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ORIGINAL RESEARCH

Patient Use Patterns of Portable Oxygen Concentrators

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ABSTRACT

Introduction: Portable oxygen concentrators (POCs) are medical devices that provide supplemental oxygen to patients requiring long-term oxygen therapy. However, little information is available on day-to-day patterns of how or even whether patients actively switch between their POC mobility features and flow setting options.

Methods: A retrospective analysis was conducted to assess POC usage among patients who used an Inogen One G5 POC in the USA. This study aimed (1) to describe the patterns of use of POCs, (2) to analyze their compatibility with the prescribed oxygen therapy settings, and (3) to demonstrate the contribution of POC usage to get a standardized long-term oxygen therapy (LTOT). Data were directly downloaded from the devices returned for service or at the end of the Medicare Durable Medical Equipment rental period and streamed via a mobile application from 2018 to 2022. Daily usage, disconnections from the device, use of prescribed pulse delivery settings, breaths per minute, power sources, and movement with the POC were assessed. Device alert histories were also examined.

Results: Data revealed a mean daily usage of 4.29 ± 3.23 h/day, ranging from 0.35 to 15.52 h/day. The prescribed pulse delivery setting was used by 31.34% of patients for at least 80% of their POC use time. When the POC was on battery power, patients were moving/mobile 41.99 ± 33.33% of the time. On the basis of the device-generated alerts, some patients continued to use their POC very close to or even beyond the lifetime of the column/sieve bed. Alerts or alarms potentially requiring repair occurred at a rate of 1.63 events per 100 years of use, indicating that device reliability did not significantly influence the use patterns.

Conclusion: Patients used their POCs when mobile and at rest. A large proportion of patients adjust their POC settings during the day, which potentially indicates the need for the dynamic individualization of oxygen dose delivery to match activities of daily living or sleep. Patients require follow-up to ensure timely replacement of POC columns.

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PLAIN LANGUAGE SUMMARY

This study aimed to (1) describe the patterns of use of portable oxygen concentrators (POCs), (2) analyze their compatibility with the prescribed oxygen therapy settings, and (3) demonstrate the contribution of POC usage to get a standardized long-term oxygen therapy (LTOT). A retrospective analysis was conducted on data downloaded directly from devices and streamed via a mobile application. Daily usage, disconnections from the device, use of prescribed pulse delivery settings, breaths per minute, power sources, and movement with the device were assessed. Device alert histories were also examined. Patients used their portable oxygen concentrators when mobile and at rest, and large proportion of patients adjust their settings during the day. There was a low incidence of alarms or alerts requiring repairs, indicating device reliability. Patients require follow-up to ensure timely replacement of columns.

Keywords: COPD; Hypoxemia; Lung disease; Oxygen; Medical device; Oxygen therapy

Key Summary Points

Why carry out this study?

Each year, approximately 1.5 million patients in the USA receive long-term oxygen therapy.

Portable oxygen concentrators (POCs) are medical devices that provide supplemental oxygen to patients requiring long-term oxygen therapy; however, little information is available on day-to-day patterns of how or whether patients actively switch between their POC mobility features and flow setting options.

A retrospective analysis was conducted to assess usage among patients using a particular POC model (Inogen One G5) in the USA.

What was learned from the study?

Data revealed a mean daily usage of 4.29 ± 3.23 h/day, ranging from 0.35 to 15.52 h/day. The prescribed pulse delivery setting was used by 31.34% of patients for at least 80% of their portable oxygen concentrator use time. While the POC was on battery power, patients were mobile 41.99 ± 33.33% of the time.

Patients used their POC when mobile and at rest. A large proportion of patients adjust their settings during the day, which potentially indicates the need for the dynamic individualization of oxygen dose delivery to match activities of daily living or sleep. Patients require follow-up to ensure timely replacement of columns.

INTRODUCTION

Each year, approximately 1.5 million patients in the USA receive long-term oxygen therapy (LTOT) [1]. Supplemental oxygen therapy should be provided on the basis of prescriptions indicating the oxygen flow required by patients and the duration of use during the day or night. Evidence suggests that LTOT improves the survival and quality of life of patients with hypoxemia [1–5]. However, information about the patterns of usage of different oxygen therapy modalities and adherence to prescription recommendations is limited. This information is important to provide oxygen therapy users with the level of effectiveness demonstrated in clinical trials.

