

## A Comparison of Health-Care Costs in Patients With Chronic Obstructive Pulmonary Disease Using Lightweight Portable Oxygen Systems Versus Traditional Compressed-Oxygen Systems

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**BACKGROUND:** Lightweight portable oxygen systems are commonly preferred by patients over compressed-oxygen systems that use E-size cylinders. However, cost is often perceived as a barrier to the prescription of lightweight portable oxygen systems. **OBJECTIVE:** To compare the overall health-care costs of patients with COPD who used lightweight portable oxygen systems to those who used E-cylinder systems. **METHODS:** All the patients who used either a lightweight portable oxygen system, an E-cylinder system, or an E-cylinder system, then a lightweight portable oxygen system, for at least 12 months during the study period (January 1, 1999, to December 30, 2004) were identified from the administrative database of our regional managed-care system. All direct medical utilization and costs were captured for at least the first 12 months that supplemental oxygen was dispensed. Other clinical factors that affect costs (including age, sex, ethnicity, and comorbidities) were examined and adjusted for. **RESULTS:** Of the 2,725 patients who met the inclusion criteria, 203 used only a lightweight portable oxygen system, 2,268 used only an E-cylinder system, and 254 switched from an E-cylinder system to a lightweight portable oxygen system. Among the patients who used only the lightweight portable oxygen system, the median total medical costs in the first year were nonsignificantly lower than those who used an E-cylinder system (\$6,515/y vs \$9,503/y). The cost difference remained nonsignificant after adjustment for clinical factors. Among the patients who switched from one system to the other in the first year, mean monthly health-care costs while using the lightweight portable oxygen system (\$1,428) were not significantly different than when using the E-cylinder system (\$1,396). **CONCLUSIONS:** The type of oxygen system used did not significantly affect overall cost of care in patients with COPD on long-term oxygen therapy. *Key words:* oxygen, liquid oxygen, portable, cost, utilization, chronic obstructive pulmonary disease, COPD. [Respir Care 2008;53(9):1169–1175. © 2008 Daedalus Enterprises]

### Introduction

For persons with chronic obstructive pulmonary disease (COPD) and chronic hypoxemia, supplemental oxygen is one of the only interventions that reduces mortality.<sup>1-3</sup> Fur-

thermore, in these patients, inhaling oxygen throughout the day substantially improves survival, compared to inhaling oxygen only at night.<sup>2</sup> Ambulatory oxygen improves exercise tolerance by reducing ventilatory demand, improving operational lung volumes, and relieving dyspnea,<sup>4</sup> and portable oxygen can improve the quality of life for those with chronic hypoxemia.<sup>5</sup>

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Patients who require a portable oxygen supply commonly use E-size cylinders of compressed oxygen, which usually have to be pulled along in a cart. E cylinders have an empty weight of approximately 7 kg if aluminum and > 14 kg if steel.<sup>6,7</sup> In one study, over 40% of patients

rejected use of a compressed-oxygen portable system, even though they reported improved symptoms and quality of life while using the system.<sup>8</sup> Lightweight portable oxygen systems, such as those based on liquid oxygen, have been available for several years but are not commonly dispensed.<sup>9</sup> More recently, portable oxygen concentrators have been developed that are small and light enough to be carried in a small backpack or carrying case, and some models have been approved for use on commercial aircraft. The newer lightweight portable oxygen systems have obvious practical advantages over E cylinders, and many patients who switch from E cylinders to lightweight portable oxygen systems report that they are more physically active and more satisfied with the lightweight portable oxygen systems, although this has not been rigorously studied. The cost of lightweight portable oxygen systems has fallen substantially: some liquid-oxygen-based portable units are less than \$1,000, and a portable oxygen concentrator is about \$3,000. Expert committees on long-term oxygen therapy have recommended for many years that the individual clinical and lifestyle needs of each patient be considered to make sure that the best and most appropriate portable-oxygen system is dispensed.<sup>5,10,11</sup> Nevertheless, only a small percentage of patients who need home oxygen are prescribed or dispensed a lightweight portable oxygen system. The reasons for this are unclear, but the perception that lightweight portable oxygen systems are prohibitively expensive is one barrier.

