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BRIEF REPORT

Comparison of Portable Oxygen Concentrators and Inspired Oxygen Levels in a Model of Respiratory Failure

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ABSTRACT

Introduction: This bench study evaluated the inspired oxygen fraction (FiO_2) delivered by different portable oxygen concentrators (POCs) compared to wall oxygen and a standalone concentrator (control device) using a respiratory failure-specific lung simulator replicating an adult with chronic respiratory disease at respiratory rates of 15, 20, 30, and 40 breaths per minute.
Methods: A lung simulator replicated an adult with chronic lung disease in respiratory failure. POCs and controls were tested at device-specific settings 2, 3, 5, and 6. One-way analysis of variance (ANOVA) assessed FiO_2 differences when more than two groups were compared; independent *t* tests were used for two-group comparisons.
Results: Wall oxygen generally delivered higher FiO_2 across all settings and respiratory rates. At 40 breaths/min and setting 2, however, the CAIRE FreeStyle® Comfort® with autoSAT® delivered a slightly higher FiO_2 than wall oxygen (0.25 vs. 0.24, $p<0.01$). Among POCs, the CAIRE FreeStyle® Comfort® (with or without autoSAT®) achieved the highest FiO_2 values at elevated respiratory rates, while devices like the Inogen G4® and G5® performed more variably and showed reduced oxygen delivery at higher breathing frequencies.
Conclusions: Wall oxygen and standalone concentrators consistently outperformed POCs across most breathing conditions. While the CAIRE FreeStyle® Comfort® with autoSAT® offered relative advantages at high respiratory rates, most POCs may not adequately sustain oxygenation during exertion or stress. These findings inform home oxygen therapy decisions, emphasizing the importance of device selection based on respiratory demand. Clinical validation of these bench findings is warranted.

Keywords: Portable oxygen concentrators; Chronic obstructive pulmonary disease; Home oxygen therapy; Respiratory care; Oxygen therapy; Obstructive lung disease

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Key Summary Points

Objective and Methodology: This bench study evaluated the inspired oxygen fraction (FiO_2) delivered by portable oxygen concentrators (POCs) compared to control devices (wall oxygen and a standalone concentrator), using a lung simulator replicating an adult with chronic lung disease in respiratory failure at respiratory rates of 15, 20, 30, and 40 breaths/min.

Key Findings on Wall Oxygen vs. POCs: Wall oxygen and standalone concentrators outperformed all POCs, particularly at higher breathing rates, suggesting that most POCs may not adequately meet oxygen demands during exertion or respiratory stress.

POC Performance Variability: The CAIRE FreeStyle® Comfort® (with autoSAT®), at both sensitivity modes, consistently achieved the highest FiO_2 among POCs at 40 breaths/min and at setting 5. These settings represent moderate oxygen delivery typical of clinical use, though actual flow equivalence varies by device.

Clinical Relevance: Fixed bolus technologies (e.g., autoSAT®) help maintain FiO_2 during exertion (e.g., 40 breaths/min), reducing the need for setting adjustments and potentially improving adherence in patients with chronic lung disease in respiratory failure.

Implications and Future Directions: Since POC performance varies significantly with respiratory rate, clinicians should consider device-specific FiO_2 data when prescribing oxygen therapy. These bench findings highlight the need for clinical validation to assess real-world outcomes such as exertional desaturation and quality of life.

INTRODUCTION

Approximately 1.5 million Americans rely on home oxygen therapy as a supplemental treatment for advanced lung disease [1]. Historically, traditional in-home oxygen therapy has depended on large, cumbersome oxygen tanks, restricting patient mobility and often rendering individuals homebound. However, technological advances, notably the development of portable oxygen concentrators (POCs), have significantly enhanced the quality of life for patients requiring oxygen supplementation. These lightweight devices not only enable ambulation but also offer a practical solution for those with advanced lung conditions, promising a future of improved mobility and independence for patients with chronic respiratory diseases and in respiratory failure [1, 2].

