Monaldi Arch Chest Dis
1999; 54: 4, 311–314

Savings obtained using an oxygen economizer device: a cost-minimization analysis

M. Neri, L. Fedi, A. Spanevello, G. Mazzucchelli, M. Grandi, M. Ambrosetti, S. Conti, G.B. Migliori

ABSTRACT: *Savings obtained using an oxygen economizer device: a cost-minimization analysis. M. Neri, L. Fedi, A. Spanevello, G. Mazzucchelli, M. Grandi, M. Ambrosetti, S. Conti, G.B. Migliori.*

As liquid oxygen represents a relevant burden on healthcare systems, different methods have been developed to reduce oxygen consumption, including economizers.

The aims of the study were: 1) to evaluate the efficacy of an economizer device (Companion 5 Oxygen Saver) in a significant sample of patients, and 2) to perform cost-minimization analysis of the possible savings to be obtained using the device. The study was designed as an open, prospective clinical trial in which equivalence in haemoglobin saturation with and without the economizer device was demonstrated, preliminary to cost-minimization analysis in patients affected by restrictive and obstructive lung disease. Patients were to use their usual O_2 flow, provided it was able to guarantee a saturation of ≥90% and an arterial oxygen tension (P_aO_2) of ≥8.0 kPa (60 mmHg) during rest, sleep and exercise with and without the economizer (mean value and different saturation ranges compared by means of parametric or nonparametric tests where appropriate). The average unit cost was calculated with and without the economizer, based on the average unit O_2 consumption, and cost-minimization analysis was performed.

In 29 patients enrolled, the mean (±SD) O_2 flow in L·min^{-1} was 1.5±0.6 during sleep, 1.4±0.6 during rest and 2.3±1.1 during exercise. The mean oxygen saturation during sleep was 91.2±19.5% without and 97.2±3.9% with the economizer device (p=0.09), the mean saturation during rest was 88.8±22.7% without and 92.1±14.9% with the economizer device (p=0.42), and the mean saturation during exercise was 84.7±19.3% without and 91.8±15.9% with the economizer device (p=0.04). The total daily O_2 consumption was significantly lower using the economizer device (2,384±950.3 *versus* 93.0±482.9 L, p<0.001).

The potential savings, estimated per patient per year, were 530,114±184,233 L, corresponding to US$2,492±866. During the first year the total unit savings would be US$ 1,892.

The savings, consistently relevant alongside the whole range of variation explored by sensitivity analysis both during the first and the following years, justify considering the adoption of similar economizers on a larger scale, although further studies should be performed to evaluate whether or not liquid oxygen really represents the most cost-effective method of treating hypoxaemic patients.
Monaldi Arch Chest Dis 1999; 54: 4, 311–314.

Keywords: Cost-minimization, economizer, effectiveness, oxygen therapy.

Fondazione Salvatore Maugeri, Clinica del Lavoro e della Riabilitazione, Care and Research Institute, Tradate, Italy.

Correspondence: M. Neri, Dept of pulmonary rehabilitation, Fondazione Salvatore Maugeri, Clinica del Lavoro e della Riabilitazione, Care and Research Institute, Via Roncaccio 16, 21049, Tradate, Italy.

Received: July 8 1998; accepted after revision September 1 1998.

This study was funded, in part, by the Fund for Current Research, Ministry of Health 1996–97.

Liquid oxygen represents a relevant burden on healthcare systems [1], particularly in countries where concentrators are not widely used, such as Italy. The standard nasal prong steady-flow O_2 delivery method is very wasteful of O_2 since the patient exhales during two-thirds of the cycle and only 30–40% of the inspired gas participates in ventilatory gas exchange [1]. Different methods have been developed to reduce O_2 consumption, including economizers [2]. They are designed to deliver O_2 during the early inspiration phase only [2]. The efficacy of the devices have been demonstrated in several studies performed in hypoxaemic patients with restrictive (interstitial lung disease (ILD)) and obstructive (chronic obstructive lung disease (COLD)) lung disease [2–4]. Cost-minimization analysis is a complete economic analysis in which the consequences of two or more alternatives are examined alongside costs, and are shown to be equivalent [5]. Since the cost-minimization analysis can be carried out without ambiguity if it is based on existing medical evidence of effectiveness, and the published studies are based on small sample sizes, the aims of this study were: 1) to evaluate the efficacy of the economizer device (Companion 5 Oxygen Saver; Puritan-Bennet, Overland Park, KS, USA) in a significant sample of patients, and 2) to perform economic (cost-minimization) analysis of the possible savings to be obtained using the device.