In patients with COPD on long-term home oxygen, we compared the direct medical costs among those who used lightweight portable oxygen systems and those who used E-cylinder systems, to see whether these 2 types of portable oxygen system are associated with significantly different health-care costs. Our rationale was that a comprehensive assessment of health-care costs in this population will help health-care providers and third-party payers understand how the costs of portable oxygen therapy fit within the scope of all health care services provided to these patients.

## Methods

### Study Site and Patients

All the patients were members of the Lovelace Health Plan, a regional managed-care provider based in Albuquerque, New Mexico. The Lovelace Health Plan averaged approximately 240,000 members during the study period, including its employment-based, Medicare, and Medicaid programs. For this study all Lovelace Health Plan members who had COPD and were continuously enrolled for at least 24 months during the study period (January 1, 1999, to December 31, 2004), who were between 40 and 89 years old on January 1, 1999, and had at least 11

fills over a 12-month interval were eligible. This study was approved by the Lovelace Health System's Human Research Review Committee and Office of Research Administration.

Patients with COPD were identified with the International Classification of Diseases, Ninth Revision, Clinical Modification diagnoses associated with procedure codes. Patients were required to have at least 2 out-patient encounters or one in-patient encounter during the study period associated with one of the following codes: 491.xx (chronic bronchitis), 492.xx (emphysema), or 496 (chronic airway obstruction not otherwise specified). In our previous studies of patients with COPD in the Lovelace Health Plan, wherein we validated this case-identification system by medical-record review of over 2,000 study candidates, we found that over 95% of the patients identified by this system had at least 2 types of documented objective evidence (eg, chest radiograph, pulmonary function test, detailed smoking history, or documentation of chronic symptoms) supporting the diagnosis.<sup>12</sup>

To avoid biases that might be associated with rare or catastrophic types of lung disease, we excluded all persons who ever had a diagnosis of pulmonary fibrosis, pneumoconiosis, lung cancer, or other chronic lung diseases not usually included in the diagnosis of COPD (Table 1).

### Data Capture

Portable oxygen use was identified via the Healthcare Common Procedure Coding System codes. In the Lovelace Health Plan, code E0431 identifies compressed-oxygen (E cylinder) systems, and E0434 identifies all other (lightweight portable oxygen) systems.

The first date that a patient had a Healthcare Common Procedure Coding System code for an oxygen system was designated as his or her index date. Patients were stratified into 3 categories:

- E-cylinder: those who had 11 or more codes over a 12-month period for a portable gaseous oxygen system
- Lightweight portable oxygen system: those who had 11 or more codes over a 12-month period for a lightweight portable oxygen system
- Mixed: those who had 11 or more fills over a 12-month period for an E cylinder system or a lightweight portable oxygen system, with at least one fill for each

We collected all health-care utilization and cost information for at least 12 months prior to the index date up through 24 months after the index date. Utilization data were stratified into in-patient, out-patient, and out-patient

Table 1. Diagnoses Excluded From the Study Cohort

Diagnosis*	Diagnosis Code(s)
Bronchiectasis	494.xx
Coal worker pneumoconiosis	500
Asbestosis	501
Pneumoconiosis due to other silica	502
Pneumoconiosis due to inorganic dust	503
Pneumoconiosis due to inhalation of other dust	504
Pneumoconiosis, unspecified	505
Respiratory conditions due to chemical fumes and vapors	506.xx
Respiratory conditions due to other unspecified external agents	508.xx
Post-inflammatory pulmonary fibrosis	515
Other alveolar and parietoalveolar pneumonopathy	516
Lung involvement in conditions classified elsewhere	517.xx
Other respiratory diseases	519.xx
Lung cancer (primary)	162.xx
Lung cancer (secondary)	197.0
Cystic fibrosis	277.0
Tuberculosis	010.x, 011.x, 012.x
Extrinsic allergic alveolitis	495.x
Lipoid pneumonia	507.1
Detergent asthma	507.8
Other diseases of the lung	518.x

\* Any patient who had one or more of these, either an inpatient or outpatient, at any time during the study period was excluded.

pharmacy categories. For procedure codes, costs were estimated with Medicare's cost to charge adjustments for the appropriate time period, and the average wholesale price was used to estimate the cost for every out-patient prescription fill. The cost paid by the Lovelace Health Plan for portable oxygen was \$43.50/month for either E0431 or E0434 during the study period.