POCs deliver oxygen via pulse-dose systems or continuous-flow mechanisms (Table 1). Pulse-dose systems detect patient breaths through adjustable trigger sensitivities, releasing oxygen boluses only during inhalation. Typically, bolus size decreases as the respiratory rate increases in most pulse-dose POCs. However, newer technologies are available, such as the autoSAT® feature, which is a proprietary technology by CAIRE that dynamically maintains a fixed pulse volume as respiratory rate increases, preventing the decline in bolus size typical in conventional devices. This ensures consistent oxygen delivery under exertional conditions. Furthermore, the UltraSense® sensitive breath technology from CAIRE identifies even the faintest breath to automatically trigger delivery so a breath is never missed.

Similar fixed-bolus designs are found in devices such as the GCE ZEN-O LITE™ (pulse mode) which uses the Rate Responsive Therapy™ feature to automatically adjust oxygen needs to the patient's breath rate; or the Drive DeVilbiss iGo®2 with Patented SmartDose™ technology, and Philips SimplyGo Mini. Evaluating these oxygen delivery technologies is essential to ensure that patients effectively meet their needs, providing reassurance about the future of treatment in those with chronic lung disease who are in respiratory failure.

Despite their benefits, POCs exhibit variable efficacy in delivering adequate oxygen across different clinical scenarios. Research comparing POC performance at diverse respiratory rates

Table 1 Characteristics of portable oxygen concentrators used in the study

Device	Flow mode	Number of settings	Feature that adjusts bolus	Inspiratory trigger sensitivity (cmH_2O)	Dimensions (H x W x D in inches)	Breath rate (Breaths/min)	Pulse or fixed volumes (mL per bolus)	
							Setting #2	Setting #5
Wall O_2	Cont	1–6	No					
CAIRE® Companion 5™ (SOC) (16.3 kg)	Cont	0.5–5	No		21 × 12.5 × 13.5			
CAIRE FreeStyle® Comfort® with autoSAT® (2.3 kg)	Pulse	1–5	Yes (autoSat®)	− 0.1[a]	10 × 3.1 × 7.3	15	NA	NA
						20	NA	NA
						30	NA	NA
						40	NA	NA
CAIRE FreeStyle® Comfort® non-autoSAT® (2.3 kg)	Fixed bolus	1–5	No	− 0.1[a]	10 × 3.1 × 7.3	15	28	70
						20	21	53
						30	14	35
						40	11	26
GCE® Zen-O-Lite™ (pulse mode) (2.5 kg)	Pulse	1–5	Yes (Rate Responsive Therapy™)	− 0.12	9.3 × 3.8 × 9.8	15	22	55
						20	22	53
						30	22	35
						40	22	26
GCE® Zen-O-Lite™ (eco mode) (2.3 kg)	Fixed bolus	1–5	No	− 0.12	9.3 × 3.8 × 9.8	15	26	70
						20	20	53
						20	13	35
						40	10	26
Philips Respironics SimplyGo Mini (2.3 kg)	Pulse[b]	1–5	Yes	− 0.2	9.4 × 3.6 × 8.4	15	22	55
						20	22	50
						30	15	33
						40	11	25

Table 1 continued

Device	Flow mode	Number of settings	Feature that adjusts bolus	Inspiratory trigger sensitivity (cmH_2O)	Dimensions (H x W x D in inches)	Breath rate (Breaths/min)	Pulse or fixed volumes (mL per bolus)	
							Setting #2	Setting #5
Drive DeVilbiss iGo®2 (2.3 kg)	Fixed bolus	1–5	Yes (SmartDose®)	− 0.05	8.4 × 3.5 × 8.6	10	44	101
						20	22	51
						30	15	34
						40	11	25
Kingon P2 (2.0 kg)	Pulse	1–5	No	− 0.12	6.3 × 3.4 × 8.7	15	28	67
						20	21	50
						30	14	33
						40	11	25

Settings refer to pulse-dose bolus volumes (mL/breath) for POCs or continuous flow (L/min) for controls. Values are nominal and may vary as a result of proprietary technologies. The specific pulse volumes for the CAIRE FreeStyle® Comfort® with autoSAT® enabled at settings 2 and 5 across respiratory rates (15, 20, 30, 40 breaths/min) are unknown because the output is dynamically regulated and proprietary