Patients and methods

Study design

The study was designed as an open, prospective clinical trial in which equivalence in haemoglobin saturation with and without the economizer device was demonstrated preliminary to cost-minimization analysis. The study was performed in patients admitted to the Dept of Pneumology, Fondazione S. Maugeri, Tradate (Italy) between June 1, 1995 and November 30, 1996. The study was approved by the Ethics Committee of the Fondazione Maugeri and each patient signed an appropriate consent form.

Patients

A significant sample of consecutive patients affected by COLD and ILD, in stable condition (no modifications of O_2 flow and infective exacerbations in the previous 2 months) was enrolled.

Patients were to use their usual O_2 flow, provided it was able to guarantee a saturation of ≥90% and an arterial oxygen tension (P_aO_2) of ≥8.0 kPa (60 mmHg) during rest, sleep and exercise. Saturation with and without the economizer was measured *via* oximetry during rest, sleep and exercise. The following exclusion criteria were applied: respiratory insufficiency requiring ventilatory support; saturation <90% and/or P_aO_2 of ≥8.0 kPa (60 mmHg) at enrolment; severe heart disease and/or general conditions contraindicating the execution of a walking test [6, 7]. The protocol is summarized in table 1.

Equipment

Arterial blood was sampled *via* radial artery puncture; pH, P_aO_2 and arterial carbon dioxide tension (P_aCO_2) were measured using a blood gas analyser (ABL 330; Radiometer, Copenhagen, Denmark), oxyhaemoglobin saturation was measured and recorded by means of an Oximeter Alpa, Nonin 8800 (Nonin Medical, Inc., Plymouth, MN, USA). O_2 flow to the patient was measured by means of a laminar flow element in the cannula for both continuous and demand flow [3]. O_2 utilization was determined by monitoring the O_2 supply cylinder pressure readings upstream from the gas regulators and using an appropriate multiplier to determine the O_2 volume delivered during rest, sleep and exercise [3]. The economizer device (Companion 5 Oxygen Saver) utilizes a standard nasal cannula for O_2 administration, delivering a pulse of O_2 in response to a negative pressure, within the cannula, of -0.04 cmH_2O. Total O_2 delivery·min^{-1} was determined by the prescribed oxygen flow rate. The volume of each O_2 pulse was continuously adjusted by the device in response to the sensed trend in respiratory frequencies such that the total O_2 delivered to the patient each minute remained constant [3]. Three safety mechanisms are incorporated, protecting the patient in case of low or high respiratory frequencies (<8 or >50 breaths·min^{-1}, respectively, with provision of additional O_2) or failure of power or the sensing device (delivering continuous O_2 flow) [3].

Table 1. – Tests performed on patients enrolled in the cost-minimization analysis

Day	
1*	Clinical evaluation, blood gases analysis (at rest), spirometry, electrocardiography
2+	Walking test, evaluation of O_2 flow adequacy during exercise
3	Evaluation of O_2 saturation (at rest and during sleep) with or without the economizer device 6-min standardized treadmill test with or without the economizer device
4	Evaluation of long-term oxygen therapy (LTOT) side-effects (with or without economizer device) by means of a questionnaire All examinations repeated without or with the economizer device
5	Evaluation of LTOT side-effects (with or without economizer device) by means of a questionnaire

*: admission; +: enrolment and randomization.

Evaluation of side effects

The presence of side-effects due to O_2 therapy was evaluated by means of a questionnaire the morning following the administration of oxygen with or without the device (table 1).

Statistical analysis

The choice to start oximetry with or without the economizer was based on a randomization list [8] derived from a table of randomized numbers [9]. The sample size protecting from a type II error with 85% power is 35 (estimated difference of clinical relevance 3%; estimated SD 0.03; standardized difference 1; significance level 0.05) [10]. Data were recorded in a database and analysed using Statgraphics Statistical Package (version 6.0; Manugistics, Rockville, MD, USA). Evaluation of effectiveness was performed by comparing saturation results obtained with and without the economizer during sleep, rest and exercise (mean value and different saturation ranges) by means of parametric or nonparametric tests where appropriate.