Prognostically important comorbidities were identified with the Deyo modification of the Charlson index, based on out-patient diagnosis codes in the 12 months before the index date.<sup>13</sup> Ethnicity was identified with a locally developed program that uses surnames to help establish the patient's ethnicity; the program's accuracy is just over 90%.

The medical records of 100 randomly selected cases were reviewed to help validate our database for the start of oxygen therapy (the index date) and that oxygen had been used for at least 12 months. The abstraction was also conducted to obtain information on the reasons that a specific type of system was dispensed, whether it was for baseline hypoxemia or desaturation only with exercise, and to collect any pulmonary function data that were collected within 12 months of initiation of oxygen therapy.

## Statistics

Normally distributed means were compared via Student's *t* test, non-normally distributed values were compared via the Wilcoxon rank-sum test, and categorical values were compared via chi-square tests. Cost estimates in United States dollars were logarithmically converted to fit a normal distribution for comparisons. Generalized linear models were created with the PROC GLM function in the statistics software (SAS 9.13, SAS Institute, Cary, North Carolina) to adjust for clinical differences between the E cylinder and lightweight portable oxygen system cohorts. Differences with  $P < .05$  were considered statistically significant.

## Results

Of the 2,725 people in the cohort, 2,268 (83.3%) used only an E-cylinder system, 203 (7.5%) used only a lightweight portable oxygen system, and 254 (9.3%) used both (Table 2). Over a third of the total cohort was < 65 y old, but age did not appear to affect choice of portable oxygen system. Although a majority of the cohort was female, women were slightly less likely to be started on a lightweight portable oxygen system, but more women were switched to a lightweight portable oxygen system after initially getting an E-cylinder system. Hispanic persons from the study area were less likely than non-Hispanic white persons to have COPD, but those who did have COPD were also less likely to start with a lightweight portable oxygen system.

Patients who were started on lightweight portable oxygen systems were less likely to be admitted to the hospital within 12 months of the index date, but that difference was not statistically significant (see Table 2). The proportion of persons with  $\geq 22$  out-patient visits in the 12 months after the index date (which is a marker of more severe disease) was high in each group, but highest in the mixed group. The prevalence of prognostically significant comorbidities was not substantially different among the groups, as indicated by the Charlson Index scores. The prevalence of sleep apnea and heart disease (conditions that might also be indications for supplemental oxygen) was also not different.

Medical records were reviewed for a random sample of 100 patients. Of these, 79 had an E-cylinder system, 7 had only a lightweight portable oxygen system, and 14 had both types during the follow-up period, as identified from billing claims. The type of portable oxygen system the patient was using was mentioned in only 13 of the patient's medical records, and the reason for the type used was never mentioned. We did not find any cases where portable oxygen was prescribed only on the basis of desaturation with exercise. Only 76 patients had spirometry

