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An evaluation of the use of concentrators for domiciliary oxygen supply for less than 8 h day^{-1}

M. JACKSON AND J. SHNEERSON

The Respiratory Support and Sleep Centre, Papworth Hospital, Papworth Everard, Cambridge CB3 8RE, U.K.

Since their introduction in 1985, oxygen concentrators have only been recommended when domiciliary oxygen is used for over 8 h day^{-1}. Subsequent changes in the prices of oxygen merit a reappraisal of the prescribing of concentrators and cylinders when oxygen is used for less than 8 h day^{-1}.

Twenty-six patients in two health districts who used oxygen for less than 8 h day^{-1} completed a crossover study in which each group received oxygen from each source for consecutive 3-month periods. The patients were visited at home before and during the study, and on each visit they completed a questionnaire asking about their use of oxygen, how acceptable they found the two sources and about several dimensions of their quality of life. The theoretical minimum cost of cylinder supply, the actual cost of cylinder supply and the average concentrator costs were assessed.

The patients found the concentrators to be more acceptable, more useful and less obtrusive than cylinders. They used more oxygen in more rooms of the home during treatment with concentrators, and there were improvements in the quality-of-life measurements. The costing information showed that, both in theory and in practice, oxygen concentrators are cheaper than cylinders when oxygen is used for more than about 1·4 h day^{-1}.

These results suggest that the provisions for the supply of domiciliary oxygen should be reviewed and that concentrators should be recommended for patients who use more than around 1·4 h day^{-1}.

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Introduction

The oxygen concentrator service was introduced into the U.K. in December 1985, and has been primarily used for the delivery of long-term oxygen therapy (LTOT) for a minimum of 15 h day^{-1} for suitable patients. There is also provision for concentrators for patients who use oxygen, for indications other than LTOT, for more than 8 h day^{-1} (the equivalent of 21 cylinders per month at 2 l min^{-1}) (1), for which the concentrator was shown to be cheaper than cylinders. Since the introduction of the service, there have been major changes in the prices of oxygen treatment, which merit a reappraisal of the costs and benefits of oxygen concentrators and cylinders.

This study does not address the merits of short burst treatment but, accepting that oxygen is frequently prescribed for this indication, it evaluates the relative cost effectiveness of the two methods available for its delivery.

Both the theoretical and the actual cost of cylinder supply of oxygen has been compared to the cost of concentrators to patients who use between 1 and 8 h day^{-1} of oxygen in two health districts. Also, the patients' view of the acceptability of the two systems and any accompanying effects on their quality of life were also examined, in order to assess whether cylinders or concentrators are preferable.

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Correspondence should be addressed to: M. Jackson, Department of Medicine, Princess Royal Hospital, Lewes Road, Haywards Heath, West Sussex RH16 4EX, U.K.

Methods

The Cambridge and Suffolk local medical committees and the Cambridgeshire and Suffolk family health service authorities gave permission for this study to be performed. The study had ethical committee approval from the Cambridge, West Suffolk, East Suffolk, Peterborough and Huntingdon health authorities. It was performed between March and August 1993.

A comprehensive list of all patients who were authorised oxygen cylinder users and registered as having a cylinder head was obtained from the Cambridgeshire and Suffolk Family Health Services Authorities (FHSAs). The patients' GPs were contacted to seek permission to approach them. The first contact was made by telephone at which it was established whether they used oxygen on average for more than 1 h day^{-1}. Those that did were invited to take part in the study. Patients were excluded if they were current smokers or if they required oxygen cylinders in order to use a small portable oxygen cylinder. The crossover design of the study entailed patients using each system for 3 months.

