

# The Economic Impact of Fleet Conversion to a Multi-Function Ventilator Due to Changes in Oxygen Usage

**Research Report**  
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## Disclosures

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## Executive Summary

VOCSN, a multi-function ventilator, has previously been shown to deliver supplemental oxygen more efficiently than other ventilators in bench studies.<sup>1,2</sup> However, VOCSN oxygen delivery and its effect on economic considerations have not been formally evaluated in a clinical setting. A before and after study was completed comparing the oxygen usage of all ventilated patients receiving wall oxygen at one long term acute care facility in New York before and after a complete fleet conversion from the Newport HT70 ventilator to VOCSN Multi-Function Ventilator in January 2020.

Daily recorded ventilator settings over two months (one month before and one month after fleet conversion) and oxygen invoices were evaluated to determine oxygen usage and the economic impact of oxygen use. Primary analysis was performed on the 22 patients present in both the before and after periods, with patients acting as their own controls. Secondary analysis was performed on 30 patients in the before and 27 patients in the after period, regardless of whether the patients were present in both the before and after time periods. To average patient differences between the before and after periods and create data that is easily transferrable to other clinical settings, we calculated the oxygen usage of 30 "average" patients with 24-hour oxygen requirements for 31 days.

Data analysis showed oxygen usage decreased for every patient, leading to annualized cost savings of over \$16,000 and annualized cost savings per patient of over \$500 due to decreased oxygen usage and required oxygen deliveries.

## Key Findings of Primary Analysis

- Every patient used less oxygen when using VOCSN compared to when using HT70.
- Using 30 “average” patients with 24-hour oxygen requirements for 31 days:
  - Patients using VOCSN used 75% less oxygen compared to patients using HT70 (3,299,920 L → 824,097 L).
  - Oxygen expenditures decreased by 75%.
  - Total oxygen expenditures (including delivery fee, tax, and flat monthly fee) decreased by 53%.
  - Annualized cost savings for total oxygen use at the facility was \$16,125.
  - Annualized cost savings per patient for total oxygen use at the facility was \$538.
  - Nine percent of patients transitioned to VOCSN in the after period no longer required oxygen and nine percent were weaned from the ventilator.

## Background

In the United States, long term acute care facilities (LTACs), also known as long term acute care hospitals (LTCHs), treat the approximately 10-20% of critically ill and medically-complex patients who necessitate hospital-level care for a prolonged period of time while being treated for critical illness.<sup>3,4,5</sup> Of these patients requiring long term care, the percentage requiring mechanical ventilation ranges from 16-30%, leading to an estimated 4,000-7,500 ventilated patients in LTACs at any given time based on an approximate total LTAC bed count of 25,000 in 2018.<sup>3,4,5</sup> With the advent of a global respiratory pandemic in early 2020, LTACs caring for ventilated patients have seen increased demand.

Ancillary services including oxygen are considerable expenses for LTACs. A key to oxygen expense is the efficiency by which a ventilator delivers supplemental oxygen to patients. Typical ventilators used in LTACs and home care utilize a reservoir, usually three liters in size and connected to the gas delivery inlet, to increase delivered oxygen. During inhalation, the ventilator delivery system draws oxygen from the reservoir and, because the volume is four to five times larger than the tidal volume, higher FiO<sub>2</sub> can be achieved. During exhalation, the reservoir refills. However, when a bias flow is present, gas from the reservoir continues to be used to enrich oxygen in

the bias flow, which reduces the FiO<sub>2</sub> that can be delivered during inhalation or requires a higher gas flow to achieve the targeted FiO<sub>2</sub>. The HT70 oxygen delivery system utilizes a reservoir.

In contrast, VOCSN is the only ventilator that leverages pulse dose technology to “front-load” the delivered breath. The use of pulse dose technology in home oxygen therapy has been shown to reduce oxygen usage and prolong the life of portable oxygen devices.<sup>6,7</sup> Further, front-loading the delivered breath has been shown to improve gas exchange and reduce oxygen use by pulsing oxygen into the gas that reaches the lung’s gas exchange units.<sup>8,9</sup> VOCSN both delivers oxygen for this front-loaded breath via a tube within the circuit that extends past the leak so that oxygen is not lost when a leak is present and shuts off oxygen flow during exhalation. Previous data from bench studies showed that when compared to the Trilogy 202 ventilator, VOCSN Multi-Function Ventilator utilized less oxygen using pulse dose oxygen delivery and using a set FiO<sub>2</sub> from a high-pressure oxygen source with both an active and passive circuit.<sup>2</sup>

The current study aimed to determine if the improved oxygen efficiency found in bench and animal studies translated to the clinical setting by analyzing the oxygen usage changes in ventilated patients and resulting economic impact after a full-fleet conversion from HT70 to VOCSN. This study assessed the efficiency by which both ventilators deliver oxygen from an external high-pressure source (wall oxygen) and not the use of the internal oxygen concentrator in VOCSN.

