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Journal of the Formosan Medical Association (2014) 113, 23–32

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ORIGINAL ARTICLE

Comparison of domiciliary oxygen using liquid oxygen and concentrator in northern Taiwan

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Received 30 September 2011; received in revised form 14 February 2012; accepted 14 March 2012

KEYWORDS
ambulatory oxygen;
domestic activity;
liquid oxygen;
oxygen concentrator

Background/Purpose: Long-term oxygen therapy has become standard treatment for patients with chronic respiratory insufficiency. However, patterns of long-term home oxygen therapy have not been well studied in Taiwan. Oxygen concentrator systems are commonly used in Taiwan, but liquid oxygen delivery systems are portable and may provide advantages over the concentrator system. This study compared oxygen usage between patients from a liquid oxygen group (LOG) and an oxygen concentrator group (OCG). The authors also assessed the physiologic responses of patients with chronic obstructive pulmonary disease (COPD) to ambulatory oxygen use at home.

Methods: The study used a retrospective, cross-sectional, observational survey design. The LOG comprised 42 patients, and the OCG comprised 102 patients. We recruited participants in northern Taiwan from July 2009 to April 2010. The questionnaire instruments that were used to collect data consisted of three parts: demographic characteristics, devices used in respiratory care, and activity status with portable oxygen. Two-minute walking tests were performed on COPD patients in their homes.

Results: COPD was the most common diagnosis in our study, with more than 50% of patients who received oxygen long term in both groups having received this diagnosis. The LOG used oxygen for

The authors have no conflicts of interest relevant to this article.

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doi:10.1016/j.jfma.2012.03.013

an average of 21.7 hours per day, whereas OCG averaged 15.2 hours per day ($p < 0.001$). In the OCG, 92.2% of patients used a concentrator alone, whereas 23.8% of the LOG used liquid oxygen alone ($p < 0.001$). The LOG patients were involved in significantly more outdoors activities ($p = 0.002$) and reported traveling with oxygen more often ($p < 0.001$) than the OCG patients. For patients with the same dyspnea level of COPD severity, those using liquid oxygen had a lower increase in pulse rate after the walking test, in comparison with the concentrator users.
Conclusion: Patients in the LOG used oxygen for longer hours, went on more outings, and were more likely to travel with oxygen than patients in the OCG. Being ambulatory with liquid oxygen might enable patients with COPD to walk more effectively.
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Introduction

A new generation of portable oxygen systems has increased the options for advanced home care worldwide. Patients with advanced chronic obstructive pulmonary disease (COPD) and chronic respiratory failure who previously would have required hospitalization or institutionalization are now able to remain at home. The use of home medical technology provides a strategy to increase the efficiency of health care.

Currently, delivery modes exist for home oxygen: oxygen concentrators, liquid oxygen, and oxygen cylinders. Oxygen concentrators are the most popular source of domiciliary oxygen used in Taiwan and other countries. The overall cost of concentrators is low, and refilling oxygen cylinders is unnecessary. However, concentrators are not versatile and the cost of electricity is often borne by patients. Few patients use small portable oxygen cylinders alone. The limited gas volume, short duration of oxygen supply, and the cost of having cylinders delivered are major limitations of portable cylinders. The liquid oxygen system provides the most flexible source of home oxygen. The light, portable containers each allow 8—10 hours of ambulatory use.[1,2] However, liquid oxygen is relatively expensive compared with the other two systems.[3]

Studies show that patients with COPD who use oxygen for more than 15 hours per day (preferably more than 20 hours) have the best survival rate.[4,5] The European Respiratory Society and American Thoracic Society guidelines both advocate 24 hours of continuous oxygen use per day, supplemented with ambulatory capacity.[6] However, this suggested standard is difficult to apply because patients are required to make a lifelong commitment to a cumbersome oxygen device. Oxygen devices restrict activities of daily living and affect patients' quality of life.[6,7] Research has suggested that poor compliance may result in lower than optimal survival rates and may increase unnecessary hospitalization.[4,8] Some studies have found that many patients use oxygen for fewer than 15 hours per day,[8,9] and that mobile patients generally use oxygen for less than the prescribed time.[8] Thus, promoting use of ambulatory oxygen is of utmost importance in improving the survival rate of patients with COPD.