With LTOT often prescribed for 15 h/day or more for people with severe resting hypoxemia, ambulatory oxygen (used during exercise or activities of daily living) has long been felt to play an important role in integrating LTOT in the daily life of mobile patients by increasing exercise capacity and reducing exertional dyspnea [2]. Use of ambulatory supplemental oxygen has also been found to reduce subjective dyspnea in patients who desaturate only on exertion [6]. Portable oxygen concentrators (POCs) represent a modality of ambulatory oxygen delivery systems and meet the American Thoracic Society (ATS)-defined criteria for portable oxygen as “oxygen delivered through systems that are sufficiently lightweight so that they can be carried or pulled by patients and allow them to leave their home” [2]. This study aimed (1) to describe the patterns of use of POCs, (2) to analyze their compatibility with the prescribed oxygen therapy settings, and (3) to demonstrate the contribution of POC usage to get a standardized LTOT.

METHODS

Study Design

A retrospective analysis was conducted to assess the patterns of POC usage among Inogen One G5 users in the USA. The Inogen G5 POC has six flow settings and each setting provides an incremental increase of 210 ml/min of oxygen via pulse delivery, as a bolus triggered upon inhalation. For example, setting 1 will deliver 210 ml/min and setting 4 will deliver 4×210 ml/min or 840 ml/min. In addition, there is a three-axis accelerometer integrated into the G5 POC. The system will read and filter the raw acceleration data and will ultimately assign whether movement (mobility) is true or false. The algorithm can detect a wide range of motion scenarios and has been particularly tuned to the use of the POC with an Inogen-approved carry bag or backpack and a walking pace of between 0.5 and 2.0 miles per hour.

A cohort of 134 patients with 168 POCs during the period between 2018 and 2022 was selected on the basis of the availability of demographic, reimbursement, device download, and app-streamed data. The dataset was anonymized prior to analysis. Data were initially collected for customer support, reimbursement eligibility assessment, and device repair and maintenance. Its use for research purposes was secondary. The analysis was conducted within the framework of user agreement, authorizing Inogen to use the collected data for business purposes.

Daily and interval usage data were obtained from the downloaded device dataset. For the time of day, daily intervals were described as morning (06:00–11:59), afternoon (12:00–16:59), evening (17:00–23:59), and night (00:00–05:59).

Interruptions in POC use, pulse delivery settings, and breaths per minute (BPM) were obtained using the downloaded device datasets. Interruption in POC use was defined as the time when the POC was shut down or when BPM was recorded as 0.

Data were collected for patient BPM when the POCs were powered with either a rechargeable battery, car charger, or wall outlet.

Patient use of prescribed settings was defined as the percentage of time spent in their prescribed setting over the total time spent using the POC based on the device downloaded data. Usage of prescribed pulse dose setting at least 80% of the time in use was defined as the threshold for adherence. While debated in recent years, 80% use as instructed has been used historically as a binary adherence threshold in pharmacology-related studies [7, 8], as well as previous oxygen adherence studies, and was thus felt to be a reasonable threshold for the purposes of this study.

Mobility was assessed using the accelerometer integrated into the Inogen One G5 POC and streamed using the Connect application. Demographic data were collected from the call centers and prescription data were obtained as part of reimbursement claims processing.

Alerts were normalized per 100 POC-years (number of events divided by POC usage in years multiplied by 100) to provide an indication of alert incidence.

Institutional review board (IRB) approval was not required for this analysis since the study meets the exemption criterion of section 45 Code of Federal Regulations (CFR) 46 §46.104 (8). A limited review of the study was conducted by WGC IRB LLC and determined that the research was conducted within the scope of the broad consent referenced in paragraph (d)(8)(i) of the corresponding section of the CFR. Broad consent was obtained from subjects in compliance with the requirements of the paragraph (d)(8)(i) of the 45 CFR 46 §46.104.

