oxygen supplementation was also addressed in this study.

### Subjects and methods

Thirty six in-patients (29 men and 7 women; mean age 62.6 yrs) evaluated for LTOT, with severe hypoxaemia at rest ( $P_{aO_2}$  <7.3 kPa while breathing room air) and in a clinically stable condition were included in the study; this stable state was confirmed by  $P_{aO_2}$  variations of 0.7 kPa or less in 27 of the 32 patients who were re-tested at least 4 weeks apart. Twenty eight had chronic airflow obstruction, 4 had evidence of pulmonary fibrosis and 3 showed a mixed pattern. The forced vital capacity ranged from 22-82% of predicted values, the forced expiratory

volume in one second ( $FEV_1$ ) from 12–88%, the total lung capacity from 51–145% and the carbon monoxide transfer coefficient from 13–138%. Baseline blood gas values are recorded in table 1.

( $SaO_2$ ) of each arterial blood sample was measured with a spectrophotometric oximeter (CO-Oximeter, model 282).

Baseline measurements while breathing room air were compared with those obtained during oxygen supplemen-

Table 1. – Arterial blood gas values (36 subjects)

		Room air	Oxygen supplementation 2 l·min <sup>-1</sup>		
			Nasal prongs	Pharyngeal catheter	Oxymizer
			NP	PC	OX
$SaO_2$	%	83 (6)	91 (4)	91 (4)	92 (4)
$Pao_2$	kPa	5.4 (0.7)	8.9 (2.0)	9.6 (2.5)	10.0 (2.5)
	mmHg	49 (5)	67 (15)	72 (19)	75 (19)
$Paco_2$	kPa	6.1 (0.9)	6.4 (1.1)	6.6 (1.1)	6.6 (1.2)
	mmHg	46 (7)	48 (8)	49 (8)	49 (9)

Data are shown as mean with sd in parentheses.

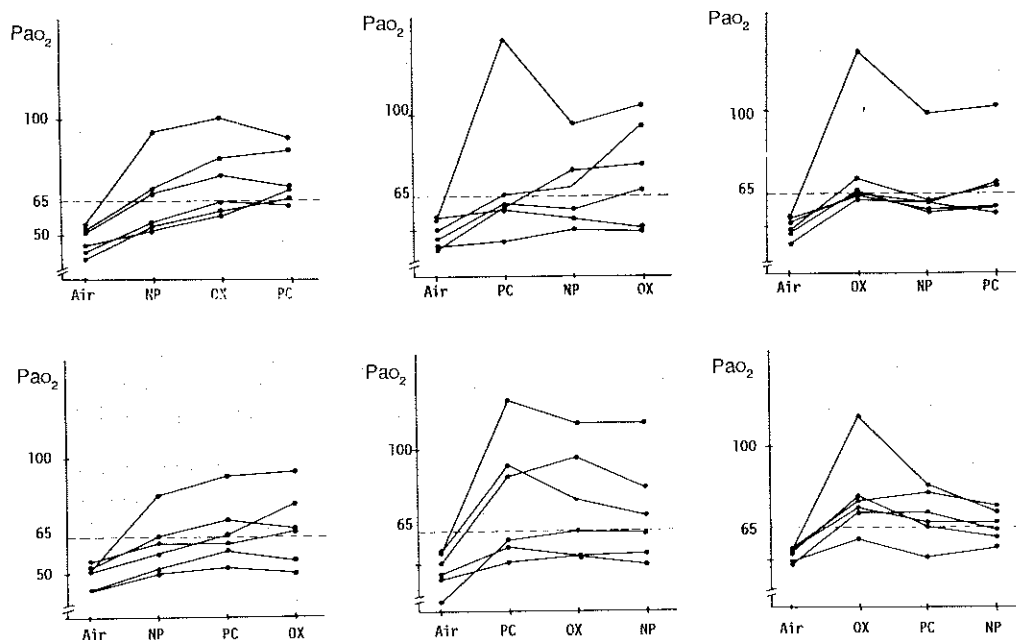


Fig. 1. – Individual evolution of arterial oxygen tension ( $Pao_2$ ) according to random assignment of the order of use of three modalities of oxygen therapy: nasal prongs (NP), pharyngeal catheter (PC) or Oxymizer (OX).

All subjects gave oral informed consent to participate in the study. Their usual medication schedule was continued, except for inhaled bronchodilators which were withheld for at least 4 h prior to the study.