In Western countries, liquid oxygen is popular for ambulatory patients who want to spend more time outside their homes and move around. Studies have reported that liquid oxygen, in comparison with cylinders or concentrators, is associated with better patient compliance and longer time spent outside the home.[10—12] However, no comparative study had been conducted in Taiwan to examine patterns of use for concentrators, liquid, and cylinders. In this study, we hypothesized that the use of liquid oxygen could improve the duration of therapy, activity level, and walking outcomes. We compared the oxygen use of patients in a liquid oxygen group (LOG) and oxygen concentrator group (OCG). We also assessed the physiologic responses of patients with COPD to the use of ambulatory oxygen at home.

Materials and methods

Patients and study design

This was a retrospective, cross-sectional study that used the observation survey technique. The data were collected from July 2009 to April 2010. Patients using oxygen at home were recruited through three major oxygen vendors in northern Taiwan. The inclusion criteria were as follows: (1) confirmed primary diagnosis of COPD from the hospital discharge data, or a COPD diagnosis previously made by the patient's physician; (2) stable clinical conditions without experiencing an acute exacerbation in the month prior to measurement; and (3) requirement for ambulatory oxygen at home. The exclusion criteria covered the following conditions: dementia, concomitant heart failure, diseases associated with inherent difficulty in mobility, and any medical condition in which exercise testing was contraindicated according to the American Thoracic Society guidelines.[13,14] The principles outlined in the Declaration of Helsinki were followed in the planning and performing of this research. Informed consent was obtained from all participants.

Study protocol

The objective of the study was fully explained to patients by phone, and home visit appointments were arranged. All patients were required to sign a written consent form. Patients (or their primary caregivers) were then asked to complete the questionnaire, and a nurse was available to clarify the content if required. Each patient was instructed to read the response statements for the Medical Research Council (MRC) scale and then select the appropriate number that best described his or her shortness of breath.

After the walk test location had been selected, the patient was instructed to read the descriptive statements of the Borg scale. The walk-test procedure was once again explained to the patients before performing the modified 2-minute walk test (2MWT). The nurse recorded the test results and filed the printed data generated by the pulse oximeter.

Instruments

A three-part questionnaire containing 25 questions was used to collect data. Part 1 covered basic demographic data (nine items); Part 2 addressed the devices used in home respiratory care (six items); and Part 3 consisted of nine items that covered the patient's activity status using portable oxygen (Appendix I). Patients' diagnoses and doctor prescriptions were obtained from the hospital discharge data.

The content of the questionnaire was validated by a formative committee, which consisted of five oxygen patients, five homecare nurses, and five chest physicians. The questions were first answered by the selected five home oxygen patients. The item wording and sequences were adjusted, and the questionnaire was then reevaluated by the home nurses and chest physicians to verify the content validity. Questions with points higher than 0.8 were included in the final questionnaire.[15]

MRC dyspnea scale

The MRC dyspnea scale is used to grade the effect of breathlessness on daily activies.[16] This scale provides a simple and valid method of categorizing the degree of disability in patients with COPD.[17,18] The current study used a modified MRC scale,[16] namely a five-point scale based on degrees of various physical activities that precipitate breathlessness. Higher scores represent greater breathlessness. The questionnaire consisted of five statements on perceived breathlessness, as follows: Grade 1, "I only get breathless with strenuous exercise"; Grade 2, "I get shortness of breath when hurrying on level ground or up a slight hill"; Grade 3, " I walk slower than people of the same age on level ground because of breathlessness, or I have to stop for a breath when walking at my own pace on level ground"; Grade 4, "I stop for a breath after walking 100 yards or after a few minutes on level ground"; and Grade 5, "I am too breathless to leave the house."

Modified 2MWT

The 2MWT is a reliable and valid instrument when used with Chinese patients with COPD who have moderate to severe disease. Previous research has found significant correlations between patients' responses on the 2MWT and the 6-minute walk test. [19]

The patients performed the 2MWT at their homes. We encouraged each participant after every minute with one of two phrases: "You are doing well" or "Keep up the good work." They were allowed to stop and rest during the test, but were instructed to resume walking as soon as they felt comfortable to continue. The patients walked with their usual supply of oxygen by either liquid oxygen or a concentrator, administered at the usual flow.