Cost-minimization analysis

The average unit cost was calculated with and without the economizer, based on the average unit oxygen consumption, and cost-minimization analysis was performed. The economic evaluation, based on the mean data derived from the sample, allowed calculation of the savings that can be achieved per patient per year. The cost of the economizer device (US$600) was discounted over the first year. To estimate the societal perspective, the savings per 100,000 population were determined separately in the Tradate district (43 patients on O_2 treatment out of 61,765 inhabitants) and in the whole Lombardy region (3,700 patients on O_2 treatment out of 8,856,074 inhabitants). The data concerning the

Table 2. – Characterization of the 29 patients enrolled in the cost-minimization analysis

Age yrs	69±7 (median 69)
Males	21
Females	8
P_aO_2 at enrolment mmHg	67.6±5.2
P_aCO_2 at enrolment mmHg	49.8±7.7
pH at enrolment	7.39±0.04
FEV1 at enrolment % pred L	44.0±19.9
FVC at enrolment % pred L	67.4±27.6
IGV at enrolment % pred L	154.4±46.3

Values are presented as mean±SD. P_aO_2: arterial oxygen tension; P_aCO_2: arterial carbon dioxide tension; FEV1: forced expiratory volume in one second; FVC: forced vital capacity; IGV: intrathoracic gas volume. (1 mmHg=0.133 kPa.)

number of patients on oxygen therapy were derived from the official register of the Lombard region, 1996. Sensitivity analysis was performed by varying the oxygen consumption and costs over an appropriate range of values.

Results

Twenty-nine patients (25 COLD, 4 ILD) out of 35 enrolled completed the planned examinations (table 2). The mean±SD O_2 flow in L·min^{-1} was 1.5±0.6 during sleep, 1.4±0.6 during rest and 2.3±1.1 during exercise.

Evaluation of effectiveness

The mean oxygen saturation during sleep was 91.2±19.5% without and 97.2±3.9% with the economizer device (no difference, p=0.09). The mean saturation during rest was 88.8±22.7% without and 92.1±14.9% with the economizer device (no difference, p=0.42). The mean saturation during exercise was 84.7±19.3% without and 91.8±15.9% with the economizer device (no difference, p=0.04).

Evaluation of side-effects

Nobody referred to side-effects due to O_2 treatment either with or without the economizer device.

Cost-minimization analysis

The total daily O_2 consumption was significantly lower using the economizer device (2,384±950.3 *versus* 931.0±482.9 L, p< 0.001). The total O_2 savings using the economizer were ~39% (table 3).

The potential savings, estimated per patient per year, were 530,114±184,233 L, corresponding to US$2,492±866. During the first year the total unit savings would be US$1,892.

The potential savings per 100,000 population in the Tradate District would be US$132,408 during the first year and US$174,408 in the following. When calculated for the whole Lombardy region the savings would be US$79,445 during the first year and US$104,645 in the following.

The total potential savings achievable with the general adoption of the economizer would be US$80,000 during the first year (and US$100,000 in the following) in the Tradate district and US$7 million during the first year (and US$9.2 million in the following) in the Lombardy region.

Discussion

The aim of this study was to evaluate the efficacy of the economizer device Companion 5 Oxygen Saver in a significant sample of patients and to perform a cost-minimization analysis of the possible savings achievable using the device.

The results of the study indicate that: 1) using the economizer device, the saturation levels obtained during sleep, rest and exercise are not significantly different from those obtained with a continuous O_2 flow in a sample of patients large enough to protect from II type error; and 2) use of the device allowed O_2 economies of approximately 39%, corresponding to 18,400 L·yr^{-1}, with monetary savings of US$2,491·patient·yr^{-1} (US$1,891 during the first year). The potential savings per 100,000 population are >US$100,000·yr^{-1}.

Other authors [11–16] have previously proved the efficiency of demand oxygen systems during seated rest and exercise. The results of the present study are similar to those of BOWER *et al.* [3] who, in a small sample (six) of hypoxaemic patients, found savings ranging from 39% during sleep to 45% during rest, using the same device.

