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Selecting a Suitable Portable Oxygen Carrier for Patients with Moderate to Severe Chronic Obstructive Pulmonary Disease: Difference between a Cylinder Cart and Backpack

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Abstract

Background: Long-term oxygen therapy, including ambulatory oxygen, has been widely used for patients with COPD having chronic respiratory failure. However, factors important for selecting suitable carriers of ambulatory oxygen, such as a cylinder cart or backpack, remain unclear for patients with moderate-to-severe COPD.

Methods: Twelve patients with moderate-to-severe COPD (mean age, 69.6 ± 7.3 years) performed a six-minute walk test (6MWT) with a cylinder cart and backpack in random order. The parameters of 6MWT with each carrier, pulmonary function test results, and a questionnaire about the preference of each carrier after 6MWTs were analyzed.

Results: The Δ distance (distance walked with a backpack - that waked with a cylinder cart) positively correlated with FEV_1 (r=0.678, P=0.02) and lung diffusing capacity for carbon monoxide (D_{LCO}) (r=0.606, P=0.048). Patients who could walk longer with a backpack were significantly higher in FEV_1 (1.3 ± 0.8 *vs.* 0.8 ± 0.1 L, P=0.040) and D_{LCO} (13.6 ± 2.1 *vs.* 8.2 ± 3.3 ml/min/mmHg, P=0.02) than those who walked longer with a cylinder cart. Additionally, patients who could walk longer with a backpack showed a lower maximum pulse rate and pulse rate after 6MWT than those who walked longer with a cylinder cart. Further, patients who preferred a backpack were significantly higher in percentage of predicted FVC (%FVC; 94.4 ± 17.2 *vs.* 65.5 ± 11.6% P=0.02) and lower in residual volume (2.7 ± 0.8 *vs.* 4.0 ± 0.6 L, P=0.042) than those who preferred a cylinder cart.

Conclusions: FEV_1, D_{LCO}, and pulse rate during and/or after 6MWT can be important factors in the selection of proper ambulatory oxygen transport carriers for greater exercise capacity in patients with COPD having chronic respiratory failure.

Keywords: Long-term oxygen therapy; Portable oxygen cylinder; COPD; Transport carrier; Pulmonary function; Pulse rate

Introduction

Long-term oxygen treatment (LTOT) has shown to increase survival in patients with COPD having chronic respiratory failure [1,2]. It also appears to improve the health-related quality of life [3,4], increase exercise capacity [5], and reduce the number of hospitalizations in patients with COPD [6]. To obtain the maximum benefits of LTOT, patients with COPD are required to use their ambulatory oxygen systems at all times, even when outside [1,2,7]. Therefore, ambulatory oxygen therapy is a common component of LTOT to maximize the number of hours per day of receiving oxygen as well as to maintain physical activity [2]. Currently, LTOT users may choose among several portable oxygen devices (e.g., portable oxygen cylinders, portable oxygen concentrators, and liquid oxygen) and/or different transport carriers (e.g., cylinder cart, backpack, and shoulder bag). However, little is known about how to select a suitable ambulatory oxygen carrier for each patient with COPD having chronic respiratory failure.

Previous studies have suggested that differences among cylinder transport carriers affect the patient's functional performance Pohle-Krauza et al. showed that the distance walked with a backpack was longer than that walked with a cylinder cart or shoulder bag in patients with COPD [8]. In other studies on LTOT for COPD, Crisafulli et al. showed that patients with severe COPD could walk longer with a cylinder cart than those with a shoulder bag [9,10], while healthy controls could walk longer with a shoulder bag than with a cart [10]. These results indicate that differences among ambulatory oxygen carriers can affect that patient's performance in daily life. In addition, a proper carrier may depend on the pulmonary function of LTOT user. Moreover, lung hyperinflation adversely impacts cardiac function by reducing the right ventricular pre-load, and in some cases, by increasing left ventricular-afterload in patients with COPD [11-13]. Cardiovascular function is also known to affect exercise intolerance in COPD [14]. However, the pulmonary or cardiovascular factors that are useful for selecting suitable ambulatory oxygen carriers in each patient remain unclear. The aim of the present study was to elucidate the factors that are important for selecting suitable transport carriers of oxygen cylinder in patients with moderate-to-severe COPD.