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TABLE 1. Physiological measurements prior to the study

	FEV_1 (l) (SD)	FVC (l) (SD)	PEF (l min^{-1}) (SD)	SaO_2 (%) (SD)
Cambridgeshire	0·75 (0·3)	1·23 (0·57)	137 (69·5)	93 (4)
Suffolk	0·68 (0·31)	1·12 (0·28)	99 (49)	93 (2)
Overall	0·72 (0·3)	1·18 (0·47)	121 (63·5)	93 (3·25)

The Cambridgeshire patients received a concentrator supply of oxygen for the first half of the study and cylinder supply for the second, and vice versa for the Suffolk patients. Each patient was visited on six occasions. The first followed the initial screening telephone contact and they were then visited at the start of the study and after 4 and 12 weeks in each treatment limb. On each visit, the patients completed a questionnaire about their use of oxygen. This included a series of visual analogue scale (VAS) questions asking about several aspects of the oxygen systems, including the acceptability of the oxygen system, how obtrusive it was and how useful they found it (see Appendix 1). An assessment of quality of life was also performed using the questions concerning fatigue, emotional function and mastery from the chronic respiratory disease questionnaire (2) adapted to VAS measurement. At each visit, the patients' forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and peak expiratory flow rate (PEF) were measured using a turbine spirometer (Micromedical Ltd), as well as the resting oxygen saturation breathing air (SaO_2) using a pulse oximeter (Minolta Pulsox-7 oximeter).

The repeatability of the VAS scores was assessed between the first and immediate pre-study home visits using the method described by Bland and Altman (3). The mean VAS scores for each group of questions and the physiological measurements in each limb of the study for each patient were compared with the patients' mean values in the other limb using the Wilcoxon matched pairs signed rank test.

The theoretical minimum cost of cylinder supply was calculated from the drug tariff assuming that the maximum of three cylinders were delivered to the patients' home at one time, the delivery distance was the minimum (0–3 miles), the patients used the *medium* setting (2 l min^{-1}) and that all the oxygen in the cylinders was fully used up. The actual costs of the cylinder supply for 3 months, both prior to the study and within the study, were provided by the prescription pricing authority. The oxygen concentrators were installed by the regional contractors (DeVilbiss Health Care U.K. Ltd) who also supplied costing data based on the average of their contract prices in the U.K. assuming a patient survival of 18 months and a back-up oxygen cylinder provision for 80% of patients.

Patients

Seven hundred and thirty-two patients were registered with the FHSAs as having an oxygen set. Of these, 227 (31%) were found to be deceased and a further 95 (13%) were no longer registered with the GP indicated on the FHSA database and could not be traced. The GPs declined permission to approach 111 patients (15·2%), and 50 patients (6·8%) were already using oxygen concentrators rather than cylinders. Two hundred and forty-nine patients were contacted by telephone, of which 63 patients thought that they used more than 1 h day^{-1} of oxygen. Eight patients were excluded because of a chest infection in the 4 weeks immediately preceding the study, and 26 patients declined to take part. Twenty-nine patients started the study but three patients in Cambridgeshire withdrew from the study while it was in progress because they were unwilling to change back from concentrator to cylinder treatment.

Fifteen patients in Cambridgeshire (12 male and three female, mean age 74 years) and 11 in Suffolk (seven male and four female, mean age 73 years) completed the study. The clinical diagnosis in all patients was chronic obstructive pulmonary disease (COPD). There were no significant differences between the two groups of patients in their physiological measurements at the start of the study (Table 1). Prior to the study, the Cambridgeshire patients had used oxygen cylinders for a mean of 65·6 months (range 14–111 months) and the Suffolk patients for a mean of 92·6 months (21–252 months) (overall mean 76·4 months).

Results

OXYGEN TREATMENT COST

The theoretical cost of oxygen cylinder supply, the actual cost of cylinder treatment for the study patients, both in the study and for the previous 3 months, and the concentrator cost are shown in Fig. 1. This shows that concentrator supply of oxygen is cheaper than cylinder supply for patients who use an average of greater than about 1·4 h day^{-1}. This price relationship was true for both the theoretical minimum cylinder cost and for the actual cylinder costs both prior to and within the study.