We used a pulse oximeter (3301, BCI International Co, WI, USA) to measure and record data on patients' pulse rate (PR) and oxygen saturation (SpO_2) every 6 seconds. Data were printed automatically. The Modified Borg scale[20] was used to evaluate the patient at rest (R) and after walking (Ex), expressed as RBorg and ExBorg, respectively.[21] Changes between R and Ex for PR, SpO_2, and Borg scores were then calculated (ΔPR, ΔSpO_2, and ΔBorg, respectively). Scores for resting pulse rate (RPR) and resting SpO_2 represent the patient's PR and SpO_2 after he or she had rested completely for 5 minutes, whereas Ex PR and Ex SpO_2 represent PR and SpO_2 immediately at the end of a 2-minute walk. We did not measure the distances patients walked during the 2-minute test because the patients' home environments varied widely, and we were thus unable to establish a standard 30-m straight path.

Statistical analysis

SPSS version 15.0 software (SPSS Inc, Chicago, IL, USA) was used for statistical analysis. The data were presented either as the relevant percentage of patients or as mean score $\pm$ standard deviation (SD). The distribution of categorical variables across the groups was tested by the chi-square test .The Student *t* test for unpaired groups was used to assess the differences between the groups regarding 2MWT parameters, and for characteristics measured as continuous variables. Analysis of variance was used to further investigate the association among the variables and the potential risk factors. A *p* value of less than 0.05 was considered statistically significant.

Results

Eighty percent of all eligible patients from the three oxygen vendors we approached agreed to be included in the study. The survey questionnaire was administered to 155 patients. Eleven patients did not fully complete the survey and were thus excluded; a final sample of 144 patients was recruited. Of the 88 patients with COPD who were enrolled, 70 participants (79.5%) successfully completed the 2MWT.

Basic characteristics of patients

The sample comprised 42 liquid oxygen (LOG) patients and 102 oxygen concentrator (OCG) patients. Table 1 lists the basic characteristics of all study participants. The most common diagnosis in both groups was COPD, followed by interstitial lung disease (28.6%), which was significantly higher in LOG patients ($p < 0.001$), and neuromuscular disease (8.8%), which was higher in OCG patients ($p = 0.047$). The overall diagnoses showed significant differences ($p < 0.001$) between groups.

Both education and marital status differed significantly between the groups; a significantly higher number of LOG patients had an educational level of "university or above" ($p = 0.003$). More LOG patients were married than OCG patients ($p = 0.044$). No significant differences were noted between the two groups for age, height, weight, sex, number of children, and status of the primary caregiver.

Devices used in respiratory care

The comparison between the LOG and OCG regarding devices used in respiratory care is shown in Table 2. The

Table 1 Demographic characteristics of patients using home oxygen.

	OCG ($n = 102$)	LOG ($n = 42$)	p value
Age (y)	60.2 ± 18.5	65.4 ± 14.9	0.109
Sex M/F	54/48	24/18	0.646
Height (cm)	158.0 ± 13.1	160.5 ± 9.9	0.277
Weight (kg)	54.5 ± 16.7	55.4 ± 12.2	0.746
Diagnosis			<0.001*
COPD	66 (64.7)	22 (52.4)	0.168
Restrictive lung diseases	6 (5.9)	2 (4.8)	0.790
Neuromuscular diseases	9 (8.8)	0 (0.0)	0.047*
Cardiovascular diseases	15 (14.7)	2 (4.8)	0.093
Cancer	3 (2.9)	4 (9.5)	0.095
Interstitial lung diseases	3 (2.9)	12 (28.6)	<0.001*
Education			0.014*
None	11 (10.8)	8 (19.0)	0.183
Primary school	32 (31.4)	12 (28.6)	0.740
Junior school	15 (14.7)	3 (7.1)	0.212
High school	31 (30.4)	7 (16.7)	0.089
College	10 (9.8)	5 (11.9)	0.708
University or above	3 (2.9)	7 (16.7)	0.003*
Marital status			0.045*
Married	71 (69.6)	36 (85.7)	0.044
Never married	23 (22.5)	3 (7.1)	0.029
Divorced	1 (1.0)	2 (4.8)	0.149
Widowed	7 (6.9)	1 (2.4)	0.286
Have children	82 (80.4)	37 (88.1)	0.267
Primary caregivers			0.057
Parents	19 (18.6)	4 (9.5)	
Spouse	30 (29.4)	20 (47.6)	
Children	25 (24.5)	13 (31.0)	
Other relatives	9 (8.8)	1 (2.4)	
Hire people to take care	14 (13.7)	3 (7.1)	
Friend	0 (0.0)	1 (2.4)	
None	5 (4.9)	0 (0.0)	