Materials and Methods

Patients

Consecutive inpatients or outpatients with COPD who participated in pulmonary rehabilitation at Chiba University Hospital between October 2011 and September 2013 were recruited. The diagnosis of COPD was made in accordance with the Global Initiative for Chronic Obstructive Lung Disease [7]. Eligible patients were in stable condition with no evidence of acute exacerbation during the past 3 months. Patients with heart failure, orthopedic or neurological disorders, obesity (body mass index >30 kg/m^2), lung cancer, or active lung disease other than COPD were excluded from the present study. Patients who were unable to complete a six-minute walk test (6MWT) because of their walking instability or their incomprehension were also excluded.

Study design

Patients performed 6MWT with a cylinder cart or backpack and then performed another 6MWT using the other carrier on the same day. The order of carrier testing was randomly assigned. All patients were tested by the same physiotherapist. A compressed oxygen cylinder (V2.1, TEIJIN Corporation, Osaka, Japan) and nasal cannula with a cylinder cart or backpack were used as transport carriers (Figure 1). The cylinder cart has two wheels and is used by pulling and weighs 4.2 kg (combined weight of cart, oxygen cylinder, and synchronizer). The backpack is used by carrying on the back and weighs 3.8 kg (combined weight of backpack, oxygen cylinder, and synchronizer).

The oxygen setting during 6MWTs (oxygen flow, continuous or intermittent use) was in accordance with that prescribed by the patient's attending physician if patient was already on LTOT. If the patient had not started LTOT, they carried out 6MWTs on room air. After the patients had completed 6MWTs with the two carriers, they answered a questionnaire, which included the following two questions: (1) "Which carrier do you prefer as the transport carriers for portable oxygen cylinder?" and (2) "Why do you prefer the carriers?"

The study was approved by the Human Ethics Review Committee of Chiba University Graduate School of Medicine (approval no. 1259), and patients provided their written informed consent prior to participation.

Pretest evaluations

The baseline measurements included age, sex, body mass index, and percentage of ideal body weight. Pulmonary function was assessed using a spirometer (CHSTAC-8900; Chest MI Corp, Tokyo, Japan) according to the method described in the American Thoracic Society 1994 update [15].

6MWT

6MWT was performed according to published guidelines [16]. In the present study, both tests were performed indoors in a corridor (30 m in length), under quiet conditions. All patients completed at least one 6MWT before data collection was started to avoid learning effects [16].

Oxygen saturation and pulse rate were monitored during 6MWT by means of a finger probe pulse oximeter (Pulsox-300i; Minolta, Tokyo, Japan). If the oxygen saturation fell to below 80%, 6MWT were terminated. We recorded the six-minute walking distance (6MWD) using both cylinder cart and backpack. We also recorded the 10-point-modified Borg scale score before and after 6MWT.

Figure 1: Transport carriers for oxygen cylinder. A: A cylinder cart, which is used by pulling, weighs 4,200 g. B: A backpack, which is used by carrying on the back, weighs 3,800 g.

Statistical analysis

The data are presented as mean ± SD. To identify differences between two carriers in each patient, a paired sample t-test was used. When the data were not normally distributed, a Wilcoxon signed-rank test was used. Pearson product-moment correlation coefficient was used to evaluate the relationship between Δ distance (distance walked with backpack – that walked with cylinder cart) and age, physical parameters, and pulmonary function parameters. When a parameter was not normally distributed, Spearman's rank correlation was used.

Then, patients were divided according to which carrier resulted in a longer walk distance. Additionally, patients were divided according to the preference of each carrier as reported after 6MWTs. The statistical significance of differences between groups was assessed with Student's t test if the data were normally distributed, and its variance was equal as determined by an F test and otherwise with Mann–Whitney U-tests. A value of $P<0.05$ was considered to be statistically significant. All analyses were carried out with the JMP10.0 software program (SAS institute, Cary, NC, USA).

