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An oxygen conserving nasal cannula

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ABSTRACT Oxygen administration via a nasal cannula incorporating a small collapsible reservoir (Oxymizer, Chad Therapeutics Inc, California) was compared with delivery via a standard nasal cannula. Twelve patients with chronic, stable hypoxaemia (arterial oxygen tension <60 mm Hg (8.0 kPa)) were studied. Transcutaneous oxygen and carbon dioxide tensions were recorded by skin electrodes and oxygen saturation by ear oximetry. Baseline measurements during the breathing of air were compared with those made during the breathing of oxygen at flow rates of 0.5, 1.0, and 2.0 l/min via each device. Increases in saturation and transcutaneous oxygen tension were significantly greater at each flow rate with the reservoir device than with the conventional cannula. To produce similar improvements in oxygenation the reservoir device required an oxygen flow rate about half that of the conventional cannula. Use of the reservoir device may reduce the inconvenience and perhaps the cost of supplying domiciliary oxygen, and prolong the time during which patients may rely on a portable cylinder.

The cost and inconvenience of supplying domiciliary oxygen is considerable, and a device that reduces the gas flow necessary to improve the oxygenation of hypoxaemic patients could bring considerable benefit. We have compared oxygen delivery via a nasal cannula incorporating a reservoir (Oxymizer, Chad Therapeutics Inc, California) with delivery via a conventional nasal cannula.

Principle of reservoir device

The general appearance of the device is illustrated in figure 1. Within an outer plastic casing is a thin membrane that acts as a collapsible reservoir of about 18 ml capacity. The outer casing is vented to allow free expansion and collapse of the inner reservoir, from which soft nasal prongs arise. Gas flow from the oxygen source is at a steady rate. During expiration the reservoir fills with oxygen from the source (fig 2*a*). At the onset of inspiration the reservoir empties, delivering this stored oxygen as a bolus (fig 2*b*). During the remainder of inspiration, after the reservoir has collapsed, the device acts like a conventional cannula delivering oxygen at the set flow rate (fig 2*c*). A simplified calculation illustrates the principle:

If the respiratory rate is 20/min, the conventional cannula at a flow rate of 2 l/min delivers 100 ml/breath. If, for example, the inspiratory time is 30% of the cycle, then 30 ml of oxygen is delivered with each inspiration.

With the reservoir cannula at a flow rate of 0.5 l/min (or 8.3 ml/s) just over 16.6 ml of oxygen is stored in the reservoir during each expiration. This "bolus" is delivered as soon as inspiration begins, with subsequent flow at 8·3 ml/s as inspiration continues. The total oxygen delivered during each inspiration is thus about 24 ml.