Data were anonymized prior to analysis and the guidelines outlined in the Declaration of Helsinki were followed.

Data Analysis and Statistics

Data for the POCs were collected and analyzed using device-generated data. Data were generated between 2018 and 2022, and streamed data were only evaluated from August to December 2022 because of the small number of records available prior to that time. The data analysis was descriptive in nature with no inferential statistics. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

Patient Demographics

In this study, data from 134 patients and 168 devices were analyzed. POC devices were primarily used by patients residing in the USA, with a mean age of 69 ± 10.64 years. Of the patients whose data were analyzed, 69.4% were male. The majority of patients (79.9%) had a diagnosis of chronic obstructive pulmonary disease (COPD), whereas others had a diagnosis of interstitial lung disease (6.7%), COVID (3%), primary pulmonary hypertension (2.2%), congestive heart failure (1.5%), or cancer (0.7%). The demographic characteristics are presented in Table 1.

Pattern of Use of POCs

The mean POC usage was 4.29 ± 3.23 h/day. Information on the use of daily intervals and weekends/weekdays is presented in Table 2. While almost all patients used their POC during the day, only 76 used it at night. POC use was also higher on weekends than on weekdays, with mean use of 4.41 ± 3.52 h/day and 3.66 ± 3.03 h/day, respectively.

Table 1 Age, gender, diagnosis and prescribed flow setting (n = 134)

	N **(%)**
Age, years, mean ± SD	69.0 ± 10.64
Age group	
< 65	38 (28.4%)
65 to < 70	27 (20.1%)
70 to < 75	34 (25.4%)
≥ 75	35 (26.1%)
Gender	
Male	93 (69.4%)
Female	41 (30.6%)
Primary diagnosis for oxygen	
COPD	107 (79.9%)
Interstitial lung disease	9 (6.7%)
COVID	4 (3.0%)
Primary pulmonary hypertension	3 (2.2%)
Congestive heart failure	2 (1.5%)
Cancer	1 (0.7%)
Cystic fibrosis	1 (0.7%)
Obesity	1 (0.7%)
Asthma	1 (0.7%)
Hypoxemia	1 (0.7%)
Pulmonary embolism	1 (0.7%)
Polyangiitis	1 (0.7%)
Other lung disorder	1 (0.7%)
Prescribed POC flow setting	
1	1 (0.7%)
2	68 (50.7%)
3	36 (26.9%)
4	16 (11.9%)
5	3 (2.2%)
6	5 (3.7%)
2–4	1 (0.7%)
0–1, 3–4	1 (0.7%)

Table 1 continued

	N (%)
2, 3	1 (0.7%)
4, 5	1 (0.7%)
4, 5, 6	1 (0.7%)

Interruptions in POC Use Periods

Most patients (125) used their POC in several sessions during the day with a mean of 1.94 ± 1 interruptions in use (Table 2). The mean duration of these interruptions was 4.18 ± 3.35 h/day (Table 2). The mean length of interruptions segmented into daily intervals is presented in Table 4, with the least number of patients interrupting the use sessions at night (36).

Use of Prescribed Pulse Delivery Settings

The Inogen One G5 POC has six pulse delivery settings, ranging from 1 to 6. Most patients (77.6%) were prescribed a pulse delivery setting of 2 or 3. Device-generated data showed that flow rate settings 2 and 3 were the most commonly used compared to other settings (69.19% of the time) (Table 3). Although pulse delivery settings for POC are generally prescribed by physicians or healthcare providers, patients may not always maintain a single prescribed setting. Many adjust their settings on the basis of pulse oximetry measurements or subjective dyspnea. The data obtained in this study indicate that 50% of the users decreased pulse delivery settings during the day, and 46% of the users increased them. Interestingly, only 31.34% of the patients used a prescribed setting for at least 80% of POC use time (Table 4).

Because POCs deliver pulse doses of oxygen during the inhalation phase, they record the patient's breathing rate. Overall, the mean BPM was 20.29 ± 5.07, with no notable differences between daily interval groups or weekday–weekend values (Table 2).