Results

Study population and 6MWT parameters

We included 12 patients with moderate-to-severe COPD in the present study (Global Initiative for Chronic Obstructive Lung Disease stage I, n=0; stage II, n=2; stage III, n=3; stage IV, n=7). Baseline characteristics of the present study are shown in Table 1. Three patients (25%) had received LTOT for at least 4 months, four patients (33%) were just prescribed LTOT, and the others (42%) were not currently on LTOT. All seven patients on LTOT were using a cylinder cart. The prescribed mean oxygen flow rate was 1.8 L at rest and 1.9 L during exercise. Results of 6MWT parameters are shown in Table 2. There

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were no significant differences in 6MWD, lowest oxygen saturation, maximum pulse rate, and Borg dyspnea index during 6MWT between using the cylinder cart and the backpack.

Characteristics	**Testing group**
Patients, n	12
Females/males, n	0/12
Age, years	69.6 ± 7.3
Height, cm	166.8 ± 6.8
Weight, kg	58.4 ± 7.5
BMI, kg/m^2	21.1 ± 3.3
%IBW, %	96.0 ± 15.2
GOLD classification of lung disease (I/II/III/IV), n	0 /2/3/7
Smoking, pack-yeas	85.5 ± 39.7
VC, liters	3.0 ± 0.8
VC, % predicted	82.3 ± 18.4
FVC, liters	2.7 ± 0.7
FVC, % predicted	76.7 ± 18.4
FEV_1, liters	1.0 ± 0.4
FEV_1, % predicted	36.4 ± 15.1
FEV_1/FVC, %	39.1 ± 15.2
D_{LCO}, mL/min/mmHg	9.0 ± 4.0
D_{LCO}, % predicted	57.8 ± 27.7
RV, liters	3.4 ± 0.9
RV, % predicted	162.4 ± 38.7
RV/TLC, %	51.5 ± 10.5
RV/TLC, % predicted	135.2 ± 24.0

Table 1: Baseline characteristics of the subjects. Data are presented as n (%), or mean ± SD. BMI, body mass index, %IBW, Percentage of ideal body weight; D_{LCO}, lung diffusing capacity for carbon monoxide; RV, residual volume; TLC, total lung capacity.

Outcomes	**Backpack**	**Cylinder cart**	**P value**
6-minute walking distance, m	355.2 ± 107.9ta	357.4 ± 100.9	0.76
PR at rest, beat/min	85.3 ± 16.4	82.5 ± 15.4	0.09
PR after 6MWT, beat/min	109.5 ± 14.3	108.7 ± 15.4	0.78
Maximum PR, beat/min	112.9 ± 12.2	111.4 ± 13.9	0.49
SpO_2 at rest, %	95.2 ± 1.9	95.8 ± 1.8	0.11
SpO_2 after 6MWT, %	84.9 ± 5.7	85.8 ± 5.7	0.47
Lowest SpO_2 during 6MWT, %	84.0 ± 5.8	84.7 ± 5.3	0.76
Dyspnea at rest, Borg score	0.2 ± 0.3	0.2 ± 0.2	1
Dyspnea after 6MWT, Borg score	4.3 ± 1.7	3.7 ± 1.9	0.24

Table 2: All outcome using backpack or cylinder cart during 6MWT. Data are presented as mean ± SD. Differences calculated using Wilcoxon test and t-test. 6MWT, 6-minute waling test, PR, pulse rate.

The relationships between Δ distance and age, physical parameters, and pulmonary function

We next assessed the associations between Δ distance and age, body weight, height, and pulmonary function. There were no correlations between Δ distance and age, body weight, or height (data not shown). However, Δ distance positively correlated with FEV_1 (r=0.678, P=0.02) and lung diffusing capacity for carbon monoxide (D_{LCO}) (r=0.606, P=0.048; Figure 2). Although the difference was not statistically significant, there were positive tendency of correlation between Δ distance and FEV_1/FVC (r=0.536, P=0.073) and negative correlation between Δ distance and residual volume/total lung capacity (RV/TLC) (r= –0.580, P=0.062).