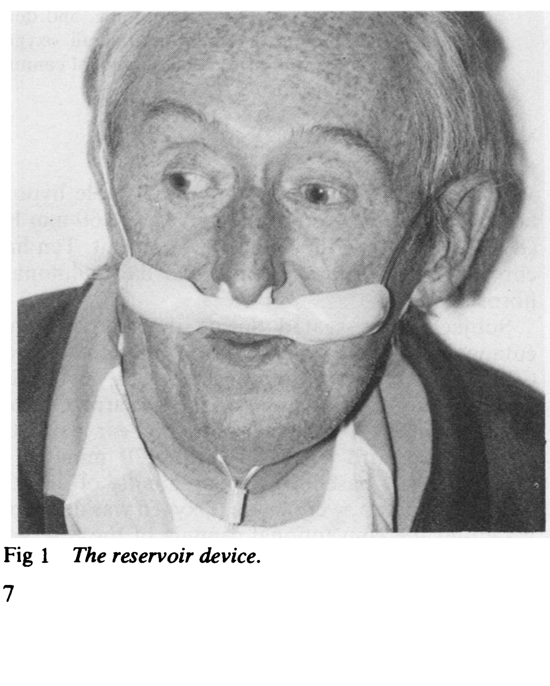

Fig 1 *The reservoir device.*

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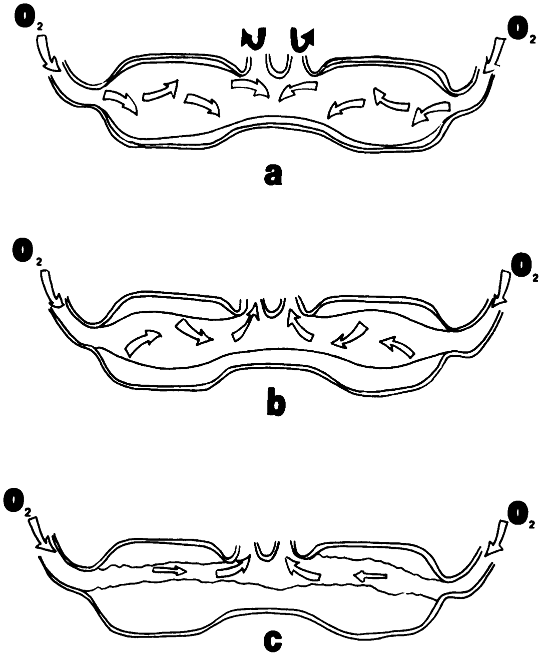

Fig 2 *(a) During expiration the reservoir fills with oxygen. (b) During early inspiration the reservoir empties to the patient. (c) The reservoir now collapsed, the device acts as a conventional cannula.*

During inspiration the reservoir cannula thus delivers only 20% less oxygen than the conventional cannula (24 ml versus 30 ml) but uses 75% less total oxygen. This theoretical advantage will in practice be influenced by flow rate, respiratory rate, tidal volume, and dead space. Additionally, the assumption that all oxygen delivered during expiration by a conventional cannula is wasted may not be correct.

Methods

We studied 12 patients with chronic stable hypoxaemia (arterial oxygen tension (Pa_{O_2}) < 60 mm Hg (8 kPa)). All gave their informed consent. Ten had chronic airflow limitation and two had pulmonary fibrosis.

Subjects were seated during the study. Transcutaneous oxygen (TcP_{O_2}) and carbon dioxide (TcP_{CO_2}) tensions were measured by electrodes (Radiometer, Copenhagen) on the forearm. Oxygen saturation (Sa_{O_2}) was measured by ear oximetry (Hewlett-Packard 47201A). After 20 minutes of breathing air baseline measurements of TcP_{O_2}, TcP_{CO_2}, and Sa_{O_2} were made. Oxygen was delivered via either the conventional cannula or the reservoir device, at 0.5, 1.0, and 2.0 l/min, for six minutes at each flow rate. Air was then breathed for 20 minutes to re-establish stable baseline readings; in every patient these were within 2 mm Hg for TcP_{O_2} and TcP_{CO_2} and 1% for Sa_{O_2} of the original baselines. Finally, oxygen was delivered for six minutes each at the above flow rates with the device not used in the first half of the study.

Increases in readings above baseline (ΔTcP_{O_2}, ΔTcP_{CO_2}, and ΔSa_{O_2}) were calculated for each device. The significance of any difference in results for the two devices was assessed by Wilcoxon's signed rank sum test for paired data.

Results

Eight subjects found the reservoir device more comfortable than the standard cannula, the others expressing no preference. None commented adversely on its cosmetic appearance.

Comparisons between the two devices of ΔTcP_{O_2}, ΔTcP_{CO_2}, and ΔSa_{O_2} for each flow rate are shown in figure 3. Increments in TcP_{O_2} and Sa_{O_2} were significantly greater at each flow rate with the reservoir cannula than with the conventional cannula.