The present study represents the first attempt to estimate, according to the principles of cost-minimization analysis, the potential savings achievable by comparing two equivalent methods (continuous *versus* demand flow) of administering liquid oxygen to a significant sample of hypoxaemic patients.

The savings, consistently relevant alongside the whole range of variation explored by sensitivity analysis during both the first and the following years, justify consideration of the adoption of similar economizers on a larger scale, although further studies should be performed to evaluate whether liquid O_2 really represents the most cost-effective method of

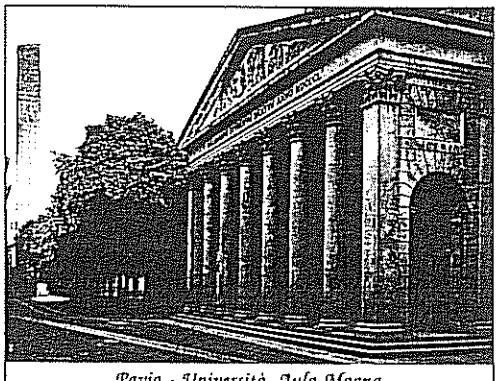
Table 3. – Total daily oxygen consumption with and without the economizer device during sleep, rest and exercise

Period	Oxygen consumption L		p-value	O_2 saving %
	With economizer	Without economizer		
Sleep	328.2±189.6	833.0±389.7	<0.001	39.4
Rest	310.1±156.3	796.0±321.7	<0.001	39.0
Exercise	293.4±186.4	755.0±379.2	<0.001	38.9
Total	931.6±482.9	2,384±950.9	<0.001	39.1

treating hypoxaemic patients. The conclusion is strengthened by the absence of observed side-effects during the use of the economizer.

References

1. Tiep LB, Nicotra MB, Carter R, *et al.* – Low-concentration oxygen therapy *via* a demand oxygen delivery system. *Chest* 1985; 87: 636–638.
2. Carter R, Tashkin D, Djahed B, *et al.* – Demand oxygen delivery for patients with restrictive lung disease. *Chest* 1989; 96: 1307–1310.
3. Bower JS, Brooke CJ, Zimmer K, Davis D. – Performance of a demand oxygen saver system during rest, exercise and sleep in hypoxaemic patients. *Chest* 1988; 94: 77–80.
4. Tiep B. – Portable oxygen therapy with oxygen conserving devices and methodologies. *Monaldi Arch Chest Dis* 1995; 50: 51–57.
5. Drummond MF, Stoddart GL, Torrance GW. – Methods for the Economic Evaluation of Health Care Programmes. Oxford, Oxford University Press, 1989.
6. Siafakis NM, Vermeire P, Pride NB, *et al.* – Optimal assessment of chronic obstructive pulmonary disease (COPD). A consensus statement of the European Respiratory Society. *Eur Respir J* 1995; 8: 1398–1420.
7. American Thoracic Society. – Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care* 1995; 152: s77–s120.
8. Freedman D, Pisani R, Purves R. – Statistics. New York, Norton, 1978.
9. Wonnacott TH, Wonacott RJ. – Introductory Statistics. New York, John Wiley & Sons, 1991.
10. Altman DG. – Statistics and ethics in medical research. III. How large the sample? *BMJ* 1980; 281: 1336–1338.
11. Tiep BL, Nicotra B, Carter R, Phillips R, Otsap B. – Low-concentration oxygen therapy *via* demand oxygen delivery system. *Chest* 1985; 87: 636–638.
12. Mecikalski M, Shigeoka JW. – A demand valve conserves oxygen in subjects with chronic obstructive pulmonary disease. *Chest* 1984; 86: 667–670.
13. Auerbach D, Flick MR, Block AJ. – A new oxygen cannula system using intermittent demand nasal flow. *Chest* 1978; 74: 39–44.
14. Leger P, Perrin F, Robert D. – Evaluation of three oxygen saving devices. *Am Rev Respir Dis* 1985; 131: 100.
15. Rinow M, Saltzman A. – Effectiveness of a new demand valve in chronic hypoxaemia. *Chest* 1986; 90: 204–207.
16. Tiep BL, Carter R, Nicotra B, Berry J, Phillips RE, Otsap B. – Demand oxygen delivery during exercise. *Chest* 1987; 91: 15–201.



Pavia - Università, Aula Magna