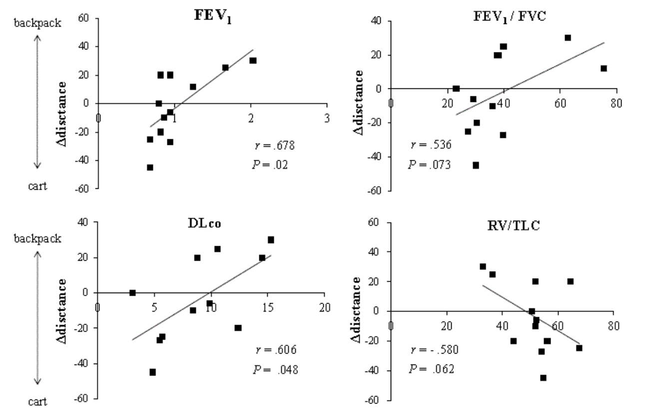

Figure 2: Correlation between Δ distance during 6MWT and pulmonary functions (FEV_1, FEV_1/FVC, D_{LCO}, RV/TLC) in COPD. Pearson product-moment correlation coefficient or Spearman's rank correlation coefficient was used for analysis. 6MWT, six-minute walk test; D_{LCO}, lung diffusing capacity for carbon monoxide; RV, residual volume; TLC, total lung capacity.

The effect of oxygen carriers on 6MWD

The impact of pulmonary function on 6MWD using different oxygen carriers is shown in Figure 3. The patients who could walk longer with a backpack were significantly higher in FEV_1 (1.3 ± 0.8 *vs.* 0.8 ± 0.1 L, P=0.040), FEV_1/FVC (50.8 ± 17.4 *vs.* 30.8 ± 5.5%, P=0.01), and D_{LCO} (13.6 ± 2.1 *vs.* 8.2 ± 3.3 ml/min/mmHg, P=0.02) than the patients who could walk longer with a cylinder cart. There was no difference in RV/TLC between the groups (45.8 ± 14.4 *vs.* 54.8 ± 6.8%, P=0.18). The impact of pulse rate of 6MWD with different oxygen carriers during 6MWT is shown in Figure 4. The patients who could

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walk longer with a backpack had significantly lower pulse rates after 6MWT (99.8 ± 9.2 *vs.* 116.4 ± 13.6 bpm, P=0.039) and maximum pulse rate (102.4 ± 7.6 *vs.* 120.4 ± 8.8 bpm, P<0.01) than the patients who could walk longer with cylinder with cart. Pulse rate before 6MWT tended to be lower in patients who walked longer with backpack than those with a cart, but this difference was not significant (74.8 ± 8.3 *vs.* 92.9 ± 16.9 bpm, P=0.054).

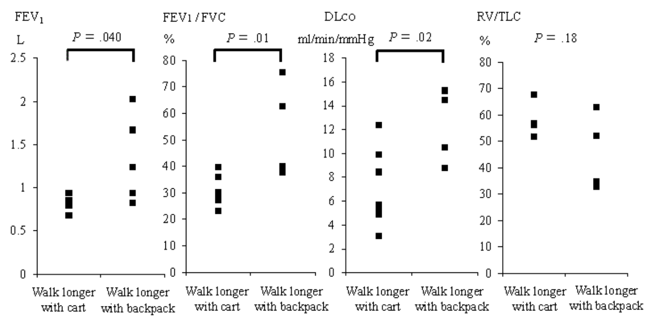

Figure 3: FEV_1, FEV_1/FVC, D_{LCO}, and RV/TLC between patients who walk longer with a cart and backpack during 6MWT. The parameters were compared using Mann-Whitney U test, P<0.05 was obtained for the comparison between two groups. *P<0.05. 6MWT, six-minute walk test; D_{LCO}, lung diffusing capacity for carbon monoxide; RV, residual volume; TLC, total lung capacity.

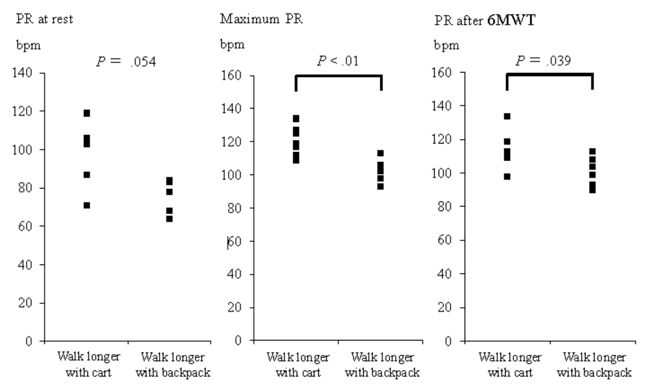

Figure 4: Pulse rate during 6MWT between patients who walk longer with a cart and a backpack. PR, pulse rate, 6MWT, six-minute walk test. The parameters were compared using Mann–Whitney U test, P<0.05 was obtained for the comparison between two groups. *P<0.05.