The patients sat in a comfortable armchair and were allowed to adopt their usual breathing pattern. A catheter was inserted in the radial or brachial artery. Determinations of blood gas levels were performed in a stepwise fashion, using an automated blood gas analyser (Corning Medical, model 175); the oxyhaemoglobin saturation

tation at a flow rate of 2 l·min<sup>-1</sup> metered by a calibrated rotameter via each considered device: the standard nasal prongs (NP), the pharyngeal catheter (PC) or an oxygen-conserving reservoir system (OX) ("Oxymizer Pendant"; Chad Therapeutics, Woodland Hills, California, USA), the same devices being used throughout the study. The pharyngeal catheter was inserted through the nose to a depth corresponding to the distance measured between the nostril and the ear lobe. The order of use of the devices was assigned randomly. An arterial blood gas

analysis and an oxyhaemoglobin saturation determination were carried out when the patient had been breathing with the first device for 30 min, in order to achieve a steady state; then the patient was switched to the next type of cannula, without discontinuing the oxygen administration and the procedure was repeated so that each patient was tested for all three devices after use of each during 30 min.

In this study, patients "refractory" to oxygen administration are defined as those who do not reach a  $P_{aO_2}$  of at least 8.6 kPa when supplemented with 2 l·min<sup>-1</sup> oxygen through the nasal prongs for 30 min.

Statistical study was performed by analysis of variance, Student's paired t-test and Chi-squared test;  $p < 0.05$  was considered to be significant.

### Results

The individual evolution of  $P_{aO_2}$  according to random assignment of the order of use of the three modalities of oxygen therapy is shown in figure 1. Average blood gas values are reported in table 1.

At the preset oxygen flow rate (2 l·min<sup>-1</sup>), significantly higher average oxygen tension (+1.1 kPa) and oxyhaemoglobin saturation (+1.3%) were achieved after 30 min with the Oxymizer (OX) in comparison with the standard nasal prongs (NP); in all but four patients, OX yielded a higher  $P_{aO_2}$  than NP. On average, the  $P_{aO_2}$  obtained with OX was higher than that observed with PC, but the difference did not reach the level of statistical significance. A slightly larger increase in carbon dioxide tension was brought about by OX and PC, as compared to NP ( $p < 0.05$ ). The results were not influenced by the order of use of the oxygen delivery systems.

There were interindividual variations in the improvement of  $P_{aO_2}$ , 14 of the 36 patients showing only a small increase (<0.7 kPa), or even a decrease, with OX as compared to NP (fig. 1).

Table 2 reports the respective number of patients reaching three levels of response to 2 l·min<sup>-1</sup> oxygen delivered through the three devices. Twenty patients failed to achieve the target level of 8.6 kPa when supplemented through NP; the hypoxaemia of nine of these "refractory" patients was adequately corrected by OX.

Table 2. - Response to oxygen supplementation (n=36)

	NP	PC	OX
$P_{aO_2} > 8.0$ kPa or 60 mmHg	23	28	29
$P_{aO_2} > 8.6$ kPa or 65 mmHg	16	21	25
$S_{aO_2} > 90\%$	22	27	27

Number of patients reaching three thresholds of response to oxygen therapy with the three considered devices; nasal prongs (NP), pharyngeal catheter (PC), Oxymizer (OX);  $P_{aO_2}$ : arterial oxygen tension;  $S_{aO_2}$ : arterial oxygen saturation.

Patients "refractory" to oxygen supplementation had a significantly lower baseline  $P_{aO_2}$  (6.0 versus 6.7 kPa) and higher arterial bicarbonate (32 versus 29 mEq·l<sup>-1</sup>) than the other patients but could not be discriminated on the basis of their spirometric, plethysmographic or carbon monoxide transfer parameters.

Subjective feelings of the patients were somewhat different during the three oxygen supplementation periods. Most patients did not like PC; some considered that the OX cannulae were a little too large and too rigid as compared to NP.

### Discussion

An adequate oxygenation is supposed to be achieved in the majority of hypoxaemic subjects with a flow rate of 2±1 l·min<sup>-1</sup> oxygen delivered by nasal prongs [4].

It has been extensively shown that oxygen-conserving devices, such as Oxymizer, can achieve the same rise in  $P_{aO_2}$  or  $S_{aO_2}$  as standard nasal prongs at a lower (about half) oxygen flow rate [5-8].

At first sight, the use of an "oxygen-sparing device" in patients treated by means of oxygen concentrators may not be beneficial since the costs are not directly related to the oxygen flow. The results of our study suggest, nevertheless, that a reservoir cannula could play a role in increasing the response to oxygen supplementation and reducing the number of "refractory" patients; this could be particularly beneficial for an individual patient who does not reach a  $P_{aO_2}$  of 8.6 kPa at 3 l·min<sup>-1</sup> oxygen with NP.