[a]Adjustable

[b]The SimplyGo version also offers a continuous mode (0.5 to 2 L/min), whereas the SimplyGo mini does not

remains scarce, particularly in respiratory failure-specific models. This study addresses the gap in comparative POC performance data by simulating a patient with chronic lung disease who has respiratory failure breathing patterns at rest (15 and 20 breaths/min) and during exertion (30 and 40 breaths/min). Our objectives were to (1) compare inspired oxygen concentration (FiO_2) delivery across a diverse range of POCs, (2) include POCs with fixed-bolus technology, (3) assess FiO_2 variations at respiratory rates of 15, 20, 30, and 40 breaths/min, and (4) evaluate differences in FiO_2 between POCs and a control device (wall oxygen and a standalone oxygen concentrator) using a respiratory failure-specific lung simulator. By focusing on device performance, this study informs prescribing decisions for home oxygen therapy, which is critical given the rising prevalence of chronic respiratory diseases and the shift toward ambulatory care.

METHODS

This article is based on a previously conducted study (see preprint) and does not contain any new studies with human participants or animals performed by any of the authors. This bench study utilized the IngMar Medical Active Servo Lung 5000® (IngMar Medical, Pittsburgh, PA) connected to flexible double-lumen endotracheal tubing to simulate an adult patient's nasal anatomy. The computer-controlled, piston-driven simulator mimicked spontaneous breathing and gas exchange in an adult subject with respiratory failure. An oxygen analyzer (MAXTEC Handi+, product number R218P12, MAXTEC, Salt Lake City, UT) was used (measurement range 0–99.9% oxygen; resolution 0.1%; accuracy ±3%; galvanic fuel sensor). The oxygen analyzer was positioned 6 inches below the simulated nares within corrugated tubing to measure FiO_2 at the trachea level. Combined

with 12 additional inches of tubing, this setup replicated the airway dead space (trachea and bronchi). A nasal cannula (Salter Labs 7-foot 16SOFT, SunMed, El Paso, TX) delivered oxygen from each POC to the simulated nares.

The lung simulator mimicked adult respiratory failure lung mechanics at respiratory rates of 15, 20, 30, and 40 breaths/min. Tested devices included the following POCs: CAIRE FreeStyle® Comfort® (with and without autoSAT®), Inogen G4®, Inogen G5®, Philips Respironics SimplyGo Mini, GCE Zen-O Lite, Drive DeVilbiss iGo®2, and Kingon P2 (see Fig. 1, Tables 1, 2), alongside controls (wall oxygen at 99.9% purity) and a CAIRE® Companion 5™ standalone oxygen concentrator at 87–95.5% purity). The autoSAT® feature by CAIRE maintains a constant pulse volume as respiratory rate increases, preventing bolus size reduction and ensuring consistent oxygen delivery during exertion. All POCs were new and verified for manufacturer-specified performance. Testing was conducted at settings 2 (about 420 mL/min oxygen output) and 5 (about 1050 mL/min oxygen output) for consistency, reflecting common clinical use at rest and being out of breath. We also compared the CAIRE FreeStyle® Comfort® (with autoSAT®) with two different sensitivity modes. The modes range from 1 to 5, where 1 is the least sensitive and 5 is the most sensitive. If the dose is falsely triggered, then the sensitivity can be reduced. On the other hand, if the patient is unable to trigger a dose, then the sensitivity can be increased. We chose sensitivity mode 2 as it is the default mode and sensitivity 5 the most sensitive mode. The subgroup analyses compared Inogen G4® at setting 3 and Inogen G5® at setting 6 against wall oxygen. Settings 1–6 refer to oxygen flow or bolus delivery settings, varying by device in pulse-dose volumes (mL/breath) for POCs or continuous flow (L/min) for controls, as detailed in Tables 1, 2. Direct equivalence across devices is challenging as a result of proprietary technologies.