USE OF OXYGEN

All of the patients reported that they used oxygen for breathlessness associated with activities of daily living. The patients used more oxygen in both limbs of the study than in the 3 months prior to the study (Fig. 2). Within the study, the patients used more oxygen while using a concentrator. The Cambridgeshire patients used a mean of 2·5 cylinder h day^{-1} and 5 concentrator h day^{-1}, and the Suffolk

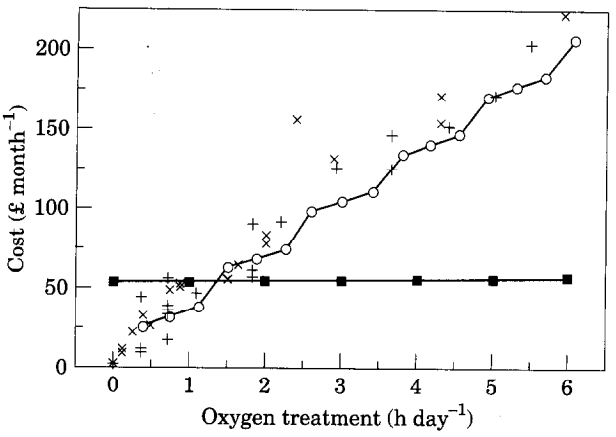

FIG. 1. The concentrator cost (■) and the theoretical and actual costs of cylinder supply of oxygen. O, theoretical minimum cylinder cost; +, cylinder costs 3 months prior to study; ×, cylinder costs within study.

patients used 4·5 cylinder h day^{-1} and 8·25 concentrator h day^{-1}.

PHYSIOLOGICAL MEASUREMENTS

There were no significant differences in the FEV_1, FVC, PEF or resting oxygen saturation in either group of patients during the two limbs of the study (Table 2).

Visual Analogue Scale Questions

REPEATABILITY OF QUESTION SCORES

The maximum possible score for each group of questions was 30, apart from the obtrusiveness group which had a maximum of 20. The scores in the initial and immediate pretreatment visits showed good repeatability with coefficients of repeatability of Fatigue (4), emotional function (6·7), mastery (7·6), ease of use (10·6), patient satisfaction (8·4) and obtrusiveness (5·8).

QUALITY OF LIFE AND PATIENT ACCEPTABILITY OF OXYGEN CYLINDERS AND CONCENTRATOR

Both groups of patients indicated improvements in all groups of questions when receiving oxygen from a concentrator compared with cylinder supply (Fig. 3). These changes were all statistically significant ($P<0·05$) except the change in 'mastery' in the Suffolk patients ($P=0·12$). Overall, the patients found the nasal cannulae (which were provided with the oxygen concentrator) and the face mask (that comes with the standard oxygen set) equally comfortable.

Discussion

The value of short burst oxygen treatment for symptomatic use by dyspnoeic patients with chronic lung disease has not