## Methods

A before and after study was completed using facility-provided daily ventilator settings and hours of oxygen use to compare the oxygen used by all ventilated patients treated in the 31 rooms with wall oxygen at the Five Towns Premier Nursing and Rehabilitation Center from December 1 through 31, 2019 (“before” period), and then again from February 1 through 29, 2020 (“after” period). A complete fleet conversion from the Newport HT70 ventilator to VOCSN Multi-Function Ventilator occurred between January 14-21, 2020.

Daily recorded ventilator settings over two months (one month before and one month after fleet conversion) and oxygen invoices were utilized to determine oxygen usage and the economic impact of oxygen use. Primary analysis was performed on the 22 patients present in both the before and after periods, with patients acting as their own controls. Secondary analysis was performed on 30 patients in the before and 27

patients in the after period, regardless of whether the patients were present in both the before and after time periods. These before and after period raw patient numbers differ because the facility's 31 rooms with wall oxygen had variable occupancy during the months studied.

Recorded ventilator settings included the fraction of inspired oxygen ( $FiO_2$ ) and the inhaled minute volume ( $V_E$ , measured in L/min) for each patient from the first ventilator check of each day. The total supplemental oxygen flow in liters per minute to a patient ventilated in the before period was calculated by the following formula:

$$(\text{Total supplemental } O_2 / \text{minute}) = \left( \frac{FiO_2 - 21\%}{79\%} \cdot V_E \right) + \left( \frac{FiO_2 - 21\%}{79\%} \cdot B \cdot 67\% \right)$$

In both terms on the right of the equation, the factor  $(FiO_2 - 21\%)/79\%$  represents the fraction of supplemental (pure) oxygen necessary to add to atmospheric air to achieve a fraction of inspired oxygen equal to  $FiO_2$ . The term to the right of the addition sign represents the amount of supplemental oxygen flowing through the ventilator during the exhalation phase:  $B$  is the bias flow through the ventilator in L/min (set at 10 L/min per the facility), and the factor of 67% represents the average fraction of time during the breath cycle spent in exhalation. Because  $V_E$  is defined as the average volume of gas delivered and the HT70 uses a continuous flow of gas, correction for percent of inhalation time is not required.

The total supplemental oxygen flow per minute to a patient ventilated in the after period was calculated by the following formula:

$$(\text{Total supplemental } O_2 / \text{minute}) = \left( \frac{FiO_2 - 21\%}{79\%} \cdot V_E \cdot 62\% \right)$$

VOCSN Oxygen Direct™ technology delivers oxygen to the patient during the first 62% of the inspiratory phase via an internal oxygen tube within the circuit and delivers that oxygen past any leak. VOCSN also shuts off oxygen flow during the exhalation phase, eliminating a calculation for oxygen use during exhalation.

The facility used a microbulk oxygen system that converts liquid oxygen to gas with one 450 L vessel in the building and two 450 L vessels outside. The oxygen vendor scheduled deliveries based on remote monitoring of liquid within the vessels. The cost of oxygen per cubic feet and the delivery charge remained consistent throughout the entire study period per facility-provided invoices.

## Results

### Primary Analysis

All patients in the before and after periods, a total of 57 patients, received oxygen from a high-pressure source piped into the wall. A total of 30 patients in the before period used HT70 ventilators delivering oxygen via a reservoir system. A total of 27 patients in the after period used VOCSN delivering oxygen via pulse dose. To limit confounding factors, patients present in both the before and after periods served as their own controls for the primary analysis. Twenty-two patients were present in the ventilator ward in rooms with wall oxygen for both the before and after periods. After transitioning to VOCSN, two of the 22 patients no longer required oxygen (nine percent) and two were weaned from ventilation requirements (nine percent).