The CAIRE FreeStyle® Comfort® was evaluated at sensitivity settings 2 and 5 to measure FiO_2 differences. Each device underwent three randomized 3-min trials per respiratory rate (9 data points per scenario) to ensure reproducibility and minimize warm-up variability. A 500-mL target tidal volume was maintained, with the simulator auto-adjusting mechanics for 15 and 20 breaths/min and manually adjusted for 30 and 40 breaths/min (settings in Table 3). These parameters ensured repeatability, reduced warm-up bias, and provided representative FiO_2 data,

Fig. 1 The different brands of portable oxygen concentrators, including one standalone oxygen concentrator used in this study

Table 2 Characteristics of the Inogen One® G4 and G5 portable oxygen concentrators used in this study

Device	Flow mode	Number of settings	Feature that adjusts bolus	Inspiratory trigger sensitivity (cmH_2O)	Dimensions (H x W x D in inches)	Breaths per minute (Breaths/min)	Pulse or bolus volume (mL per bolus)			
							Setting #2	Setting #3	Setting #5	Setting #6
Inogen One® G4 (1.3 kg)	Pulse	1–3	No	− 0.12	7.2 × 2.7 × 5.9	10	42	63		
						20	21	32		
						25	17	25		
						40				
Inogen One® G5 (2.2 kg)	Pulse	1–6	No	− 0.12	7.1 × 3.3 × 7.2	15	57	42	70	84
						20	21	32	53	63
						30	14	21	35	42
						40	11	16	26	32

Values are nominal and may vary as a result of proprietary technologies

Table 3 Lung measurement settings for the IngMar Medical Active Servo Lung 5000® simulating an unassisted adult patient with respiratory failure and a target achieved tidal volume of 500 mL

Respiratory rate scenario	Compliance	Resistance trachea (in/out)	Inspiratory muscle pressure	iTime (s)	I:E ratio	Peak inspiratory flow
15 breaths/min	66 L/cmH_2O	12 cmH_2O/L/s 25 cmH_2O/L/s	17 cmH_2O	1	0.5	23.5 L/min
20 breaths/min	66 L/cmH_2O	12 cmH_2O/L/s 25 cmH_2O/L/s	17 cmH_2O	1	0.5	23.5 L/min
30 breaths/min	66 L/cmH_2O	12 cmH_2O/L/s 25 cmH_2O/L/s	26 cmH_2O	0.83	0.71	41.5 L/min
40 breaths/min	66 L/cmH_2O	12 cmH_2O/L/s 25 cmH_2O/L/s	36 cmH_2O	0.62	0.71	54.7 L/min

The I:E ratio is defined as the inspiratory-to-expiratory ratio

aligning with moderate oxygen delivery in clinical settings.

All data reflect mean FiO_2 values from three trials per device for each respiratory rate. Analysis of variance (ANOVA) was used for comparisons of more than two groups; independent *t* tests were used for two-group comparisons. Means and standard deviations were calculated for descriptive statistics. To isolate POC differences, one-way ANOVA was used to compare FiO_2 across devices, with and without controls. Independent *t* tests were used to assess the effects of Inogen G4® (setting 3) and Inogen G5® (setting 6) against wall oxygen. The assumptions for the statistical tests were met with significance set at $p<0.05$. Analyses were performed via SPSS version 25 (Armok, NY).

RESULTS

Device settings were standardized across POCs and controls to reflect commonly used nominal oxygen delivery configurations. FiO_2 decreased with increasing respiratory rates across all devices (Figs. 2 and 3).

At setting 2, wall oxygen delivered the highest FiO_2 at 15, 20, and 30 breaths/min (0.28, 0.28, and 0.26, respectively). Notably, at 40 breaths/min, the CAIRE FreeStyle® Comfort® with autoSAT®—at both sensitivity levels—outperformed wall oxygen ($FiO_2=0.25$ vs. 0.24, $p<0.01$). This demonstrates the fixed-bolus advantage of the autoSAT® feature under exertional conditions.

At setting 5, wall oxygen again delivered the highest FiO_2 across most breathing rates, reaching 0.40 at 15 breaths/min. Among POCs, the CAIRE FreeStyle® Comfort® without autoSAT® delivered the highest FiO_2 at that same rate (0.32, $p<0.01$), followed closely by its autoSAT® variant. However, at 40 breaths/min, the CAIRE FreeStyle® Comfort® (with and without autoSAT®) continued to deliver the highest FiO_2 among all POCs, maintaining 0.26 compared to lower values from others (e.g., 0.25 or less).