## EFFECT OF PORTABLE OXYGEN SYSTEM TYPE ON HEALTH-CARE COSTS

Table 2. Demographic and Clinical Characteristics of the Study Cohort

	E-Cylinder Oxygen System (n = 2,268)	Lightweight Portable Oxygen System (n = 203)	Used Both Types (n = 254)	All (N = 2,725)
Mean age* (y)	68.1	67.7	69.5	68.2
Age ranges (%)				
40–65 y	37.7	34.5	29.1	36.7
66–75 y	34.7	42.4	45.3	36.2
76–90 y	27.6	23.1	25.6	27.1
Female (n and %)	1,304 (57.5)	94 (46.3)	150 (59.1)	1,548 (56.8)
Hispanic† (n and %)	538 (23.7)	25 (12.3)	54 (21.3)	617 (22.6)
Hospitalized‡ (n and %)	845 (37.3)	59 (29.1)	95 (37.4)	999 (36.7)
> 22 out-patient† encounters‡ (n and %)	1,124 (49.6)	108 (53.2)	189 (74.4)	1,421 (52.2)
> 50 prescription fills‡ (n and %)	545 (24.0)	42 (20.7)	65 (25.6)	652 (23.9)
Charlson index (mean ± SD)§	1.9 ± 1.5	1.6 ± 1.2	1.7 ± 1.5	1.8 ± 1.6
Comorbidities§				
Sleep apnea	25 (13.8)	264 (11.6)	34 (13.4)	326 (12.0)
Heart disease	42 (20.7)	547 (24.1)	56 (22.1)	645 (23.7)
Spirometry (L and % predicted)				
FEV <sub>1</sub>	1.50 (50)	0.90 (29)	1.01 (44)	1.17 (48)
FVC	2.15 (63)	1.71 (41)	2.01 (66)	2.10 (63)

\* At index date

†  $P < .05$  for difference across groups

‡ During the first 12 months after the index date

§ During the 12 months before index date

data obtained within 12 months of initiation of oxygen therapy. Those who received lightweight portable oxygen systems tended to have worse lung function, although that difference was not statistically significant (see Table 2).

### Unadjusted Total Cost Comparisons

There was no significant difference in total health-care cost per year between those who had only E-cylinder systems and those who had only lightweight portable oxygen systems. Figure 1 shows the box-plot comparisons in log-dollars for those who had E cylinder systems, those who had lightweight portable oxygen systems, and those who switched. In all the figures the box-plots illustrate the inter-quartile ranges, the median is indicated by the horizontal line, and the 5% outliers are marked by asterisks. The annual cost among those with 24 months of follow-up were not substantially different from those with just 12 months of follow-up. Patients who used E cylinders had a median total cost in the first 12 months of \$9,503 per year (interquartile range \$4,392–20,447), whereas those with lightweight portable oxygen systems had a median total cost of \$6,515 per year (interquartile range \$3,076–12,840).

There was a nonsignificant trend for older persons and those with a higher Charlson Index score to have higher costs (Figs. 2 and 3). Sex and ethnicity (Hispanic vs non-Hispanic) had no effect on cost (data not shown).

As expected, cost significantly increased as in-patient (Fig. 4), out-patient (Fig. 5), and pharmacy (Fig. 6) utili-

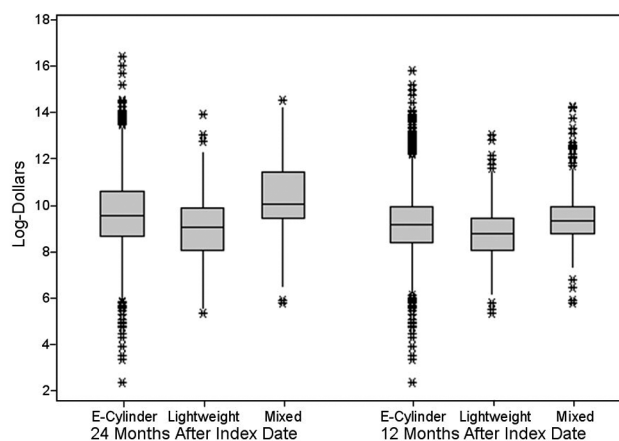


Fig. 1. Total annual health-care costs among patients with chronic obstructive pulmonary disease on home oxygen, at 24 months and 12 months after the index date, relative to type of portable oxygen system. Lightweight = lightweight portable oxygen system. Mixed = changed from E-cylinder system to lightweight portable oxygen system.

zation increased. Costs were not substantially different between the E-cylinder, lightweight-portable-oxygen, and mixed-system groups, when stratified by utilization type.