Patient Mobility with POCs

The patients were mobile 41.99 ± 33.33% of the time while the POC was on battery power (Table 2). Power sources for POCs may provide further insight into patient mobility. Patients used their POC on a battery source 58.6 ± 45.31% of the time, a car charger 3.41 ± 16.7% of the time, and a wall outlet 38 ± 44.8% of the time. The battery and car charger may be indicative of patient mobility, displaying a higher BPM than while powered by wall outlet. The BPM was the highest on battery power (mean of 21.26), followed by car charger power with an average BPM of 20.92, and wall outlet with an average BPM of 18.30 (Table 2). In addition to being ambulatory with their POCs, some patients adjusted their flow rate settings when switching between a mobile or non-mobile status. Of the patients who changed their flow settings when switching between mobile and non-mobile, 19.8% increased their settings when going from not mobile to mobile, while 21.4% decreased their settings when going from not mobile to mobile (Table 5). Conversely, 25.4% of patients decreased their settings when going from mobile to not mobile, while 22.2% of patients increased their settings when going from mobile to not mobile (Table 5).

POC Device Errors

POC devices display alerts when improper functioning of POC is detected. Most alerts were related to the normal use of the device, such as situations in which breath was not detected or the battery needed to be recharged. Six of the 168 devices (3.6%) displayed no errors or alerts. The alerts or alarms potentially requiring repair occurred at a rate of 1.63 events per 100 years of use.

Sieve-life warning alerts were reported by 33 POCs (19.6%), with 40 devices having remaining sieve lives of 1–20%.

Table 2 Pattern of use of portable oxygen concentrators

	N	Mean	SD	Minimum	25th	Median	75th	Maximum
Daily use (h/day)	134	4.29	3.23	0.35	1.75	3.48	6.16	15.52
Daily use by intervals								
Night	76	1.83	1.48	0.17	0.66	1.32	2.85	4.88
Morning	128	1.98	1.38	0.08	1.02	1.55	2.68	5.72
Afternoon	131	1.94	1.18	0.02	0.97	1.72	2.88	4.98
Evening	121	1.91	1.70	0.02	0.67	1.39	2.64	6.82
Daily use by weekdays group								
Weekdays	115	3.66	3.03	0.23	1.36	3.01	4.88	15.73
Weekend	132	4.41	3.52	0.36	1.70	3.50	5.86	18.25
Daily interruptions (number)	125	1.94	1.00	1.00	1.25	1.67	2.33	6.00
Interruptions by weekdays group								
Weekdays	87	2.06	1.48	1.00	1.00	1.50	2.58	9.00
Weekend	119	1.92	0.89	1.00	1.25	1.67	2.33	5.44
Duration of interruptions (hours)	125	4.18	3.35	0.31	1.82	3.08	5.39	16.55
Duration of interruptions by daily intervals								
Night	36	1.19	0.75	0.30	0.52	1.06	1.78	3.11
Morning	87	1.35	0.97	0.28	0.58	1.16	1.83	4.52
Afternoon	90	1.51	0.79	0.28	0.93	1.47	1.98	4.82
Evening	68	1.26	0.79	0.28	0.59	1.00	1.89	2.95
Daily breath rate (breaths/minute)	134	20.29	5.07	6.90	16.85	19.75	22.82	38.33
Breath rate by daily intervals								
Night	77	19.14	5.97	8.60	14.74	18.31	23.00	41.58
Morning	127	19.93	5.10	6.39	16.48	19.71	22.58	34.35
Afternoon	131	20.88	4.93	6.99	17.59	20.40	23.60	36.91
Evening	121	20.53	5.38	8.27	17.14	20.35	23.46	42.78
Breath rate by weekdays group								
Weekdays	115	20.64	5.37	7.22	17.05	19.83	23.17	38.66
Weekend	132	20.28	5.09	6.84	16.78	19.98	22.87	38.30
Usage per day on battery power (h/day)	126	1.78	1.49	0.11	0.64	1.40	2.41	7.68
Proportion of time mobile (% of time on battery power)	126	41.99	33.33	0.00	12.50	40.91	67.88	100.00
Proportion of time not mobile (% of time on battery power)	126	58.01	33.33	0.00	32.12	59.09	87.50	100.00