Comparative subgroup analyses further revealed that wall oxygen outperformed both Inogen One® G4® and G5® devices across matched settings. At setting 3 and 6 respectively, wall oxygen consistently achieved higher FiO_2 (ranging from 0.31 to 0.26 across increasing respiratory rates), whereas the Inogen G4® and G5® showed a marked drop in FiO_2 delivery at higher rates, falling to 0.24 and 0.26, respectively, at 40 breaths/min (Fig. 3, $p\leq0.01$).

These FiO_2 differences are clinically relevant. For example, the CAIRE FreeStyle® Comfort®

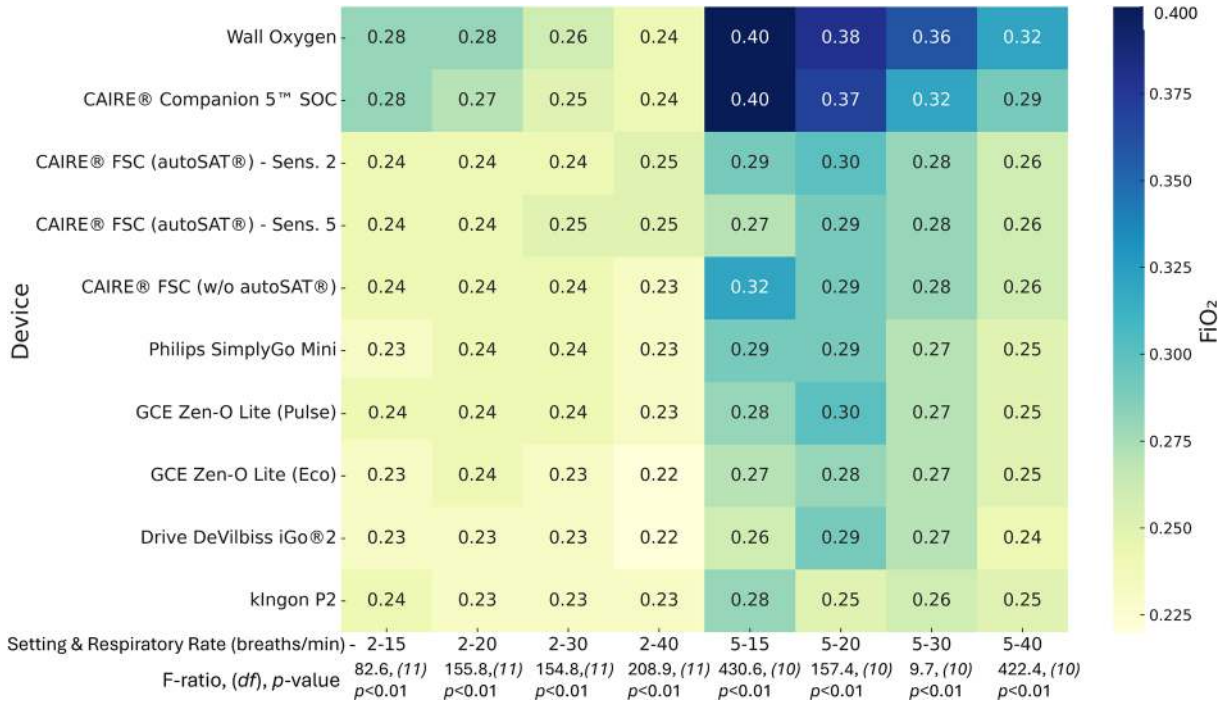

Fig. 2 Mean fraction of inspired oxygen (FiO_2) delivered by different oxygen delivery systems across various flow settings and respiratory rates. Each cell displays the mean FiO_2 value measured at a specific flow rate (in liters per minute, L/min) and respiratory rate (in breaths per minute, (breaths/min), shown as Setting e.g., 2–15. The color scale represents the magnitude of FiO_2, with lighter shades indicating lower oxygen concentrations and deeper blue shades indicating higher FiO_2 delivery. Devices tested include Wall Oxygen (control), CAIRE® Companion 5™ SOC, CAIRE® FreeStyle Comfort (FSC) with and without autoSAT® (sensitivity levels 2 and 5), Philips SimplyGo Mini, GCE Zen-O Lite (Pulse and Eco modes), Drive DeVilbiss iGo® 2, and Kingon P2. Statistical significance across groups is indicated below each column using F-ratios, degrees of freedom (*df*), and *p* values: For example: $F = 82.6$, $df = 11$, $p < 0.01$ for the 2–15 setting. This visualization highlights that wall oxygen achieves highest FiO_2 at all settings; CAIRE FSC (autoSAT®) performs best among POCs but still falls short of wall oxygen at high RR (30–40 bpm)