The questionnaire regarding preference for each carrier

A summary of the questionnaire administered after two 6MWTs is shown in Figure 5. Four patients who preferred backpack were significantly higher in %FVC (94.4 ± 17.2 *vs.* 65.1 ± 11.6%, P=0.02) and lower in RV (2.7 ± 0.8 *vs.* 4.0 ± 0.6 L, P=0.042) than five patients who preferred the cylinder cart.

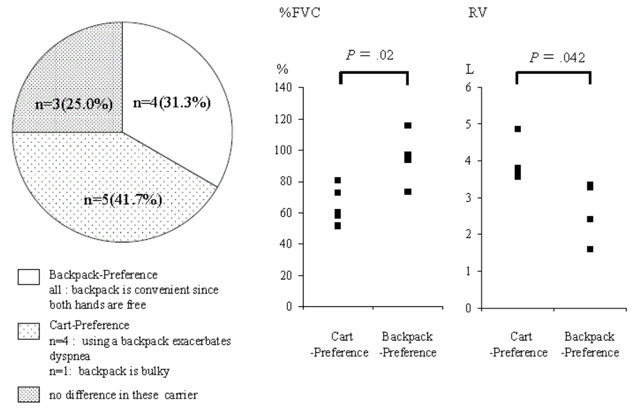

Figure 5: Summary of the questionnaire after two 6MWTs and %FVC and RV between patients who prefer a cylinder cart and backpack. The parameters were compared using Mann–Whitney U test, P<0.05 was obtained for the comparison between two groups. *P<0.05. 6MWT, six-minute walk test; %FVC, percentage of FVC, RV, residual volume

Discussion

In this study, we demonstrated the important findings regarding selection of a suitable ambulatory oxygen cylinder transport carrier for patients with moderate-to-severe COPD. Patients with modestly maintained FEV_1 and D_{LCO} and lower pulse rate during and after 6MWT were able to walk longer when using backpack, even with moderate-to-severe COPD. Conversely, patients with COPD having opposite parameters were able to walk longer when using a cylinder cart. This result suggested that the combination of airflow limitation and diffusing capacity and cardiovascular function quantified by post-test and maximum pulse rate may be potential factors in selecting a suitable ambulatory oxygen carrier for patients with moderate-to-severe COPD.

Recently, some studies have reported the influence of the cylinder transport carrier on a COPD patient's performance of 6MWT [8-10]. These studies implied that a proper carrier has an important effect on the patient's performance but may differ according to study population, which is related to variations in pulmonary function. Moreover, another previous study [14] showed that resting pulse rate increases with severity of COPD and is also associated with exercise capacity in patients with COPD. Therefore, the relationship between these parameters (e.g., pulmonary function and pulse rate) and oxygen carriers was analyzed to elucidate which factors are important for selection of a suitable oxygen carrier to maximize patient's performance. Our results revealed that differences in patient's performance using different oxygen transport carriers may depend on air flow limitation, diffusing capacity, and post-test and maximum pulse rates.

In COPD, airflow limitation resulted in dynamic hyperinflation, which is closely associated with exertional dyspnea and is a main contributor to exercise intolerance in COPD [7]. Previous studies reported that the relationship between airflow limitation quantified by FEV_1 and 6MWD was stronger in more severe disease [17,18]. Additionally, lower D_{LCO} in COPD was reported to reflect the reduction of alveolar–capillary gas transfer due to emphysema [7,19], indicating that low D_{LCO} contributes to exercise intolerance in COPD. Other studies have reported that low D_{LCO} is associated with decreased 6MWD in ex-smokers with normal spirometry [20] and patients with COPD [21]. Therefore, our findings that air flow limitation and diffusing capacity affect the choice of portable oxygen carrier for patients with moderate-to-severe COPD are compatible with previous reports.