Data are represented as n (%) or mean ± standard deviation. *$p < 0.05$. COPD = chronic obstructive pulmonary disease; LOG = liquid oxygen group; OCG = oxygen concentrator group.

average length of time that the patient had been using home respiratory care devices was more than 2 years in both groups. The LOG patients tended to use only oxygen without a ventilator (66.7% of LOG patients without ventilator) ($p < 0.001$), whereas OCG patients used significantly more ventilator support than did the LOG patients (72.5% of OCG patients ventilator usage). A higher percentage of OCG patients had undergone tracheotomy ($p = 0.003$). Differences in the type of oxygen source reached a level of statistical significance ($p < 0.001$) with the following findings: 73.8% of LOG patients used both liquid and concentrator; 23.8% of LOG patients used liquid only; and 92.2% of OCG patients used only the concentrator.

The use of a nasal cannula with demand flow was relatively common in 90.5% of LOG patients ($p < 0.001$), and 67.6% of OCG patients used a nasal cannula only ($p < 0.001$). Oximeter monitors were used by 61.9% of LOG patients but by only 29.4% of OCG patients ($p < 0.001$). When asked to rate the need for home service, significantly more LOG than OCG patients expressed the view that home service was not necessary ($p = 0.009$).

Patterns of domestic activity and ambulatory oxygen usage

Table 3 lists the patterns of oxygen usage. The MRC scores were similar for both groups. The LOG patients used oxygen for a longer period each day, at 21.7 hours/day ($p < 0.001$). The two groups differed significantly for reported frequencies of outings ($p = 0.002$). More OCG patients reported "0 to 1" outings per week ($p < 0.001$), and more LOG patients reported "10 or more" per week ($p = 0.012$). More LOG patients reported that they had been traveling with oxygen ($p < 0.001$). However, after covariance adjustments (Table 4, the outcomes of motivation for outing were not affected by liquid oxygen. We also found the pattern of oxygen use differed significantly between the two groups ($p = 0.006$), with a higher percentage of LOG patients using oxygen during activity ($p = 0.003$) or at both "rest and activity" ($p = 0.027$).

The heaviness of the oxygen source was cited as a limiting factor for going outdoors by more OCG than LOG patients (32.4% and 14.3%, respectively) ($p = 0.027$). A higher percentage of LOG patients reported two limiting factors ($p < 0.001$), whereas more OCG patients reported

Table 2 Devices used in respiratory care.

	OCG ($n = 102$)	LOG ($n = 42$)	p value
Treatment time (mo)	30.8 ± 43.0	25.7 ± 31.0	0.490
Ventilator usage	74 (72.5)	14 (33.3)	<0.001*
Tracheostomy	23 (22.5)	1 (2.4)	0.003*
Oxygen source			<0.001*
Liquid only	0 (0.0)	10 (23.8)	<0.001*
Concentrator only	94 (92.2)	0 (0.0)	<0.001*
Liquid and concentrator	0 (0.0)	31 (73.8)	<0.001*
Concentrator and cylinder	8 (7.8)	0 (0.0)	0.062
All three	0 (0.0)	1 (2.4)	0.118
Oxygen device			<0.001*
Nasal cannula	69 (67.6)	3 (7.1)	<0.001*
Simple mask	4 (3.9)	1 (2.4)	0.646
Tracheal mask	16 (15.7)	0 (0.0)	0.007*
No device	9 (8.8)	0 (0.0)	0.047*
Nasal and mask	4 (3.9)	0 (0.0)	0.193
Nasal demand flow	0 (0.0)	38 (90.5)	<0.001*
Oximeter monitor	30 (29.4)	26 (61.9)	<0.001*
Requirement for home health care services			0.014*
Extremely necessary	35 (34.3)	8 (19.0)	0.069
Necessary	44 (43.1)	13 (31.0)	0.174
Depends	14 (13.7)	11 (26.2)	0.727
Not necessary	8 (7.8)	10 (23.8)	0.009*
Does not help and increases cost	1 (1.0)	0 (0.0)	0.520

Data are represented as n (%) or mean ± standard deviation. *$p < 0.05$. LOG = liquid oxygen group; OCG = oxygen concentrator group.

three limiting factors deterring them from going outdoors ($p = 0.02$). The differences between the two groups for the limiting factors cited reached a level of significance ($p = 0.001$).