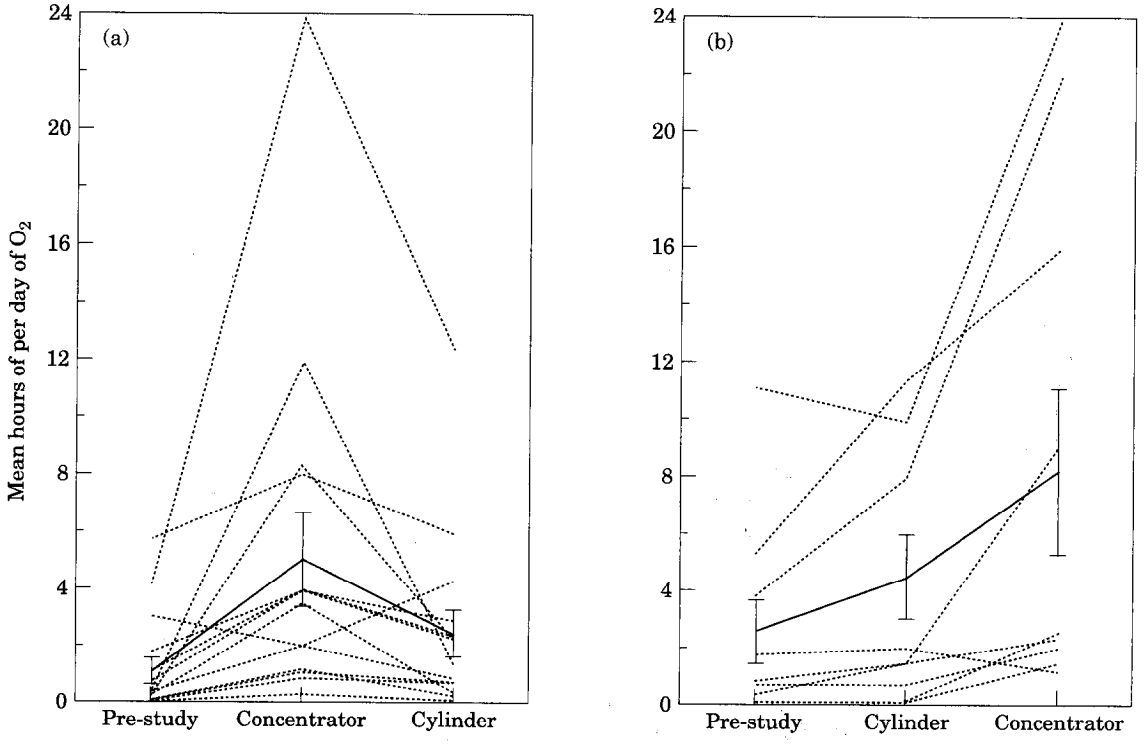

FIG. 2. The number of hours per day of oxygen used prior to and during the study. (a) Cambridgeshire, (b) Suffolk. ——, Mean (standard error) of patient group; · · · ·, individual patients.

TABLE 2. Physiological measurements in the two treatment limbs

		First limb of study [mean (SD)]	Second limb of study [mean (SD)]
Cambridgeshire	FEV_1 (l)	0·84 (0·39)	0·84 (0·39)
	FVC (l)	1·24 (0·49)	1·18 (0·52)
	PEF (l min^{-1})	153 (83)	152 (75)
	SaO_2 (%)	93 (1·6)	92 (2·5)
Suffolk	FEV_1 (l)	0·65 (0·26)	0·62 (0·3)
	FVC (l)	1·05 (0·32)	1·05 (0·32)
	PEF (l min^{-1})	120 (66)	115 (79)
	SaO_2 (%)	92 (1·7)	91 (2)