with autoSAT® (sensitivity 2) at the respiratory rate of 40 breaths/min [achieved an estimated p_AO_2 of approximately 135 mmHg[1] 40 breaths/min, compared to approximately 113 mmHg for GCE Zen-O Lite (Eco) and the Drive DeVilbiss iGo® 2. This approximately 22 mmHg advantage has implications for maintaining adequate oxygenation in patients experiencing exertional hypoxemia or respiratory stress.

Figures 2 and 3 underscore that both wall oxygen and standalone concentrators deliver consistently superior FiO_2 across all respiratory rates compared to POCs. While the CAIRE FreeStyle® Comfort® with autoSAT® offered relatively better performance among POCs, most devices—including the Inogen models—demonstrated a substantial decline in oxygen delivery at higher respiratory rates. These results suggest that during periods of elevated ventilatory demand, many current-generation POCs may fail to sustain optimal oxygenation, a limitation that should be considered in clinical practice.

[1] Alveolar pO_2 (p_AO_2) = (barometric pressure − water vapor pressure) × FiO_2 − (arterial carbon dioxide pressure ÷ respiratory exchange ratio). Or at sea level, this is estimated as (760 − 47) × 0.25 − (35 ÷ 0.8) = 135 mmHg. The 35 mmHg arterial carbon dioxide pressure is from hyperventilation at 40 breaths/min and the FiO_2 is 0.25 from Fig. 2.