### Cost Modeling

Generalized linear models were used to adjust for differences between the E cylinder and lightweight portable oxygen system groups. Independent variables included age,



## EFFECT OF PORTABLE OXYGEN SYSTEM TYPE ON HEALTH-CARE COSTS

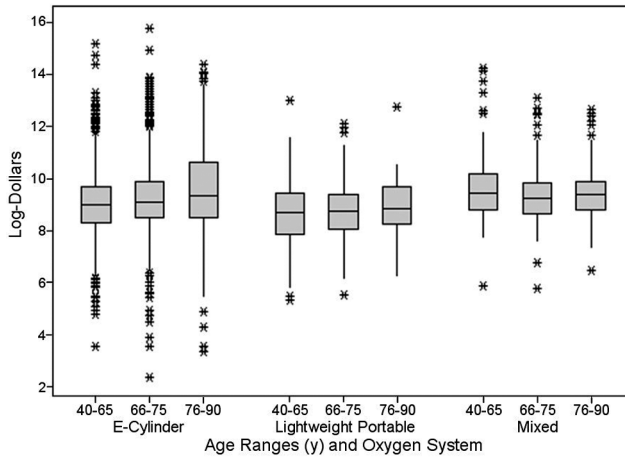


Fig. 2. Total annual health-care costs relative to age group and type of portable oxygen system. Mixed = changed from E-cylinder system to lightweight portable oxygen system.

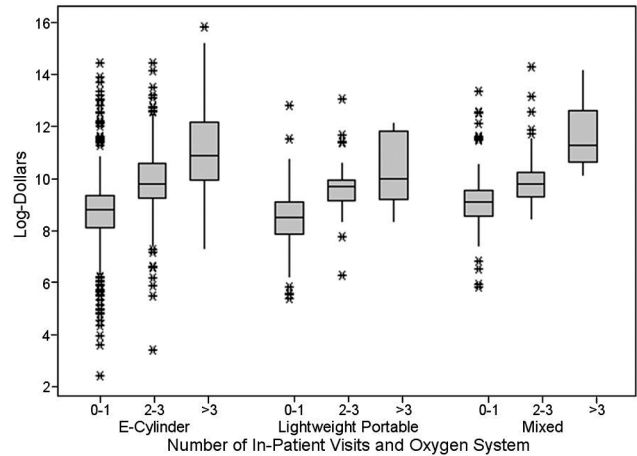


Fig. 4. Total annual health-care costs relative to number of in-patient visits and type of portable oxygen system. Mixed = changed from E-cylinder system to lightweight portable oxygen system.

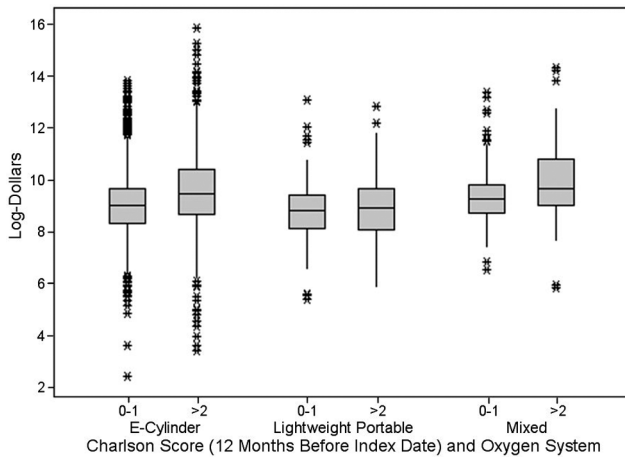


Fig. 3. Total annual health-care costs relative to Charlson Index score and type of portable oxygen system. Lightweight = lightweight portable oxygen system. Mixed = changed from E-cylinder system to lightweight portable oxygen system.

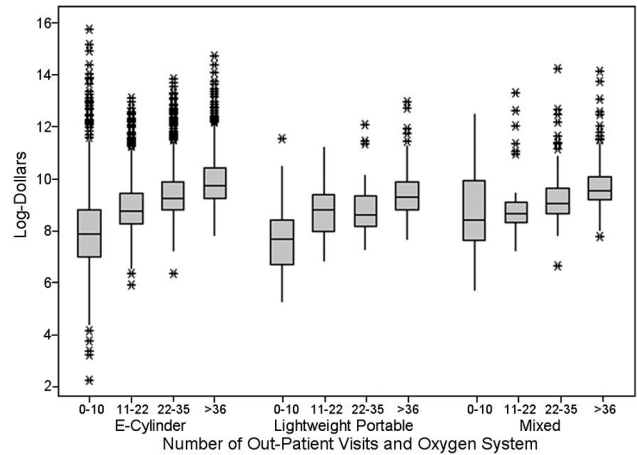


Fig. 5. Total annual health-care costs relative to number of out-patient visits and type of portable oxygen system. Lightweight = lightweight portable oxygen system. Mixed = changed from E-cylinder system to lightweight portable oxygen system.