Table 2 continued

	N	Mean	SD	Minimum	25th	Median	75th	Maximum
Breath rate on battery power (BPM)	119	21.26	5.25	11.33	17.75	20.63	23.87	43.06
Breath rate on car charger (BPM)	58	20.92	5.23	9.26	17.20	20.88	24.67	37.19
Breath rate on wall outlet (BPM)	94	18.30	5.49	1.00	14.74	18.03	21.56	39.00

Tables shows daily use (device-generated data), interruptions within day per period (device-generated data; interruptions defined as time when the POC was shut down or when BPM was recorded as 0), duration of interruptions within day per period (device-generated data; interruptions defined as time when the POC was shut down or when BPM was recorded as 0), BPM per period (device-generated data), usage and mobility when using POCs on battery power (device-generated and streamed data), and breath rate by power source (device-generated and streamed data)
BPM breaths per minute

Table 3 Flow settings by categories per period (% of time at a specific pulse dose setting; denominator is total POC use time; device-generated data)

	1	2	3	4	5	6	Increase	Decrease
Daily	1.25	36.95	32.24	14.75	7.72	7.09	0.46	0.50
Daily intervals								
Night	1.42	37.62	27.49	16.70	7.68	9.10	0.28	0.38
Morning	1.17	37.68	30.49	16.16	7.15	7.34	0.29	0.34
Afternoon	1.43	36.02	33.74	14.38	7.68	6.76	0.38	0.40
Evening	1.09	37.50	30.93	13.69	8.98	7.81	0.35	0.35

Table 4 Use of prescribed pulse dose setting (device-generated data)

	N (patients)	Use of the prescribed pulse dose setting (% of POC use time)							Use of the prescribed pulse dose setting ≥ 80% of POC use time (% of patients)
		Mean	SD	Minimum	25th	Median	75th	Maximum	
Daily	134	39.29	42.28	0.00	0.24	15.97	94.96	100.00	31.34
Daily intervals									
Night	76	34.18	43.82	0.00	0.00	0.47	96.65	100.00	26.32
Morning	128	39.17	42.45	0.00	0.00	15.85	94.75	100.00	30.47
Afternoon	131	39.67	43.05	0.00	0.00	20.48	95.09	100.00	30.53
Evening	121	35.82	42.59	0.00	0.00	5.00	90.04	100.00	27.27

N number, *%* percentage, *SD* standard deviation, *25th* 25th percentile, *75th* 75th percentile

Table 5 Proportion of patients with flow setting changes when mobility status changes (device-generated and streamed data; *n* = 126 patients using POC on battery power)

	% Patients
Patients where the flow setting increased when going from not mobile to mobile	19.8
Patients where the flow setting decreased when going from not mobile to mobile	21.4
Patients where the flow setting increased when going from mobile to not mobile	22.2
Patients where the flow setting decreased when going from mobile to not mobile	25.4

DISCUSSION

This study demonstrated that patients used their POCs for a mean of 4.29 ± 3.23 h/day, with fewer patients using them during the night. This is an expected finding, since many patients in the USA have a secondary source of oxygen, a compressed gas tank, or a stationary oxygen concentrator, which they might use preferentially while at home. Data from such devices were not available for this study; hence, no conclusions could be drawn regarding the overall use of LTOT or preferential use of a particular type of device in a given setting. However, the maximum duration of observed use being more than 15 h/day indicates that some patients may be using POCs as the sole or preferred oxygen delivery modality.

The analysis demonstrated that only approximately one-third of the patients used the prescribed settings for at least 80% of the time. This is consistent with the previous descriptions of adherence to stationary/continuous-flow concentrators [9]. However, it is important to note that in those cases, “adherence” is typically defined as overall hours of use with no mention of flow rate adjustment [10].