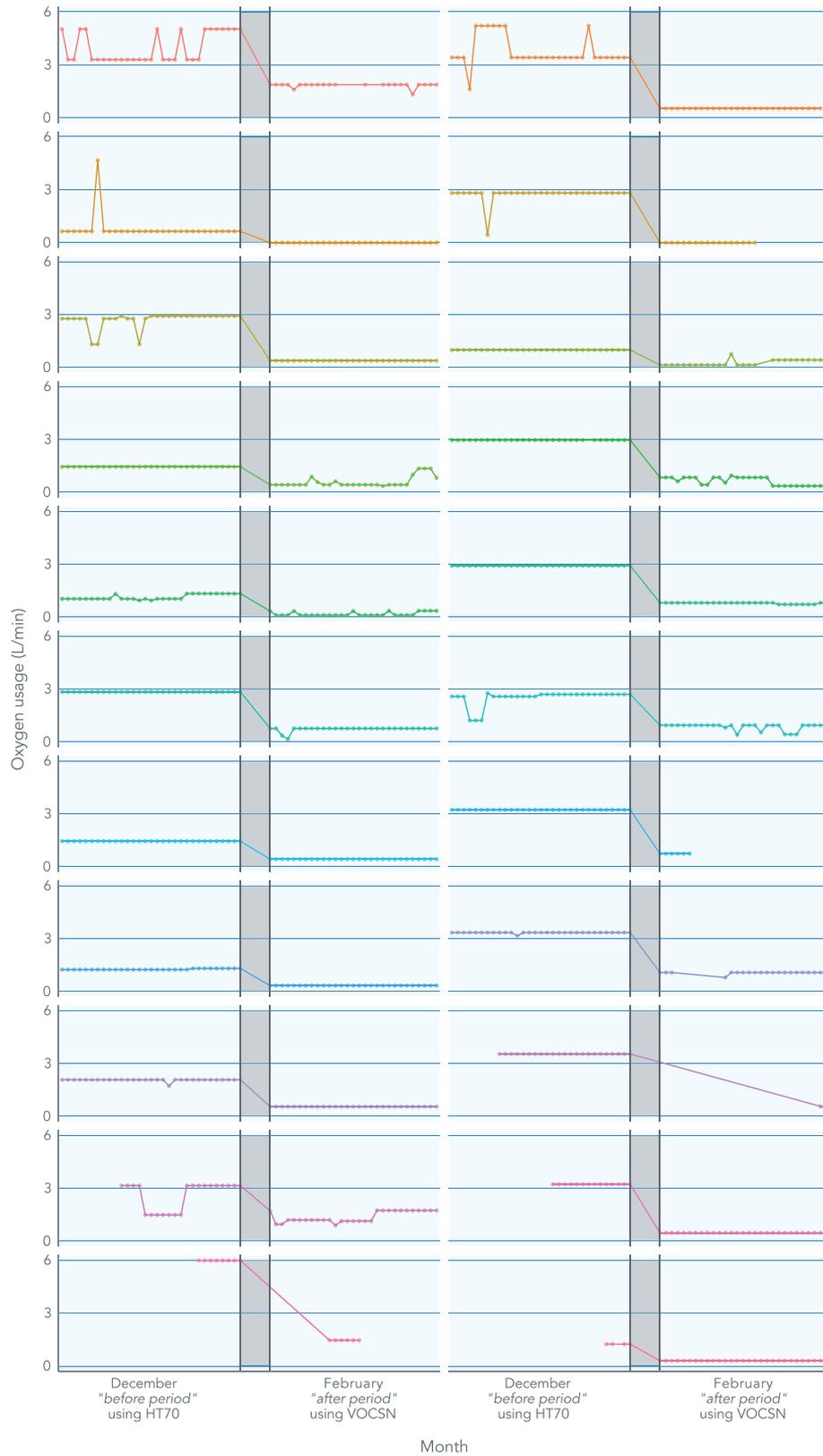
To average patient differences between the before and after periods, results were calculated using 30 “average” patients with 24-hour oxygen requirements for 31 days. For the primary analysis, total oxygen usage decreased from 3,299,920 L in the before period to 824,097 L in the after period, a 75% decrease. The oxygen expenditures also decreased by 75% and total oxygen expenditures (including delivery fee, tax, and flat monthly fee) decreased by 53% between the before and after periods. This translated to an annualized cost savings for total oxygen expenditures of \$16,125 and annualized cost savings per patient of \$538 (Table 1).