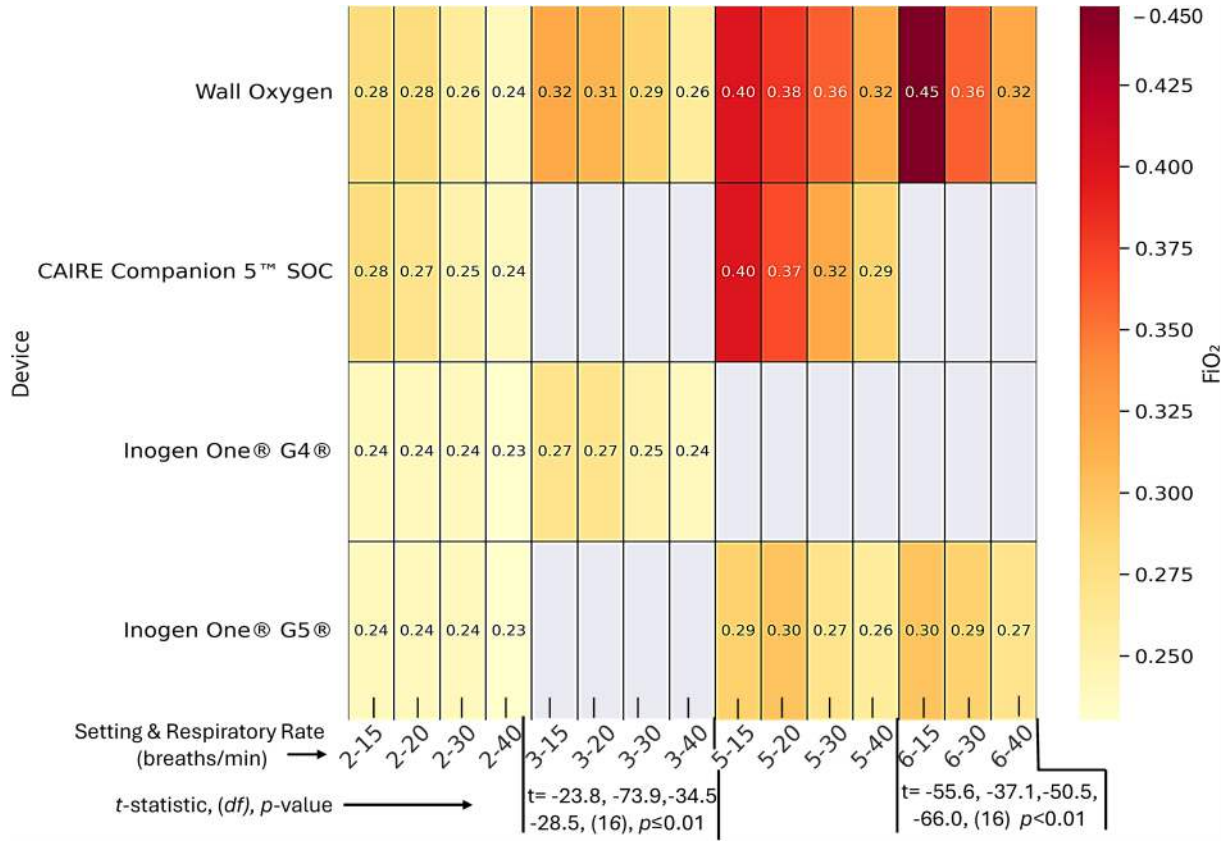

Fig. 3 Mean fraction of inspired oxygen (FiO_2) delivered by different oxygen delivery systems across various flow settings and respiratory rates. Each cell displays the mean FiO_2 value measured at a specific flow rate (in liters per minute, L/min) and respiratory rate (in breaths per minute, (breaths/min), shown as Setting e.g., 2–15. The color scale represents the magnitude of FiO_2, with lighter shades indicating lower oxygen concentrations and deeper red shades indicating higher FiO_2 delivery. Devices tested include Wall Oxygen (control), CAIRE Companion 5™ SOC (control), Inogen One® G4®, and Inogen One® G5®. Missing values are shaded in gray, indicating unmeasured or non-applicable conditions. Statistical significance is indicated below the axis with paired *t* test results comparing device performances: $t = -23.8, -73.9, -34.5, -28.5$, $df = 16$, $p \leq 0.01$; $t = -55.6, -37.1, -50.5, -66.0$, $df = 16$, $p < 0.01$. The results clearly shows Inogen G4® and G5® deliver substantially lower FiO_2 than controls at equivalent settings. There are significant differences in FiO_2 delivery between devices across a range of clinically relevant settings. Wall oxygen FiO_2 remains around 0.38–0.45 at setting 5, even at high respiratory rates, whereas most POCs drop to 0.25–0.30. F-ratio results are presented in Fig. 2

DISCUSSION

This study extends prior research on POCs [3–9] by evaluating device performance at respiratory rates up to 40 breaths/min—simulating physical exertion or acute exacerbations in patients with chronic lung disease and respiratory failure. As expected, wall oxygen outperformed POCs in most scenarios, reflecting its high oxygen purity (99.9% vs. 87–95.5% for POCs). However, the CAIRE FreeStyle® Comfort® with autoSAT® exceeded wall oxygen performance at 40 breaths/min at setting 2, likely owing to its fixed-bolus delivery system maintaining consistent oxygen output during rapid breathing.

Compared to other POCs, the CAIRE FreeStyle® Comfort® with autoSAT® achieved a FiO_2 approximately 3% higher than the GCE Zen-O Lite (Eco) and Drive DeVilbiss iGo® 2,

and 2% higher than the Kingon P2, GCE Zen-O Lite (Pulse), and Philips SimplyGo Mini. Even modest differences in FiO_2 can translate into clinically meaningful changes—approximately 22 mmHg in alveolar oxygen pressure (p_AO_2)—which may reduce exertional desaturation [5, 10]. These findings suggest that autoSAT® and similar fixed-bolus technologies could help improve oxygenation and quality of life in active patients.