sex, ethnicity, Charlson score, and the 3 utilization types. After controlling for the other independent variables, patients who used E cylinders had higher total costs than those who used lightweight portable oxygen systems, although the difference did not reach statistical significance. After translation from log-dollars to dollars, patients who used E-cylinder had a mean total cost of \$14,115 per year, versus \$10,625 per year for patients who used lightweight portable oxygen. This model explains about 51% of the difference in the costs in the 12-month period after the index date.

### Costs Among Patients Who Used Both Systems

For the 254 patients who used both E cylinder and lightweight portable oxygen systems, we compared their costs

per month while on either system (Table 3). The mean total cost did not substantially increase after conversion to the lightweight portable oxygen system.

### Discussion

In our study of patients with COPD who used supplemental oxygen for at least 1 year, use of a lightweight portable oxygen system was associated with lower total annual health-care costs (unadjusted mean of \$6,515 vs \$9,503 for E-cylinder systems), although the difference was not statistically significant. Older age and the presence of comorbid conditions, such as heart disease, tend to be associated with higher total costs. However, even after adjustment for clinical differences, there were still no sig-

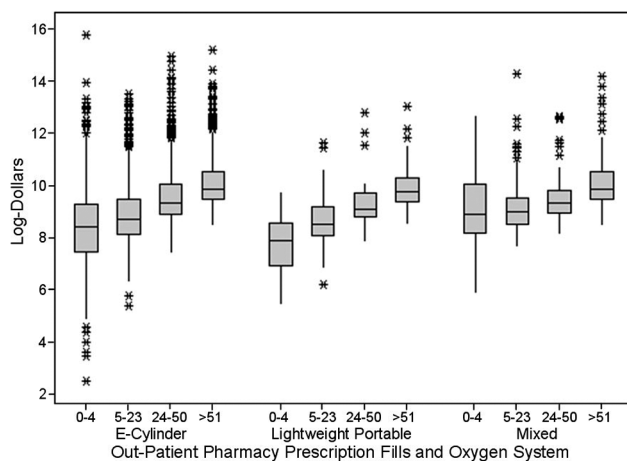


Fig. 6. Total annual health-care costs relative to number of out-patient pharmacy prescription fills and type of portable oxygen system. Lightweight = lightweight portable oxygen system. Mixed = changed from E-cylinder system to lightweight portable oxygen system.

Table 3. Mean Monthly Total Health Care Costs Among Subjects Who Switched Oxygen Systems During the First Year

Portable Oxygen System Type	Total Months	Cost per Month (mean and 95% CI \$)
E-cylinder system	6,330	1,396 (879–1,914)
Lightweight portable system	11,445	1,428 (1,201–1,655)

CI = confidence interval

nificant differences in mean total costs among the groups. Because this was not a prospective randomized study, we cannot say that this is definitive proof that lightweight portable oxygen systems have no effect on total health-care costs. However, the fact that average monthly costs did not significantly increase for patients who switched from an E cylinder (\$1,396) to a lightweight portable oxygen system (\$1,428) suggests that the type of portable oxygen system does not substantially affect total health-care costs.

The cost of portable oxygen is not negligible, but neither is it an extraordinary part of the total direct medical costs for persons on home oxygen. The Lovelace Health Plan paid an average of \$522 per year per patient for either the E cylinder or lightweight portable oxygen systems (which is greater than the average Medicare allowed payment of \$432 per year), so portable oxygen accounted for only 7.9% of average total direct medical costs for patients on lightweight portable oxygen systems and 5.4% of average total direct medical costs for patients on E-cylinder systems. Prescription medications account for approximately 11% of total health-care costs for the average patient with COPD.<sup>12</sup> Since portable oxygen is proven to

improve physical functioning and quality of life in patients with chronic hypoxemia, its cost-effectiveness is likely to compare favorably to that of prescription medications.