MOORE-GILLON *et al.* [9] also found a larger increment in transcutaneous oxygen tension with OX than with NP at an oxygen flow rate of 2 l·min<sup>-1</sup>. The higher  $S_{aO_2}$  that we obtained with OX is in perfect accordance with the findings of GOULD and co-workers [10] and MOORE-GILLON *et al.* [9] but lower than the average increment of 3.1% reported by TIEP *et al.* [6] whose patients had, nevertheless, a higher baseline  $S_{aO_2}$ .

A clinical problem with LTOT is that a substantial number of patients cannot be adequately oxygenated with a standard 2 l·min<sup>-1</sup> flow using nasal prongs: up to 7% of the patients in the Nocturnal Oxygen Therapy Trial (NOTT) study required an NP oxygen flow rate of 4 l·min<sup>-1</sup> in order to achieve a suboptimal  $P_{aO_2}$  of at least 8 kPa [11]. In our "refractory" patients, the flow rate could indeed have been increased but one should bear in mind that, with standard nasal prong delivery, it may not be possible to substantially increase the oxygen flow because of the irritating effects on the nasal mucosae. On the other hand, oxygen delivered by most of the oxygen concentrators rapidly falls to less than 90% when the flow rate is increased above 3 l·min<sup>-1</sup> [12, 13].

The interindividual variations that we observed are also suggested by GOULD and co-workers [10]. The group of "refractory" patients was significantly reduced but not abolished by OX. The presumed mechanisms for the improvement in oxygenation with Oxymizer as compared to standard nasal prongs are the relative independency from the breathing pattern and the bolus effect from the

coupled reservoir during early inspiration; the bolus effect could also be an explanation for the better results obtained with Oxymizer as compared to the pharyngeal catheter even if the difference does not reach the level of statistical significance. With the nasal prongs, the inspired oxygen concentration achieved depends largely on the patient's mouth or nose breathing pattern, a phenomenon in part responsible for interindividual variations in response. GOULD and co-workers [14] have shown that voluntary mouth or nose breathing has no significant effect on the efficiency of the Oxymizer; however, everyone can ascertain that the reservoir does not empty itself during inspiration in case of pure mouth breathing, so that we deem that the Oxymizer behaves exactly like standard nasal prongs when the patient adopts this mode of breathing.

Because of the variation in response and considering the greater cost, it is absolutely necessary to document that the reservoir cannula produces a significant improvement in oxygenation. An individual assessment of each candidate to LTOT is needed and if the patient appears to be "refractory" to standard nasal prong oxygen therapy, a trial with Oxymizer is recommended but the device is prescribed only in case of substantial improvement of oxygen delivery.

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*Amélioration de l'oxygénation de patients sévèrement hypoxémiques par des canaux nasales à réservoir. Ph. Collard, F. Wautelet, J.P. Delwiche, J. Prignot, P. Dubois.*

RÉSUMÉ: Chez 36 patients sévèrement hypoxémiques ( $P_{aO_2}$  inférieure à 7.3 kPa ou 55 mmHg), candidats à l'oxygénothérapie au long cours, nous avons comparé l'efficacité de 3 systèmes d'administration d'oxygène, les canules nasales conventionnelles, un système à réservoir dit économiseur ("Oxymizer Pendant") et le cathéter nasopharyngien de référence, au débit préétabli de 2 l·min<sup>-1</sup>. Après 30 minutes, le système économiseur (OX) était au moins aussi efficace que la cathéter pharyngien (PC) et significativement meilleur que les canules nasales (NP), les gains moyens en  $P_{aO_2}$  et  $S_{aO_2}$  étant respectivement supérieurs de 1.1 kPa (8.1 mmHg) et 1.3% avec OX par comparaison à NP. Vingt patients n'atteignaient pas le niveau cible de 8.6 kPa (65 mmHg) de  $P_{aO_2}$  avec les canules nasales, mais les canules à réservoir permettaient à 9 de ces patients "réfractaires" d'atteindre cet objectif thérapeutique, résultat indiquant une tendance nette à une meilleure réponse immédiate à l'administration d'oxygène. Quoiqu'initialement conçues pour épargner l'oxygène, les canules à réservoir peuvent selon nous être utilisées dans un autre but, celui d'optimiser l'oxygénation chez certains patients traités par un oxyconcentrateur. En effet, comme avec les oxyconcentrateurs actuels le débit d'oxygène ne peut être accru de façon fiable au-delà de 3 l·min<sup>-1</sup>, le système à réservoir pourrait se révéler plus efficace chez certains patients sélectionnés dont l'hypoxémie ne peut être corrigée adéquatement à des débits faibles par les canules nasales conventionnelles.

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