Adjustments in flow rate settings may indicate variable oxygen requirements during the day and highlight the need for individualized dynamic oxygen dosing plans that offer flexibility to meet patient oxygen requirements to maintain peripheral oxygen saturation (SpO2) within the target range. Such an approach may present a challenge in terms of prescribing and presenting an additional burden to patients by requiring them to have a high-quality pulse oximeter to monitor oxygen saturation values repeatedly throughout the day and adjust their settings frequently. This burden may warrant the development of an automated or semiautomated solution for optimal outcomes.

Data collected from this study showed that patients frequently take advantage of POC portability, being mobile almost 42% of the time when using battery power. Many also used their POC during vehicular travel, with the devices plugged into car chargers. Assumptions about patients being active when using their POCs are validated by the mean BPM being higher when patients are mobile and using battery power or when using car chargers compared to the BPM when POCs are connected to a wall outlet. However, patient mobility or non-mobility with POC resulted in minimal changes in pulse delivery settings, with more patients decreasing their settings when switching from a mobile to non-mobile state. A subset of patients decreased their pulse setting when switching from non-mobile to a mobile state, which would seem paradoxical. Further study will be needed to ascertain the reason for this behavior.

POC devices generate alerts that warrant patient attention to ensure that appropriate oxygen supplementation is administered. Most alerts observed in this analysis were transient and associated with typical use situations, such as when breath was not detected as a result of the cannula not being in the patient’s nose or low battery due to normal use. The rate of alerts indicating a potential need for support or maintenance was low, indicating that reliability was not a factor affecting usage patterns. As might be expected, sieve-life warnings commonly arise towards the end and past lifetime of sieve beds/columns. Therefore, patients should replace these parts according to the annual POC maintenance schedule to ensure adequate device functioning.

The interruption of POC use during the day is an important consideration for defining the required duration of battery life to support patient autonomy, as such interruptions provide opportunities for recharging or replacing the batteries while the patient is using alternative sources of supplemental oxygen.

While this study adequately described patient use patterns of POCs, some limitations exist owing to the nature of the study. This retrospective study was observational in nature and, as such, is prone to bias and confounding factors. Patient socioeconomic status, which could play a significant role in patients' access to healthcare, differing lifestyles, and could impact usage patterns with POC, was not addressed in this study. This study qualitatively analyzes device-generated data, largely focusing on descriptive statistics, and hence it does not allow for testing the significance of the observed differences. The rationale for patients changing their pulse settings was also not captured, making it unclear whether these settings were altered on the basis of clinical evidence (such as pulse oximetry), subjective factors (such as dyspnea), or instruction from a clinician or equipment supplier.

CONCLUSION

This analysis was conducted, in part, to assess patterns of POC usage. Data suggest that patients used their POC daily, with a mean usage of 4.3 ± 3.23 h/day, being mobile for nearly 42% of the time while on battery power. Patients used their POCs both at home and while ambulatory, including in the car, and adjusted their settings during the day and night to meet their oxygen needs. Patients interrupt use of their POCs 1.94 ± 1.00 times during the day on average, perhaps switching to alternative oxygen sources. The mean duration of these interruptions was 4.18 h/day. Approximately 31% of patients used the prescribed pulse delivery settings for at least 80% of the time. It may be beneficial to prescribe a range of settings that patients can use throughout the day adjusted for their physical activity and individual oxygen needs. Development of a device that can automatically adjust dose delivery on the basis of changes in physiological markers of oxygen demand (such as pulse oximetry, heart rate, and/or respiratory rate) may also be of value. This is likely true for devices that provide continuous flow. While POCs have demonstrated high reliability, alert analysis points to the need to educate patients to replace device sieve bed columns in a timely manner to ensure continuous device functioning.

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Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest. Dr. Stanislav Glezer is an employee and shareholder of Inogen Inc. Mr.

Michael W Hess is an employee of the COPD Foundation and serves as a member of an Advisory Board and is a paid consultant for Inogen Inc. Dr. Alan K. Kamada is an employee of Inogen Inc.

Ethical Approval. This analysis meets the exemption criterion of section 45 CFR 46 §46.104 (8), thus IRB approval was not required. A limited review of the study was conducted by WGC IRB LLC who determined that the research was conducted within the scope of the broad consent referenced in paragraph (d)(8)(i) of the corresponding section of the CFR.

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