**Table 1: Primary Analysis Oxygen Usage and Cost Differences**

	HT70 (Before Period)	VOCSN (After Period)	Difference	Percent change
From raw data				
Total oxygen usage (L)	2,060,085	436,934	-1,623,151	-79%
Total ventilation time (hour)	13,934	11,834	-2,100	-15%
Oxygen usage rate (L/min)	2.46	0.62	-1.85	-75%
<b>30 "average" patients with 24-hour oxygen requirements for 31 days</b>				
Oxygen usage (L)	3,299,920	824,097	-2,475,823	-75%
Oxygen expenditures (dollar)	\$1,655	\$413	-\$1,241	-75%
Deliveries needed	6	2	-4	-67%
Oxygen delivery fee and tax (dollar)	\$192	\$64	-\$128	-67%
Oxygen storage equipment fee (dollar)	\$755	\$755	\$0	0%
Total oxygen usage expenditures (dollar)	\$2,602	\$1,232	-\$1,370	-53%
Annualized expenditures (dollar)	\$30,634	\$14,508	-\$16,125	-53%
Annualized expenditures per patient (dollar)	\$1,021	\$484	-\$538	-53%

As shown in Figure 1, each patient in the primary analysis decreased their oxygen usage between the before and after periods.

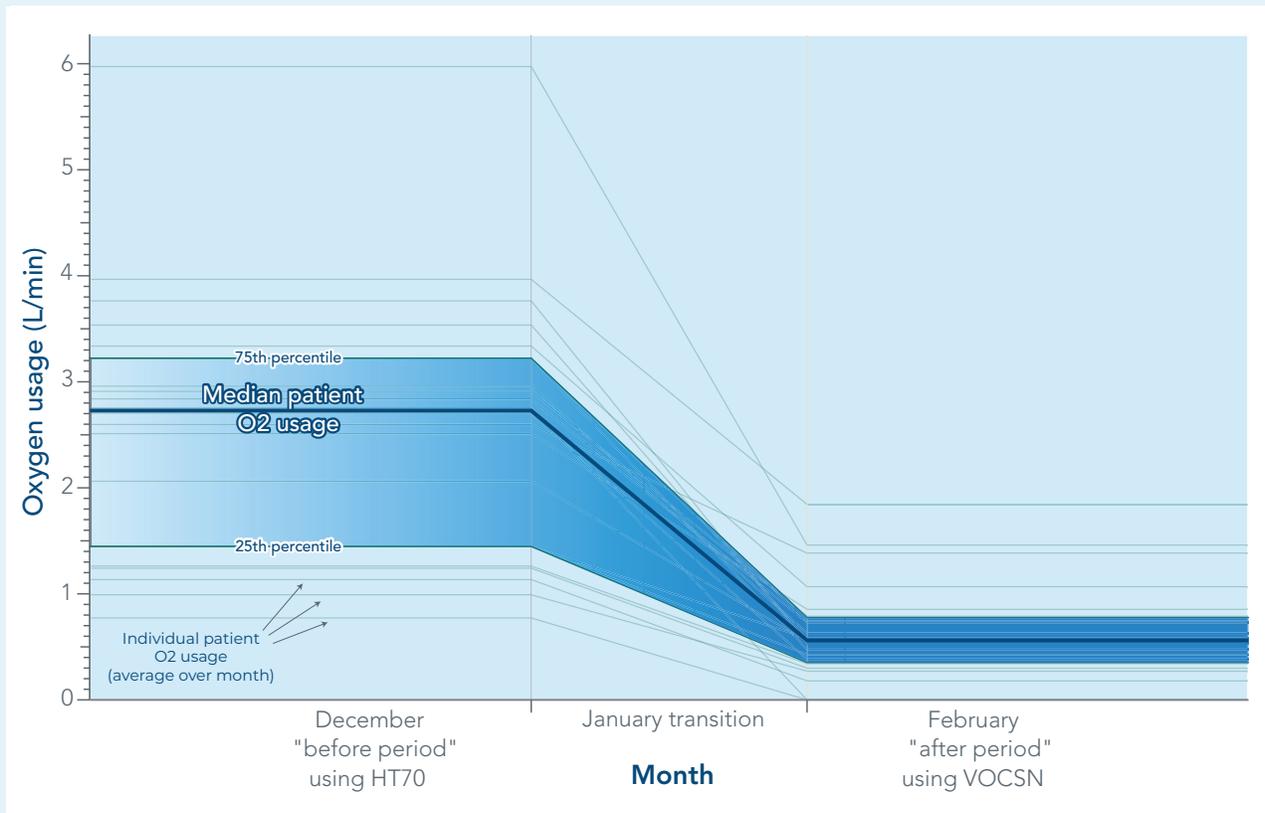
Figure 1: Patient-level Daily Oxygen Usage



Note: Shaded area marks ventilator transition period.