Clinical Relevance

POC performance at elevated respiratory rates (e.g., 40 breaths/min) is critical for patients with chronic lung disease in respiratory failure, particularly during physical activity (e.g., walking or climbing stairs) or during exacerbations when oxygen demand increases [10, 11]. O'Driscoll noted that respiratory rates frequently exceed 30 breaths/min during exertion in such patients [10]. The CAIRE FreeStyle® Comfort® with autoSAT® demonstrated the ability to maintain FiO_2 under these conditions, reducing the need for frequent setting adjustments and potentially improving adherence and treatment effectiveness [12, 13]. Therefore, clinicians should evaluate device-specific FiO_2 data when prescribing oxygen therapy—especially for ambulatory or active patients [1].

Limitations

This study employed a lung simulator tailored to replicate respiratory failure physiology, including resistance, compliance, and dead space. However, the model cannot fully reproduce dynamic factors such as intrinsic PEEP, ventilation–perfusion mismatch, or chemoreceptor-mediated respiratory drive. As such, while our results are robust in a controlled bench setting, they should be validated in clinical trials measuring real-world outcomes like pulse oxygen saturation (SpO_2), exertional desaturation, or patient-reported comfort.

Although this study was funded by CAIRE, Inc., data collection and statistical analysis were performed independently by non-funded researchers. The grant recipient (Douglas S. Gardenhire) reviewed the results solely for factual accuracy. Industry support is common in pulmonary device research [1, 6, 14], and this transparency should aid readers in evaluating potential biases.

CONCLUSIONS

Wall oxygen consistently delivered higher FiO_2 than POCs across most breathing rates and settings. However, the CAIRE FreeStyle® Comfort® with autoSAT® demonstrated a clinically meaningful advantage at 40 breaths/min, highlighting its potential utility during exertion. Overall, POC performance declines with increasing respiratory demand, underscoring the importance of individualized device selection. Fixed-bolus technologies like autoSAT® reduce the need for manual setting adjustments and may improve therapy adherence in active patients.

Bench studies like this one provide essential insight into device performance, but clinical validation remains necessary. Transparency in manufacturer-reported bolus volumes, such as those outlined in Tables 1 and 2, would further support informed clinical decision-making for home oxygen therapy. Despite funding from CAIRE, Inc., the integrity of the research process was maintained through independent data handling and analysis.

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Author Contributions. Dr. Douglas S. Gardenhire. secured the funding. Dr. Douglas S. Gardenhire, Dr. Kyle J. Brandenberger, Mr. Robert B. Murray, and Mrs. Robin E. Gardenhire designed the study, prepared the manuscript, and reviewed the data, and conducted the statistical analyses. All experimental procedures, data collection, and analyses were conducted

independently by Dr. Kyle J. Brandenberger, Mr. Robert B. Murray, and Mrs. Robin E. Gardenhire. To ensure objectivity, Dr. Douglas S. Gardenhire was not involved in data collection or statistical analysis; his role was limited to providing technical expertise on device specifications, ensuring accurate lung simulator setup, and reviewing the draft and final manuscript version for factual accuracy. Dr. Gerald S. Zavorsky developed the final figures and tables and completely re-wrote the final manuscript version. All authors approved the final version of the manuscript.

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Data Availability. Due to the proprietary nature of the equipment setup, the complexity of replicating the exact experimental conditions, and institutional data management policies, the raw data are not publicly available. Any data related to the study can be provided at reasonable request to Dr. Douglas S. Gardenhire.

Declarations

Conflict of Interest. Dr. Douglas S. Gardenhire received an unrestricted grant from CAIRE Inc. for salary support for the faculty. No other author has any relationship or any financial ties to CAIRE. Mr. Robert B. Murray has nothing to disclose. Mrs. Robin E. Gardenhire has nothing to disclose. Dr. Kyle J. Brandenberger has nothing to disclose. Dr. Gerald S. Zavorsky has nothing to disclose.

Ethical Approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

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