2MWT for patients with COPD

A total of 19 LOG patients and 51 OCG patients performed the 2MWT with an oxygen supply. Patient characteristics, MRC scale rating, and oxygen flow rate during walking were similar for both groups, as shown in Table 5. However, a higher percentage of LOG patients did not use a ventilator ($p = 0.024$). The $RSpO_2$ and RBorg were the same, but RPR differed significantly between the groups, with LOG patients having a higher RPR (83.3 ± 2.7 beats/minute for OCG, 94.2 ± 5.8 beats/minute for LOG; $p = 0.006$). The ExPR, $ExSpO_2$, and ExBorg at the end of the walking test were similar between groups. The groups showed a statistically significant difference for ΔPR ($P < 0.001$), but ΔSpO_2 and ΔBorg were similar for both groups. Covariance adjustments confirmed the benefits on pulse rate change during walking when patients used liquid oxygen (Table 6).

Discussion

The MRC trial[4] and the Nocturnal Oxygen Therapy Trial (NOTT)[5] suggested that a minimum of 15 hours of daily oxygen supplementation was vital to prolong life in patients who require oxygen therapy. The European Society of Pneumology Task Group agreed that 15 hours should be the minimum duration of daily oxygen use, and that the benefits of long-term oxygen therapy depend on the daily duration of oxygen use.[22] Our own study patients, whether using concentrators or liquid oxygen, reportedly used oxygen therapy for at least 15 hours per day. However, LOG patients used oxygen for significantly longer periods than did OCG patients. Previous research has suggested that the use of liquid oxygen, either alone or together with other oxygen sources, could increase oxygen therapy compliance and thus increase the benefits of long-term oxygen therapy.[8]

The MRC and NOTT studies indicated that long-term oxygen therapy improves the survival of patients with COPD[4,5]; however, no clinical trials have been done on patients without COPD.[4,5] Medicare data for 1991 and 1992[23] indicate that COPD is the most common diagnosis in patients who use oxygen in the United States. Our sample in northern Taiwan showed the same pattern. Furthermore, a relatively large number of LOG patients in our study had interstitial lung disease. Patients with interstitial lung disease require a high oxygen flow,[24] and this high demand promotes the selection of liquid oxygen over a concentrator.

Patients in our LOG were significantly more active in outdoor activities, for both the frequency of outing and traveling with oxygen. Our findings indicated that LOG patients experienced an enhanced quality of life relative to OCG patients. Patients in the LOG tended to desire to go outdoors more than did OCG patients. Our results also demonstrated that patients with COPD may benefit from portable liquid oxygen because of the improved pulse rate change that was evident during the 2MWT (Table 5).

Bestall et al[17] used MRC grades 3 to 4 as the major determinants of disability for exercise performance in patients with COPD.[17] In our study, the MRC grades of all patients with COPD were between 3 and 4. Those patients with COPD in the LOG who had MRC grades 3 and 4 displayed significantly less change

Table 3 Patients' MRC scale rating and patterns of oxygen use.

	OCG ($n = 102$)	LOG ($n = 42$)	p value
MRC scale rating	3.3 ± 1.7	3.4 ± 1.0	0.814
Oxygen usage (h/day)	15.2 ± 7.3	21.7 ± 5.0	<0.001*
Total time spent outdoors (h/day)			0.133
None	16 (15.7)	6 (14.3)	
<4 h	66 (64.7)	20 (47.6)	
4–8 h	19 (18.6)	15 (35.7)	
8–12 h	1 (1.0)	1 (2.4)	
Outings frequency (times/wk)			0.002*
0–1	50 (49.0)	7 (16.7)	<0.001*
2–3	20 (19.6)	9 (21.4)	0.804
4–6	18 (17.6)	11 (26.2)	0.245
7–9	7 (6.9)	6 (14.3)	0.158
10 or more	7 (6.9)	9 (21.4)	0.012*
Travel with oxygen (times/y)	0.3 ± 0.6	4.5 ± 11.1	<0.001*
Enhanced motivation to go outdoors	60 (58.8)	37 (88.1)	<0.001*
Pattern of oxygen use			0.006*
Rest, activities, and sleep	82 (80.4)	33 (78.6)	0.804
Rest only	1 (1.0)	0 (0.0)	0.520
Activities only	1 (1.0)	5 (11.9)	0.003*
Sleep only	8 (7.8)	0 (0.0)	0.062
Rest and activities	0 (0.0)	2 (4.8)	0.027*
Rest and sleep	6 (5.9)	1 (2.4)	0.375
Activities and sleep	4 (3.9)	1 (2.4)	0.646
Oxygen flow rate at rest[a]	2.5 ± 1.3	2.8 ± 1.7	0.426
Oxygen flow rate at sleep[b]	2.5 ± 1.2	2.8 ± 1.5	0.364
Factors that limit going outdoors			0.001*
None	15 (14.7)	9 (21.4)	0.325
Not enough oxygen supply time	31 (30.4)	14 (33.3)	0.729
Not enough cylinders	2 (2.0)	0 (0.0)	0.361
Oxygen too heavy	33 (32.4)	6 (14.3)	0.027*
Two of the above	9 (8.8)	13 (31.0)	<0.001*
All three of the above	12 (11.8)	0 (0.0)	0.020*