The median oxygen usage in the before period was 2.73 L/min (25<sup>th</sup> percentile 1.45 L/min, 75<sup>th</sup> percentile 3.22 L/min) and in the after period was 0.56 L/min (25<sup>th</sup> percentile 0.35 L/min, 75<sup>th</sup> percentile 0.78 L/min).

**Figure 2: Patient-level Monthly Oxygen Usage**



Figures 3 to 5 are exemplars of the oxygen use decrease found across a select sample from the primary analysis.

Figure 3: Patient-level Daily Oxygen Usage, Patient 1

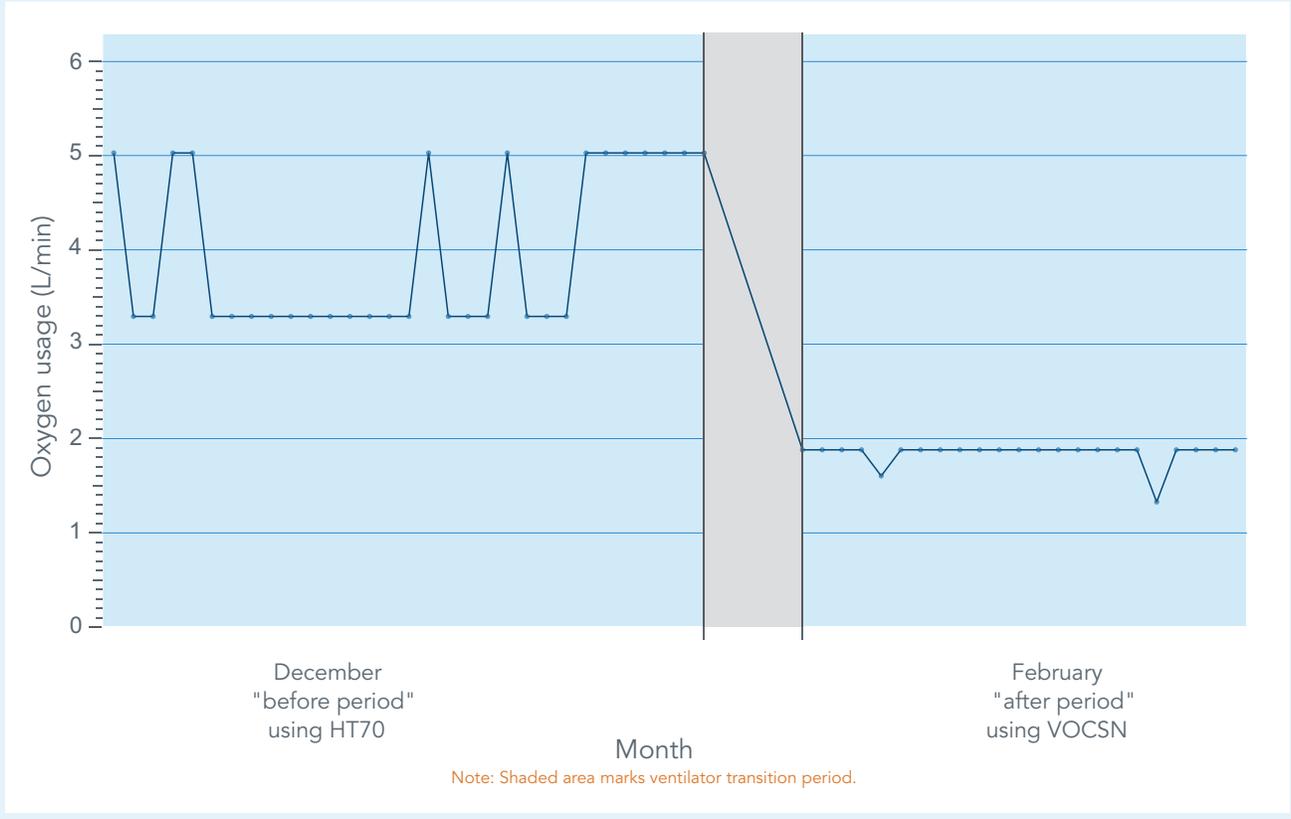


Figure 4: Patient-level Daily Oxygen Usage, Patient 10

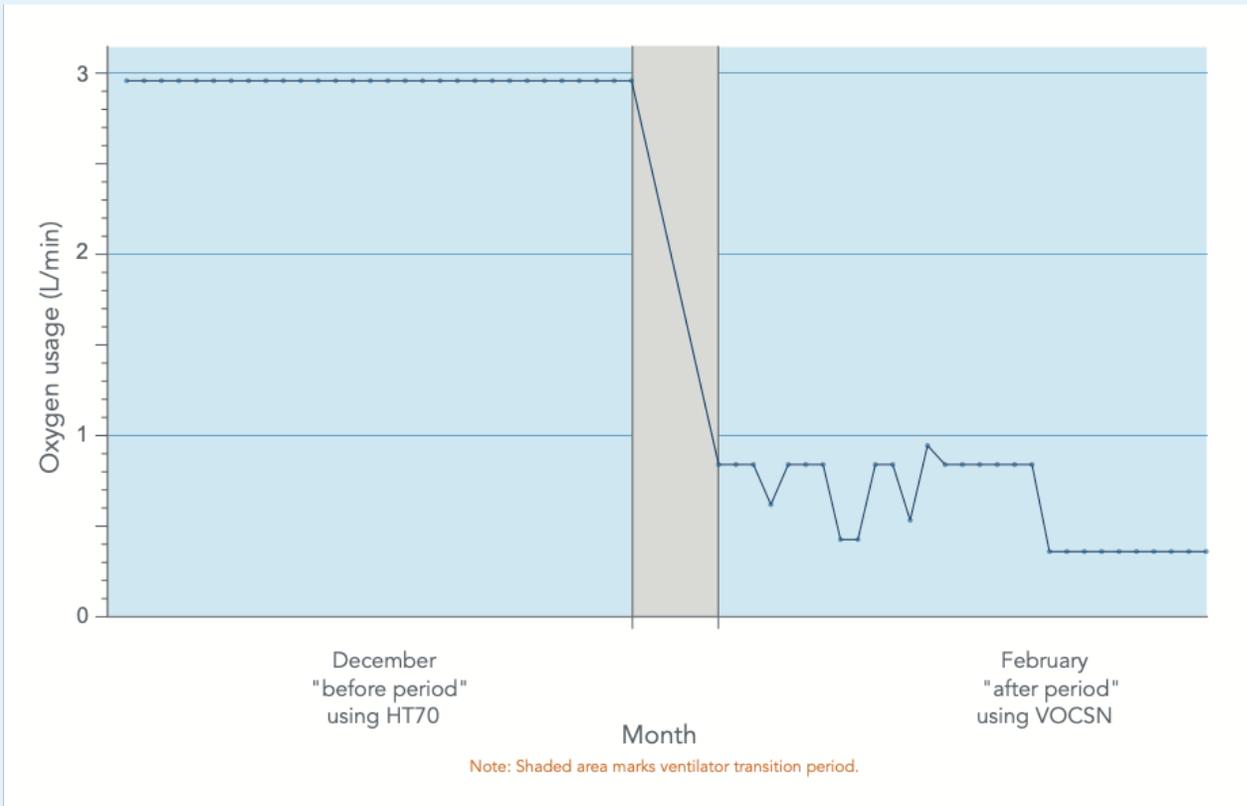
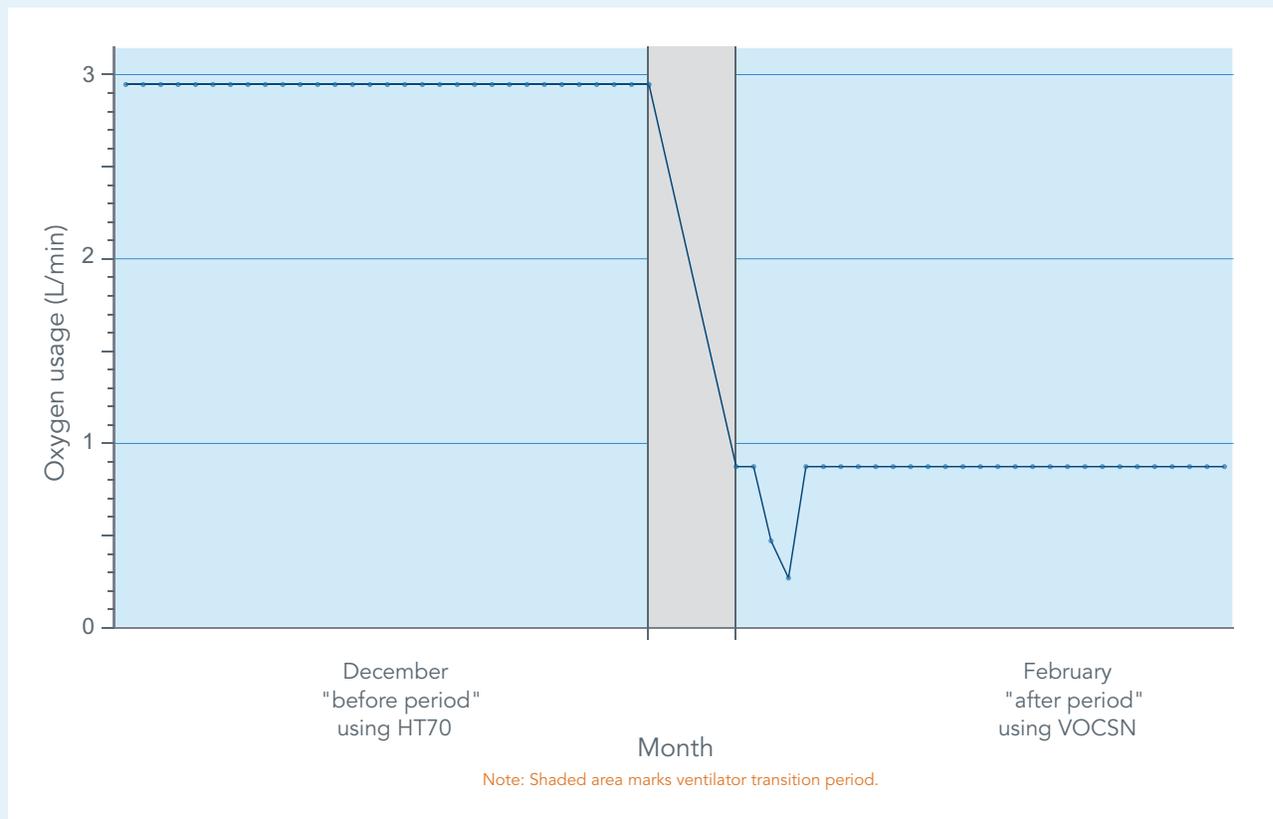