We did not find any consistent reasons for why some patients received a lightweight portable oxygen system, either as their initial oxygen system or as a change from an E-cylinder system. In discussions, the contracted oxygen providers noted that a lightweight portable oxygen system is dispensed only if the physician orders it or if the patient specifically requests it. The most common lightweight portable oxygen system dispensed during the study period was a liquid-oxygen carrier that weighs < 4 kg filled and has a continuous-flow device. Historically there has been a substantial economic disincentive for oxygen suppliers to offer lightweight portable oxygen systems that use liquid oxygen, which is the higher initial equipment cost and the greater number of home visits needed to refill oxygen tanks.<sup>9</sup> However, reduction in the cost of newer lightweight portable oxygen technology and the introduction of smaller refillable compressed-oxygen bottles and oxygen concentrators that are small and light enough to be carried will create a growing economic incentive for oxygen providers to encourage lightweight portable oxygen systems, especially as fuel prices and transportation costs drive up the cost of home visits.

There are some limitations to this study that should be considered, especially when comparing our results to other systems. This project was based on data from only one health-care system. Although it was comprehensive in its ability to capture an entire population and all of their direct medical costs, and it had sufficient power to detect relatively small cost differences, utilization and costs in other systems will undoubtedly be different. However, since reimbursement rates for portable oxygen systems are set by Medicare and vary little across the United States, the absolute contributions of portable oxygen systems to overall costs should be very similar. We limited this study to persons on long-term oxygen (at least 12 months of continuous therapy), so it is possible that persons who had shorter courses of treatment had a greater difference in costs. We also limited this analysis to persons with COPD, so we do not know whether these observations are true for persons who require oxygen for other lung diseases.

We found no published articles in the medical literature that compared the medical costs of patients with COPD who used lightweight portable oxygen systems to those who used traditional portable oxygen systems. In an economic study of 61 patients with COPD on long-term oxygen therapy in France, home oxygen systems averaged \$3,640 per patient per year in 1995 United States dollars (36.9% of all direct medical costs), but the relative contribution of portable oxygen in that total was not defined.<sup>14</sup> In a descriptive study of Medicare beneficiaries receiving home oxygen in 1991 or 1992, only 60% also had a por-

table system.<sup>15</sup> Of those who were given a portable system, only 19% had a liquid-oxygen-only or a gas-and-liquid system, but it is not known how many had a lightweight portable oxygen system. There was no effort to compare the expenses of patients who used different portable oxygen systems.

Several studies have demonstrated that ambulatory oxygen improves exercise capacity and reduces breathlessness,<sup>16,17</sup> but whether portable oxygen should be prescribed at all remains a controversial issue. A recent randomized crossover trial with 24 patients with COPD and hypoxemia at rest found no improvement in total daily duration of exposure to oxygen, quality of life, or exercise tolerance with administration of portable oxygen,<sup>18</sup> although the methods used in that study have been strongly criticized.<sup>19,20</sup> It is even more difficult to demonstrate the efficacy of portable oxygen in patients who have hypoxemia only with exercise.<sup>21</sup> The cost-effectiveness of the various modalities of portable oxygen will be difficult to prove until there is a better understanding of how to measure the effectiveness.<sup>10</sup>

### Conclusions

Lightweight portable oxygen systems are not associated with significantly higher total health-care costs. The cost of providing lightweight portable oxygen traditionally has not been adequately reimbursed, but advances in portable-concentrator and liquid-oxygen technology are making lightweight portable oxygen systems more practical and less expensive, and soon they may be more financially advantageous for the oxygen supplier. In the United States, Medicare currently spends over \$2 billion per year for oxygen supplies and, as the population ages and the number of patients with COPD increases, that burden will rapidly grow. Newer and less expensive lightweight portable oxygen technologies will not only provide a more practical way for patients to use portable oxygen, they may provide an opportunity for payers to help control the cost of portable oxygen therapy. Health policy makers and public health agencies should support the development and implementation of new lightweight portable oxygen technologies that may ultimately benefit patients, providers, and payers.

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