Data are represented as n (%) or mean ± standard deviation.
*$p < 0.05$. LOG = liquid oxygen group; OCG = oxygen concentrator group.
[a] Number of patients in OCG:LOG = 88:26.
[b] Number of OCG:LOG = 100:31.

in PR during the walking test, even when their RPR had been higher. In addition, compared with OCG patients, our LOG patients with COPD experienced no change in resting oxygen saturation or sensation of breathlessness. We tested walking status by measuring walking time rather than walking distance because we could not measure distances accurately in the patients' homes. Nonetheless, the changes in PR we observed during the 2MWT may provide a reliable clinical measure of exercise performance in patients with moderate to severe COPD.[19] Thus, we surmised that patients may increase their activity levels and use of oxygen when provided with liquid oxygen.[10]

Leach et al[25] conducted a prospective, randomized multicenter trial comparing oxygen concentrators with

Table 4 Analysis of covariance in patients with home oxygen ($n = 144$).

Factors (df)/outcomes	Oxygen usage (h/day)		Outings frequency (times/wk)		Travel with oxygen (times/y)		Enhanced motivation to go outdoors	
	F value	p value	F value	p value	F value	p value	F value	p value
MRC scale rating (1/133)	7.268	0.008*	10.334	0.002*	1.272	0.261	1.810	0.181
Ventilator usage (1/133)	0.041	0.839	0.573	0.451	0.125	0.724	0.026	0.872
Tracheostomy (1/133)	45.152	<0.001*	6.258	0.014*	0.000	0.989	2.581	0.111
Diagnosis (5/133)	1.762	0.125	0.468	0.800	1.462	0.207	2.678	0.024*
Education (1/133)[a]	1.852	0.176	0.921	0.339	1.993	0.160	0.075	0.784
Liquid oxygen (1/133)	41.331	<0.001*	16.911	<0.001*	7.308	0.008*	2.389	0.125

Education was divided into two levels: "University or college" and "lower than university". * $p < 0.05$. MRC = Medical Research Council.
[a] Education was divided into two levels: "University or college" and "lower than university".

Table 5 Two-minute walking test of patients with COPD.

Item	OCG ($n = 51$)	LOG ($n = 19$)	p value
Characteristics			
Age (y)	62.6 ± 15.2	69.3 ± 9.4	0.077
Sex M/F	25/26	13/6	0.147
Height (cm)	160.6 ± 9.6	160.6 ± 6.5	0.981
Weight (kg)	55.3 ± 14.6	52.0 ± 9.5	0.370
Ventilator usage	34 (66.7)	7 (36.9)	0.024*
Tracheostomy	11/51 (21.6)	1/19(5.3)	0.108
MRC scale rating	3.3 ± 1.2	3.1 ± 0.9	0.525
Response			
Oxygen flow rate (L/min)[a]	3.0 ± 1.2	2.6 ± 1.7	0.260
Rest SpO_2 (%)	94.6 ± 2.8	94.3 ± 2.3	0.668
Exercise SpO_2 (%)	88.8 ± 5.3	88.4 ± 5.0	0.738
ΔSpO_2 (%)[b]	-5.8 ± 4.2	-6.0 ± 4.7	0.888
Rest PR (beats/min)	83.8 ± 12.7	94.2 ± 15.8	0.006*
Exercise PR (beats/min)	102.8 ± 13.6	102.1 ± 17.7	0.843
ΔPR (beats/min)[b]	19.1 ± 9.7	7.8 ± 5.5	<0.001*
Rest Borg	2.9 ± 1.1	3.0 ± 1.4	0.850
Exercise Borg	5.7 ± 1.9	5.3 ± 1.8	0.430
ΔBorg[b]	2.7 ± 1.6	2.3 ± 1.5	0.286