Figure 5: Patient-level Daily Oxygen Usage, Patient 13



### Secondary Analysis: All-Patient Analysis

Analyzing all patients in the before and after periods, regardless of whether they were present in both the before and after periods, was performed as a secondary analysis. This analysis showed a similar decrease in oxygen usage and related oxygen expenditures as the primary analysis.

Similar to the primary analysis, results were calculated using 30 "average" patients with 24-hour oxygen requirements for 31 days to average patient differences between the before and after periods. In this secondary analysis, the oxygen usage between the before and after periods decreased from 3,271,939 L to 874,209 L, a 73% decrease. Oxygen expenditures decreased by 73% and the total oxygen expenditures (including delivery fee, tax, and flat monthly fee) decreased by 51% between the before and after periods. Annualized cost savings for total oxygen expenditures was \$15,644, and annualized cost savings per patient was \$522 (Table 2).

**Table 2: Secondary Analysis Oxygen Usage and Cost Differences**

	HT70 (Before Period)	VOCSN (After Period)	Difference	Percent change
<b>From raw data</b>				
Total oxygen usage (L)	2,341,665	558,601	-1,783,064	-76%
Total ventilation time (hour)	15,974	14,262	-1,712	-11%
Oxygen usage rate (L/min)	2.44	0.65	-1.79	-73%
<b>30 "average" patients with 24-hour oxygen requirement for 31 days</b>				
Oxygen usage (L)	3,271,939	874,209	-2,397,730	-73%
Oxygen expenditures (dollar)	\$1,641	\$438	-\$1,202	-73%
Deliveries needed	6	2	-4	-67%
Oxygen delivery fee and tax (dollar)	\$192	\$64	-\$128	-67%
Oxygen storage equipment fee (dollar)	\$755	\$755	\$0	0%
Total oxygen usage expenditures (dollar)	\$2,588	\$1,257	-\$1,330	-51%
Annualized expenditures (dollar)	\$30,469	\$14,804	-\$15,664	-51%
Annualized expenditures per patient (dollar)	\$1,016	\$493	-\$522	-51%