Pulse rate in COPD has been reported to be significantly higher both at rest and during exercise compared with healthy people [22]. It is also reported that resting pulse rate in patients with COPD increases with degree of airflow severity [23]. In these studies, higher pulse rate is considered to be caused by mainly hypoxia [24] and lower cardiac output [25]. Emphysema and severe airflow obstruction were related to left ventricular filling, reduced stroke volume, and lower cardiac output [25], which result in an increased pulse rate for maintaining cardiac output. Moreover, another study [14] also reported that a higher resting pulse rate is associated in patients with severe COPD, and it also independently associated with exercise capacity in patients with COPD. In our study, although the difference was not statistically significant, resting pulse rates tended to be lower in patients who walked longer with a backpack than those with a cart, and pulse rate after 6MWT and maximum pulse rate were significantly lower in the patients who walked longer with a backpack than those with a cart. This observation emphasizes that cardiovascular state reflected in pulse rate affects the choice of portable oxygen carrier for the patients with moderate-to-severe COPD.

For proper interpretation of our findings, distinctive features of each carrier should be considered. First, carrying a backpack might negatively influence the patient's lung function and attenuate the patient's performance. Previous studies [26-28] reported that when patients use a backpack, the load of weight and tightness of fit induces respiratory muscle fatigue and restrictive impairment in healthy subjects. Second, using a cylinder cart may assist and reduce the burden in patients with severe COPD. Past studies [9,10,29] showed that patients with COPD improved walking distance when using a cylinder cart. Walking while a pulling cart allows the patients to stabilize their arms, which in turn allows their arm and shoulder muscles to assist respiration efficiently [9]. Third, using a cylinder cart may interfere with walking in patients with COPD having relatively maintained pulmonary and cardiovascular functions. Crasafulli et al. [10] reported that walking distance with a cylinder cart was shorter than with a shoulder bag in healthy subjects. From the results in these past reports and the present study, a cylinder cart may be more suitable for patients with COPD having severely decreased pulmonary function and greatly increased heart rate during exercise, whereas a backpack is suitable for patients with COPD having relatively maintained pulmonary functions and moderately increased heart rate during exercise.

Previous studies indicated that the benefits of LTOT are related to the average daily duration of oxygen use [1,2]. Ambulatory oxygen allows LTOT users to prolong the daily use of oxygen therapy. Nevertheless, it is known that LTOT users frequently fail to adhere to ambulatory oxygen [30-32]. The reasons for this have been reported as follows: ambulatory oxygen is too heavy to carry, fear about amount remaining in the cylinder, and embarrassment regarding appearance [33,34]. In the present study, the reported reason for backpack preference was convenience since both hands are free. Indeed, when using a cylinder cart, one hand is always pulling the cart. In addition, patients must lift the cylinder cart while they traverse stairs and uneven terrain. Especially, in some situations such as uneven terrain, shopping, and field walk, using a backpack is more convenient compared with a cart. Meanwhile, the reported reason for preferring a cylinder cart in our study was that using a backpack exacerbates dyspnea; patients who preferred the cylinder cart had significantly lower pulmonary function. Patients with COPD having severely decreased pulmonary function found the exacerbation of dyspnea outweighed the benefits of using a backpack and thereby preferred the cylinder cart. Therefore, selecting transport carriers based on pulmonary function may enable patients with COPD to improve not only their performance but also their adherence to LTOT.

Limitation

The present study had the following limitations. First, because this study was performed as a pilot study, the total number of enrolled subjects was small. Further investigation is required. Second, our study included patients who were not using LTOT even with a more than moderate grade of COPD. Third, patients' individual living environment, such as stairs and uneven terrain, was not considered in the present study. However, 6MWT was selected for this study because it is a widely accepted and reliable test to evaluate physical performance in COPD.

Conclusion

The present study demonstrates that patients with COPD having modestly maintained airflow limitation, diffusing capacity, and circulation state after 6MWT were able to walk longer when using backpack. In contrast, patients with COPD having severely decreased airflow limitation and diffusing capacity and higher pulse rate during and after 6MWT were able to walk longer when using a cylinder cart. These components of the pulmonary function should be considered when selecting a suitable ambulatory oxygen transport carrier in patients with moderate-to-severe COPD.

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