Data are represented as n (%) or mean $\pm$ SD. *$p < 0.05$.
COPD = chronic obstructive pulmonary disease; LOG = liquid oxygen group; MRC = Medical Research Council; OCG = oxygen concentration group; PR = pulse rate; SpO_2 = oxygen saturation.
[a] Oxygen flow rate during walking.
[b] Δ = change in score (exercise score minus rest score).

liquid oxygen during a 6-month period. The results showed significant differences in favor of the liquid oxygen group in the following categories or dimensions: physical function, ambulation, social interaction, and total Sickness Impact Profile (SIP) score.[25] Our findings also showed that liquid oxygen increases patients' activity at home; a higher percentage of LOG patients used ambulatory oxygen during both rest and activity. However, the difference between the LOG and OCG for total duration of time spent outdoors did not reach a level of significance in our study.

A European 8-week, double-blind, placebo-controlled study using cylinder oxygen versus cylinder air suggested that ambulatory oxygen appears to enhance activities, and that patients need time to learn how to use an oxygen cylinder.[26] It suggested that patients are likely to benefit from using ambulatory oxygen after they have learned of the cylinder. Our findings that LOG patients went out of the home more and traveled more were consistent with these suggestions. However, ambulatory devices such as small gas cylinders and battery-powered compact concentrators are available for OCG patients to use in vehicles or outdoors. Such substitutes might explain our finding that both LOG and OCG patients spent similar lengths of time outdoors.

A study conducted with limited data from the French ANTADIR registry advocates the use of liquid oxygen for selected patients who wish to be mobile.[8] In the United States, a liquid oxygen system is used to improve patient's mobility.[27] We compared our data to those of a 1991–1992 home oxygen therapy study among US Medicare beneficiaries. [23] In our study, 6.9% of patients (10 of 144) used liquid oxygen only, which was slightly lower than the 9.5–13.9% of patients reported by Medicare.[23] We believe the cost of liquid oxygen in northern Taiwan is a determining factor in such decisions. Fewer of our participants used portable systems (50 of 144 used 42 liquid and 8 cylinder, 34.7%) compared with Medicare participants (58%), and more of our participants used only a concentrator (92.2% vs. 80%).[23] Although cultural beliefs and reimbursement fees for oxygen differ between the United States and Taiwan, the characteristics of study participants in our study may have been similar to those reported by Leach et al.[25] They found that liquid oxygen use was associated with people who lived in nonmetropolitan areas and tended to be white collar workers, whereas we found that liquid oxygen users tended to have higher educational levels, and were usually married.

Table 6 Analysis of covariance in patients with COPD ($n = 70$).

Factors (d.f.)/ outcomes	Rest pulse rate		ΔPR (beats/min)	
	F value	p value	F value	p value
MRC scale rating (1/65)	3.424	0.069	0.306	0.582
Ventilator usage (1/65)	1.578	0.213	0.990	0.323
Tracheostomy (1/65)	0.092	0.763	1.016	0.317
Liquid oxygen (1/65)	11.521	0.001*	21.661	<0.001*

* $p < 0.05$.
COPD = chronic obstructive pulmonary disease; ΔPR = exercise pulse rate minus rest pulse rate; MRC = Medical Research Council.

Limitations

Our study had several limitations. First, we did not have access to data on the patients' initial arterial blood gas analysis; hence, we presumed that all our participants met the criteria for long-term oxygen therapy. Second, we used the 2MWT to compare the beneficial effects of ambulatory oxygen administered either in liquid form or through a concentrator. However, the 2MWT did not test the real-life tolerability of oxygen devices for portability and ambulatory design.[28,29] Therefore, we had insufficient evidence to draw firm conclusions about the efficacy of liquid oxygen. Third, the possible influence of the cost of different types of oxygen supply and the patients' home environments was not studied, and further investigation of both these factors is needed. Fourth, the acuity level of patient condition differs between LOG and OCG. Thus, selection bias may have played a role when physicians decided which type of oxygen therapy to prescribe for their patients.