## Discussion

Major findings of this analysis include a reduction in oxygen usage and a decrease in oxygen-related expenditures afforded by the utilization of pulse dose oxygen technology integrated with a ventilator. The reduction in oxygen use translated into savings related to fixed costs associated with oxygen deliveries as well. Oxygenation in individual patients was maintained through monitoring of pulse oximetry and the facility reported no changes in incidents related to hypoxemia. This is the first study evaluating pulse dose oxygen technology in patients, with the findings confirming evidence from bench and animal studies.<sup>8,9</sup>

The idea of using pulse dose technology to “front-load” oxygen delivery has been present in the literature for a decade, with studies showing reduced oxygen usage and prolonged life of portable oxygen devices.<sup>8,9</sup> VOCSN is the only ventilator that leverages pulse dose technology to “front-load” the delivered breath. Further, VOCSN both delivers oxygen for this front-loaded breath via a tube within the circuit that extends past the leak so that oxygen is not lost when a leak is present and turns off oxygen delivery during exhalation. This study shows in a clinical setting that the oxygen delivery system of VOCSN, when compared with the reservoir system used by most ventilators in long term acute care facilities, decreases oxygen usage and, thus, oxygen expenditures.

To limit confounding factors, we performed a primary analysis of patients present in both the before and after periods so that patients could serve as their own controls. Ventilator settings including the desired FiO<sub>2</sub> remained unchanged in the two periods. To create data that is easily transferrable to other clinical settings, we calculated the oxygen usage of 30 “average” patients using oxygen for 24 hours a day. In these average patients, oxygen usage with VOCSN decreased by 75%, leading to annualized cost savings of over \$16,000 and annualized costs savings per patient of over \$500.

Evaluating all patients in the secondary analysis, which studied patients in the before and after periods regardless of whether they were present in both periods, lead to similar results. Calculating the oxygen usage of 30 “average” patients using oxygen for 24 hours a day, we found total oxygen usage with VOCSN decreased by 73%, leading to annualized cost savings of over \$15,000 and annualized costs savings per patient of over \$500. Given ancillary services including oxygen are considerable expenditures for LTACs, such a reduction in oxygen and its associated expenditures may have a significant impact on a LTAC’s operating expenses.

The expense of oxygen and its usage are generally considered the cost of doing business in hospitals,<sup>10</sup> whereas home care companies providing oxygen therapy place a priority on reducing oxygen use and expense. The current state-of-the-art, in-home oxygen therapy is primarily provided by oxygen concentrators, in large part due to the expense associated with delivery of compressed gas cylinders to patient homes.<sup>11</sup> Pulse dose oxygen is considered standard of care in the home care setting because it is known to be more efficient, particularly when portable concentrators are used.<sup>12</sup> The results from this trial suggest that the efficiency of pulse dose oxygen delivery can be expanded to long term mechanical ventilation in any setting sensitive to the expense of oxygen.

While the cost of oxygen (the gas) is small compared to many other consumables in the healthcare space, such as drugs and IV fluids, the use of high bias flow (flow during exhalation) requiring oxygen supplementation escalates the expense unnecessarily. Most ventilators, whether in the ICU, long term care, or home care environments, utilize a bias flow to stabilize PEEP, compensate for leaks, and improve trigger sensitivity.<sup>13</sup> The bias flow of many current generation ventilators ranges from 2-20 L/min. In the case of devices that utilize a reservoir system to provide oxygen supplementation, oxygen flow during exhalation is exhausted and, hence, wasted to the atmosphere. As an example, a patient receiving a respiratory rate of 20 bpm and tidal volume of 500 ml has a minute ventilation of 10 L/min. At an FiO<sub>2</sub> of 0.40 this requires an oxygen flow of 3 L/min. Thus, a bias flow of 10 L/min (only occurring during exhalation) increases oxygen usage by 30-50%. Our analysis suggests this oxygen use has financial consequences and pulse dose oxygen delivery eliminates this problem.

There are several limitations to our analysis. First the data, while collected and entered into the electronic medical record prospectively, was retrieved retrospectively. Analyzed data is based on the first ventilator performance check of the morning and, as such, changes during the day may not be reflected despite our attempt to capture all changes to ventilator settings daily. Further, the facility practice was to use a bias flow of 10 L/min, and we do not know if a lower flow, which would have decreased oxygen usage in the HT70, would have proven sufficient to allow for triggering and to overcome leaks. Changes in patient condition could also account for some changes in oxygen requirements, but in this long term ventilation group, ventilator settings were similar between time frames. Finally, ancillary uses of oxygen, such as for manual resuscitators and nebulizer treatments, were not captured, though we do not believe such ancillary uses would have significantly changed the results.

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