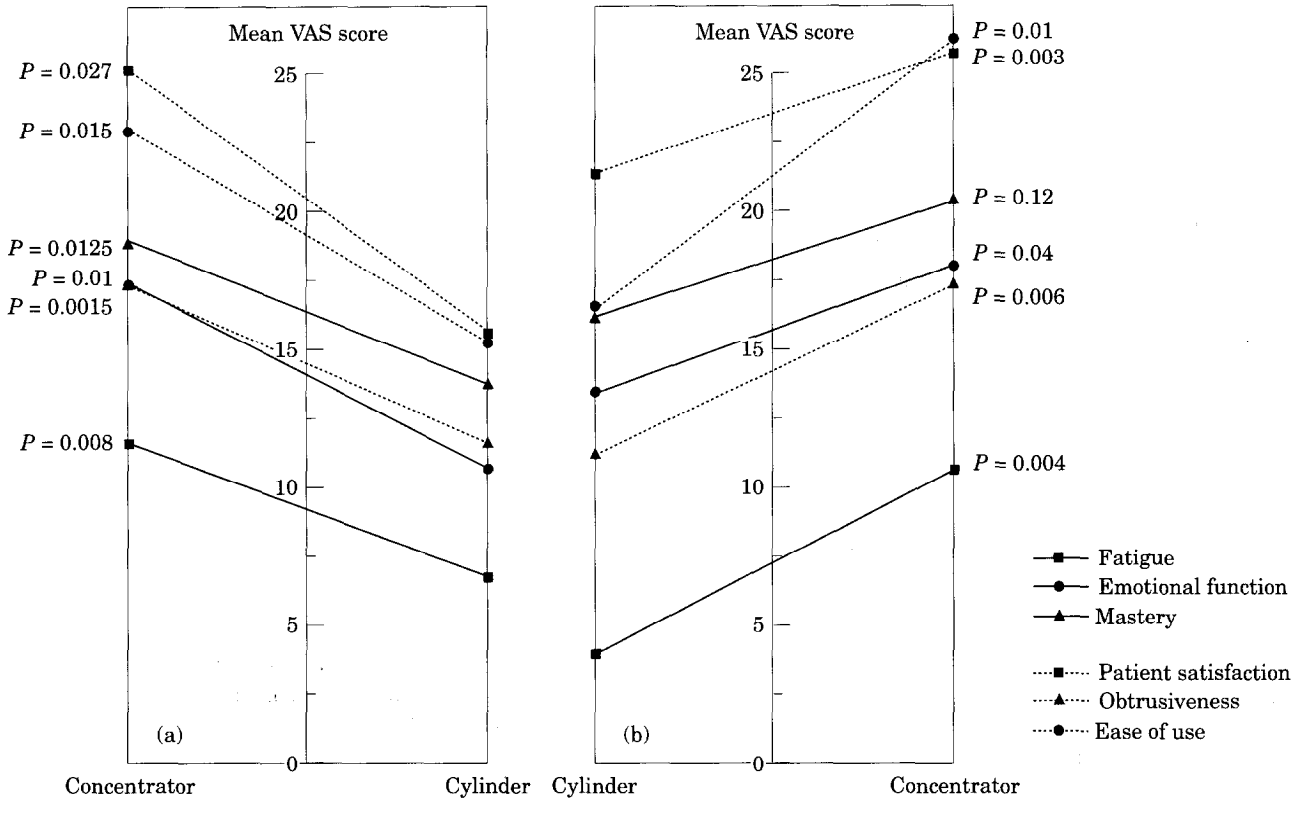

FIG. 3. The mean visual analogue scale (VAS) scores for the quality of life and patient acceptability questions (higher values represent better result). (a) Cambridgeshire, (b) Suffolk.

been studied in controlled trials. The benefits are difficult to judge, particularly since there is a large placebo response to oxygen used in this way. Nonetheless, it is frequently prescribed and accounts for the majority of expenditure on oxygen in the U.K. – costing a total of £14·2 million in 1991–92 compared with £6·9 million for the oxygen concentrator service (4). This study does not address the arguments regarding the merits of short burst treatment but, accepting that oxygen is frequently prescribed for this indication, it evaluates the relative cost effectiveness of the two methods available for its delivery.

The study has highlighted some important aspects of the cost of oxygen treatment. Thirty-eight percent of the patients who were registered with the FHSAs as authorised users of cylinder oxygen were either deceased or had changed to an oxygen concentrator, and a further 13% could not be traced because of inaccurate information regarding the registered GP. This has important cost implications since the monthly reimbursement to pharmacists for each oxygen set supplied is based on the FHSA list. The sets assigned to patients who are no longer using cylinders must be either unused or re-issued to other patients – duplicating the reimbursement. Although the charge for each oxygen set is only small (£2·03 $month^{-1}$), it may represent a significant cumulative cost if these findings are representative of the U.K. as a whole.