Conclusion

Patients using liquid oxygen went out of the home more often and demonstrated longer periods of daily oxygen use compared with patients using concentrators. Our findings for pulse rate change suggested that an ambulatory supply of portable liquid oxygen may enhance the domiciliary walking of patients with COPD. We recommend that health care practitioners consider ambulatory liquid oxygen for patients who want to be active and for patients seeking the benefits of physical reconditioning.

Acknowledgments

This study was supported by operating grants from Taipei Medical University-Shuang Ho Hospital. The authors wish to thank Canadian Respiratory Rehabilitation consultant Kenneth Tin for evaluating the questionnaire, and the home care nurse Wang Chiang-Yi for her tender support of patients.

Appendix

Home Oxygen Questionnaire

Section I: Personal Information

1. Age: _____

2. Height: _____ cm

3. Weight: _____ kg

4. Sex: ☐ Female ☐ Male

5. What was your primary diagnosis for oxygen treatment? (Your answer should be consistent with what you were told by your doctor. Please assist the interviewer to categorize your diagnosis.)
   ☐ Restrictive lung disease ☐ Neuromuscular disease ☐ Cardiovascular disease
   ☐ Cancer ☐ Chronic airway disease ☐ Interstitial lung disease

6. Your educational background:
   ☐ None ☐ Elementary School ☐ Junior High school
   ☐ High School or vocational school ☐ Junior college ☐ College or University or higher

7. Marital status: ☐ Single ☐ Married ☐ Divorced ☐ Widowed

8. Children: ☐ Yes ☐ No

9. Who is your main caregiver?
   ☐ Parent(s) ☐ Spouse ☐ Children ☐ Relatives ☐ Hired nurse
   ☐ Friends ☐ None

Section II: Respiratory Care Details

1. How long have you been receiving oxygen therapy? _____ month(s)

2. If any, what type of ventilator are you using? (Please help the interviewer identify the type of ventilator.)
   ☐ Noninvasive ventilation ☐ Invasive ventilation ☐ None

3. Do you have a tracheotomy? ☐ Yes ☐ No

4. What interface is used in your oxygen usage?
   ☐ Nasal cannula ☐ Simple mask ☐ Tracheal mask ☐ Nasal cannula and mask ☐ Demand flow trigger cannula ☐ None

5. Do you have an oximeter set up at home? ☐ Yes ☐ No

6. What do you think of medical professionals providing site services to you on a regular basis?
   ☐ Extremely necessary ☐ Necessary ☐ It depends ☐ Not necessary ☐ Useless/Extra charge

Section III: Daily Activities Using a Portable (Ambulatory) Oxygen Device

1. MRC level related to daily activities:
(1) I only get breathless with strenuous exercise
(2) I get shortness of breath when hurrying on level ground or up a slight hill
(3) I walk slower than people of the same age on level ground because of breathlessness, or have to stop to breathe when walking at my own pace on level ground
(4) I stop for a breath after walking 100 yards or after a few minutes on level ground
(5) I am too breathless to leave the house

2. How many hours per day do you use oxygen equipment? _ hours

3. How long do you usually go out in a day?
☐ None ☐ Less than 4 hours ☐ 4~8 hours ☐ 8~12 hours

4. How often do you go out in a week?
☐ None or once a week ☐ Twice or three times ☐ 4~6 times ☐ 7~9 times
☐ 10 times or more

5. How many times a year do you travel with oxygen equipment? _ times

6. If possible, would you go out more often in the future? ☐ Yes ☐ No

7. What factors relating to your oxygen equipment restrain you from going out?
☐ No restrictions ☐ Short duration of oxygen supply
☐ Insufficient number of cylinders ☐ Heaviness of the equipment

8. Based on your daily life, please write down specific information related to your oxygen usage.

Oxygen type / Daily life	Liquid oxygen	Oxygen concentrator	Oxygen cylinder
Doing activities	(l/m)	(l/m)	(l/m)
Taking a rest	(l/m)	(l/m)	(l/m)
Sleeping	(l/m)	(l/m)	(l/m)

9. I'm willing to walk for 2 minutes in the room wearing my oxygen device.
☐ Yes ☐ No

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