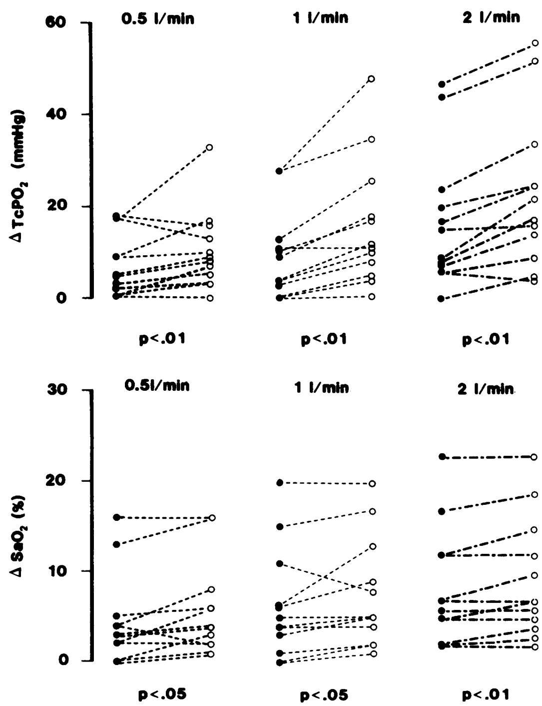

Fig 3 *Increases in transcutaneous oxygen tension. (TcP_{O_2}) and increases in oxygen saturation (Sa_{O_2}): comparison between the reservoir device (○) and a conventional cannula (●) at each flow rate studied.*

Changes in $TcPco_2$ were observed in only one subject, similar rises occurring with the two devices.

Mean increases in $TcPo_2$ at flow rates of 0.5, 1.0, and 2.0 l/min were 12.0, 16.2, and 22.8 mm Hg with the reservoir device and 6.0, 9.7, and 17.0 mm Hg with the standard nasal cannula. For Sao_2 the corresponding figures were 5.7%, 7.6% and 9.5% (reservoir cannula) and 4.3%, 6.2%, and 8.3% (conventional cannula). These figures suggest that the increases in $TcPo_2$ given by the conventional cannula at the three flow rates tested could be produced by the reservoir cannula at lower flow rates, with oxygen savings of about 50%, 60%, and 45% respectively. The results for oxygen saturation suggest corresponding savings of 30%, 37.5%, and 32.5%.

Discussion

The reservoir device requires a considerably lower oxygen flow rate than a conventional cannula to achieve a given rise in $TcPo_2$ and Sao_2. The reduction in oxygen consumption is less than that found by Tiep *et al* in a recent study that evaluated only saturation changes,[1] but still represents an impressive saving. Devices have been described in the past that conserved oxygen by inspiration phased oxygen delivery (IPOD).[2,3] One recently investigated by Winter *et al*[4] appears to be a considerable advance over previous approaches to the problem; it uses a conventional nasal cannula and a sensor detects pressure changes in the oxygen tubing during the respiratory cycle to open and close a valve, so that oxygen delivery takes place only during inspiration. It gives oxygen savings similar to those found in the present study, but it still has some of the disadvantages associated with the earlier devices. It requires a battery or power source and is less portable than the reservoir cannula. There may be limits on the length of tubing, beyond which the sensor of the IPOD device is unreliable at detecting the pressure changes of respiration; and this might restrict the patient's movement around the house. The initial capital cost of such electromechanical devices is inevitably higher than that of the reservoir cannula, although the continuing costs might be lower.

The reservoir device was relatively less efficient at 2 l/min than at the lower flow rates; we did not evaluate it at rates higher than 2 l/min. Consideration of the principle by which it works suggests that at high flow rates the reservoir would "overflow" during expiration and so waste oxygen, and might not fully collapse during inspiration. At increasing flow rates it would thus behave progressively more like a conventional cannula and its advantages would progressively diminish.

The cost savings made by use of the reservoir device would depend on its selling price and lifespan. The manufacturers recommend replacement every 10–14 days but no data are available to support this advice. Halving the number of oxygen cylinders required each week might greatly reduce the practical problems of delivery and storage for many patients. The benefits for those with oxygen concentrators are less clear cut, but if the required oxygen flow were halved then conceivably concentrators that were smaller, cheaper, and more economical to run might be developed. The value of portable oxygen cylinders is at present greatly limited by their necessarily small capacity. Doubling the length of time that could be spent away from the main oxygen source by using the reservoir cannula might for some patients lead to a major improvement in enjoyment of life and ability to travel.

We conclude that the reservoir device could reduce the difficulties of supplying domiciliary oxygen and might improve the quality of life of some patients. Its price and lifespan will determine the size of any financial savings.

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