The gradual changes in both cylinder and concentrator costs since 1985 have changed the point, in number of hours

per day of oxygen, at which concentrator supply becomes cheaper (the cost crossover point). The authors' theoretical calculations of the minimum cost of cylinder oxygen, based on drug tariff charges, are very close to the actual costs for the patients. The present actual and theoretical cost crossover point is around 1·4 h day^{-1} rather than the presently recommended 8 h day^{-1}. These calculations have assumed an average patient survival of 18 months which seems reasonable since the patients in this study had used cylinders for a mean period of 76 months prior to the study. Assuming an average patient survival of 6 or 36 months, the cost crossover point would be 1·7 or 1·35 h day^{-1}, respectively. This and other work (5) suggest that the majority of patients who have cylinders use oxygen only infrequently and intermittently with the 1·4 h day^{-1} threshold exceeded by around 10% of them.

The authors have shown that access to concentrator supply may be associated with an increase in the number of hours per day of oxygen used by the patients. The overall cost of the concentrator service is only marginally changed by this increased usage since the majority of the cost is a fixed monthly charge for the machine installation, service and rental with a relatively small component of electricity cost. Even if the concentrator usage is increased to 24 h day^{-1}, the resulting cost would only be equivalent to around 1·8 h day^{-1} of cylinder oxygen. Similarly, potential changes to taxation on domestic fuel would have little effect on the cost crossover point. If patients use oxygen at the *high* (4 l min^{-1}) cylinder setting, the cost crossover point is reduced to around 0·7 h day^{-1} since the cylinder cost is doubled whereas the concentrator cost is the same at any flow rate. The patients found the oxygen concentrator a more useful and acceptable means of oxygen delivery, and the VAS results also suggested that this may be associated with improvements in several dimensions of quality of life. These results must be interpreted with some caution since the patients were not blind to the treatment they were receiving, and may have been influenced by several factors such as the novelty of the concentrator and the increased interest shown in them associated with the study. Clearly, however, the use of oxygen concentrators was not associated with any reduction of patient acceptability. The improvements may well be real since all of the patients used oxygen for symptomatic relief of shortness of breath, and concentrators can be more widely used around the home than cylinders. These are usually only available in one or two areas of the home, and because of the short length of oxygen tubing that is supplied, patients are usually restricted to using oxygen after activity. The concentrator service includes the installation of oxygen delivery tubing to wherever the patient may require oxygen, and 'trailing leads' allow its use during activity which may improve confidence and mobility.

The patients in this study took advantage of this facility, using oxygen in more rooms and for more hours per day during concentrator treatment. They also reported that the concentrator was less 'in the way' and occupied less space in the home, presumably because cylinders must be positioned in the main areas of use – usually the bedroom and living room – whereas the concentrators can be installed in a less prominent position away from the main living areas. Other factors that may have contributed to the improvements in the VAS question scores include the lack of need for repeat prescriptions, less fear of running out of oxygen, and not having to wait for a cylinder delivery.

This study of patients who use oxygen for less than 8 h day^{-1} suggests that a concentrator supply would be better accepted by these patients and would be more cost effective than cylinder supply for those patients who regularly use more than about 1·4 h day^{-1} (or 4 cylinders month^{-1} at 2 l min^{-1}). These results suggest that the present recommendations for oxygen concentrator prescription should be modified.

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Appendix 1: Visual analogue scale questions

PATIENT SATISFACTION GROUP

1. Overall, how happy have you been with the present oxygen system?
   (Extremely happy . . . Extremely unhappy)
2. How relaxed have you felt whilst using the present oxygen system?
   (Extremely relaxed . . . Not at all relaxed)
3. Overall, how comfortable have you been while using the oxygen system?
   (Extremely comfortable . . . Not at all comfortable)

USEFULNESS GROUP

1. Overall, how useful has your oxygen been to you? (Extremely useful . . . Not at all useful)
2. How convenient is your present oxygen system to use? (Extremely convenient . . . Not at all convenient)
3. Over the last 2 weeks, how free have you felt to move around the house while using oxygen? (Extremely free . . . not at all free)

OBTRUSIVENESS GROUP

1. How much 'in the way' is the present system? (At lot . . . Not at all)
2. How much space has the oxygen system taken up? (No space at all . . . A lot of space)